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NSW DEPARTMENT OF
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Pastures in cropping rotations – North West NSW

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SUMMARY

Pastures are an essential component of most sustainable cropping systems. Well managed pastures improve chemical and physical soil fertility which can reduce nitrogen fertiliser input and increase grain yields in following crops. A legume based pasture phase is necessary to help maintain soil organic carbon and nitrogen levels.

Improved pastures are a valuable source of livestock fodder. Stocking rates of 10 DSE/ha and above are possible on well managed pastures on the North West Slopes and Plains. Well managed lucerne and mixed grass/legume pastures will provide similar or greater annual dry matter (DM) production than forage crops. The financial return from beef cattle on improved pastures compares favourably to dryland cropping in NSW Department of Primary Industries' Farm Enterprise Budgets which are available on the internet.

Producers will gain the maximum benefit from pastures in the cropping rotation by using best

Direct drilling pasture and fertiliser into wheat residue with an airseeder (Quirindi)

CONTENTS

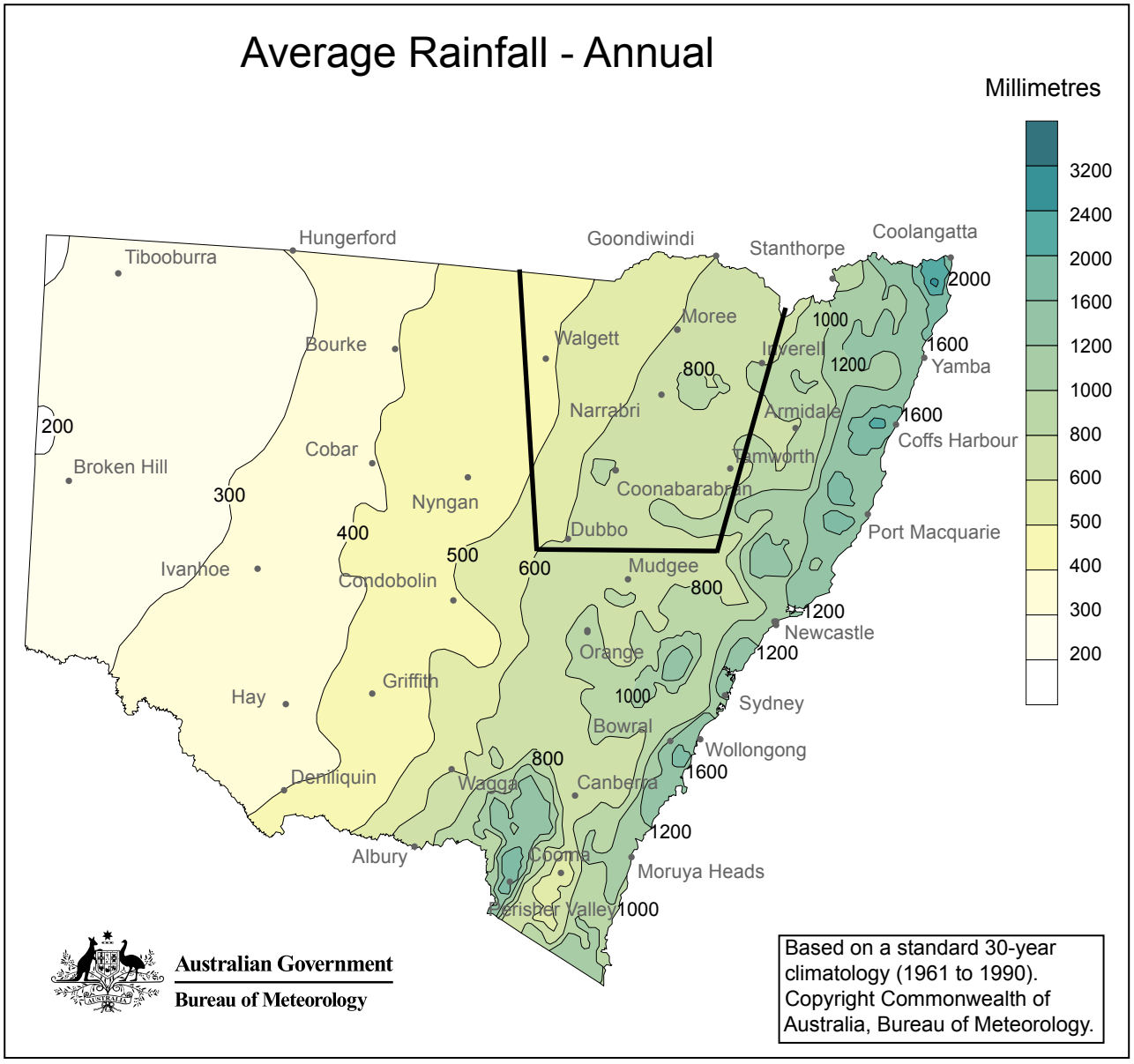
management practices. This publication outlines these practices.

Best management practices – summary

1. Pastures improve the sustainability of cropping rotations; however, the degree of improvement depends on characteristics of the individual farm, cropping enterprises and managerial expertise of the producer.
2. Detailed farm planning and economic evaluation of changes including pastures and livestock are essential before decisions are made and resources committed.
3. Pastures will only perform to their potential if species are correctly matched with the enterprise and environment (e.g. soil type, rainfall, temperature). Forward planning is important when establishing pastures to ensure adequate soil moisture, good weed control and timely sowing.
4. Livestock and pastures must be well managed for best performance. Adequate nutrition, tactical grazing and good animal husbandry are essential to optimise pasture production and stand life; and achieve livestock production targets and favourable economic outcomes.
5. Producers should take steps to minimise the problems which can occur with livestock in cropping systems. These problems include soil compaction, crop diseases carried over on pastures and the provision of adequate infrastructure.
6. Well managed pastures in the cropping rotation can reduce soil degradation and greatly improve soil nutrition, water infiltration and reduce rates of salinisation and acidification in some situations.
7. Producers must acquaint themselves with animal health problems associated with particular pasture species such as bloat by some legumes.

INTRODUCTION

Soil fertility decline, as indicated by depletion in organic matter and nitrate nitrogen, affects about 70% of cropping land in NSW. The damage is most obvious in lighter textured soils but decline of organic matter and nitrate nitrogen occur in our best bread wheat growing soils. Average



grain protein has declined steadily since broad-scale cropping commenced, early in the 20th century.

The farming community recognises this fertility decline and has adopted substantial nitrogen fertilisation and /or nitrogen-fixing and nitrogen-sparing pulse crops in cereal rotations to maintain yields and protein percentages of wheat.

In addition to these remedies, there is compelling evidence of the vital role of legume and grass pastures, which can be regarded as the 'unsung heroes' of sustainability in NSW cropping and livestock systems. Vigorous pastures are considered by many to be an essential part of more sustainable livestock and cropping systems in North West NSW. Soil cannot maintain viable long-term crop production without cumulative loss of soil organic matter, nitrogen, deterioration in soil structure and irreplaceable loss of soil capital.

Permanent legume based pastures with tactical graze-spell management and legume based pasture phases in rotation with crops, can provide soil with substantial physical and fertility benefits which flow on as economic benefits to farmers. They can directly contribute to the soil by way of more organic matter, soil nitrogen, beneficial soil organisms, and better soil structure, water infiltration and water holding capacity. This reduces the rate of soil degradation, can reverse the decline in the productiveness of soils and improve the long-term viability of the farm.

The zone covered by this publication (see map on the previous page) extends from the Qld

border as far south as Dubbo, westwards to the limit of wheat cropping, and eastwards to Tamworth and Inverell. Local interpretation is necessary as there are significant farm-scale differences in soils, rainfall, elevation and aspect which impact on pasture selection and management.

Advantages of pastures in cropping rotations

These advantages will apply to individual farms and individual paddocks in varying degrees depending on each situation.

1. Diversification of income
2. Complementarity of enterprises
3. Efficient use of capital and resources
4. Soil nitrogen accretion
5. Soil structure benefits
6. Soil organism enhancement
7. Maintenance of VAM (*Vesicular Arbuscular Mychorriza*)
8. Disease break
9. Weed control
10. Efficient water use
11. Reduced soil acidity
12. Control of rising water tables and reduced salinisation
13. Ability to restore compacted soil
14. Better ground cover giving reduced erosion and better infiltration
15. Recycling nutrients from depth

Disadvantages of pastures in cropping rotations

1. Difficulty in terminating the pasture phase when it contains persistent species
2. Herbicide residue problems
3. Soil compaction and pugging by livestock on heavy soils
4. Reduced moisture in the soil profile for following crops (particularly with lucerne)
5. Carry-over disease (depending on species and following crop)

Other considerations

1. More complex management requirements
2. Lack of infrastructure and additional capital investment required
3. Risk of bloat and other livestock disorders
4. Need for livestock and pasture expertise

ECONOMICS

Long-term view

A long-term approach is required when assessing the economics of pasture/crop rotations. This can take into account both short-term and long-term benefits of pasture to soils, which can take time to flow through to the following cash crops. The pay back time for investment in pastures can be considerable depending on management, the size of the investment per hectare, seasonal conditions, current profitability of particular markets and the local soil fertility and rainfall.

A good analysis should consider the changes that could happen in the 'no ley pasture' scenario as well as the new scenario. These changes could include; altering the cropping rotation in some way e.g. an alternative crop, growing dual purpose cereals or growing lucerne for hay instead of grazing.

Bench marking is most usefull when applied to a particular business over time (rather than different businesses), since most farm businesses differ in the key assets and resources that underpin the business such as land, labour (including management skills) and capital. Benchmarking using technical efficiency ratios and enterprise gross margins between farms runs the risk of being misleading. A farm could have high gross margins or low cost of production due to good resources. Another farm may have lower gross margins and/or high costs of production, but have good management doing their best with poor resources e.g. poor soil type. Also, an enterprise may have high costs and low profitability, but this may be because its scale is too small, and it would perform better if expanded.

Cost of production accounting should also be used with caution. Many enterprises are interdependent, and if one is removed due to high relative costs, the other(s) could suffer. For example, a ley pasture grown for three years between crop phases could provide valuable feed for finishing young stock from a breeding

enterprise on permanent pasture. If the ley pasture wasn't there, young stock would have to be sold as weaners instead, for less income. The rotation benefits of the pasture for the following crops would also be foregone (such as the potential boost to soil organic carbon as well as weed and disease breaks).

In some situations even a relatively small area of high quality pasture which does not impinge significantly on the overall cropping enterprise, can make a large contribution to the livestock enterprise. Improved pastures that are vigorous and well managed are capable of high carrying capacity and high levels of animal performance in terms of growth rate, conception, marking percentage and wool production.

A study on the economic outcomes of various crop and pasture rotations in Central West NSW indicated that 5–6 years of pasture provided the best economic returns over a wide range of wheat and canola prices. This relies on effective management and weed control strategies to ensure persistence of the legume pasture for the full duration of the pasture phase. A report on this study by D Patton is available from NSW Department of Primary Industries, Trangie.

Basic principles

Generally, it is the big strategic decisions that have the biggest effect on business survival and asset growth. These include 'extensification' vs. intensification, specialisation vs. diversification, enterprise type, gearing and land and machinery purchases.

A whole-farm approach to economic and financial assessment should be taken. This is because there will be interactions with livestock within the system. Also with crop/pasture rotation it is unlikely that there will be a time when the whole farm is solely under crop or solely under pasture. For example, for a rotation that is four years pasture and six years crop, an average forty percent of the farm area will be under crop and sixty percent under pasture. In addition, there may be an additional pasture area on the farm that is never cropped, and the livestock run on this may also be run on the ley pasture. Therefore, the livestock enterprise will gain from having the ley pasture. The gains could be increased stocking rate, or the opportunity to turn off young stock to a different market.

It may help to think of the comparison you are making as a 'farm benefit-cost ratio'. In this case, you have a 'without change' scenario (but even the status quo will change somewhat – fertiliser costs can rise, relative commodity prices can change), and a (or more than one) 'with change' scenario.

It would be worth looking at each alternative using financial tools such as 'start balance sheet', 'expected operating profit', 'net cash flow' (before and after debt servicing) and the 'end balance sheet'. The cash position of a business and expected cash flows in and out during the year are a major infuence on crop sequence decisions. Alternative crop and pasture rotations have different impacts on the timing and level of peak debt, and the timing of income to service overdrafts and/or reduce debt.

Some suggested economic criteria to use are;

- Net return on invested capital (after tax is paid)
- Net cash flow until some steady state is reached
- Break-even criteria for the different options, and
- Debt reduction and equity growth, currently and over time (use the farm balance sheet).

FARM PLANNING

A basic plan

Developing a flexible long-term plan encompassing family or life goals and objectives for the whole farm as a unit is fundamental. Part of this long-term approach should include livestock and permanent pastures. It is essential to construct a whole farm physical plan which will provide an inventory of the farm's physical attributes, limitations and potential.

An integral part of the farm plan must involve a pasture plan, with actual location of pastures, choice of species, method of establishment, subdivision and future grazing management. A whole farm plan can be prepared with assistance from government agencies, or by using the 'Property planning do-it-yourself physical property planning kit' from Tocal Agricultural Centre, 'Tocal' at Paterson NSW.

The farm plan assists in assessing soil quality, topography, defining land capability classes, and

the division of the farm into distinctive zones of suitability for a range of farming enterprises, operations and practices. Most mixed farms include some Class I and Class II land which have the best soil, the flattest topography and best farming land. There could be some Class III land which would grow excellent pasture and limited cropping, and some Class IV land which is unsuitable for cultivation but provides good grazing. There could also be some Class V land which is rugged and unsuitable for agriculture but is a valuable resource of native vegetation and biodiversity.

Courses are available which will help landholders assess the capabilities of their land. For example, Landscan is an easy knowledge and training course conducted by NSW DPI for small groups. It focuses on learning to identify the specific attributes and limitations of each paddock or land type and helps achieve more sustainable productivity and improved environmental outcomes by matching production to the land's potential.

From the basic plan it is possible to define and fence those areas and paddocks intended exclusively for crops, those exclusively for pastures and particular pasture types, and those where crops and pastures can be rotated. The plan can also assist in locating suitable areas and zones for re-vegetation, linkages and corridors.

Infrastructure and animal enterprises

The cost of infrastructure for livestock enterprises can be considerable depending on the situation. Pasture development costs can also be considerable and purchase of livestock can be a very high cost, depending on the type and number of animals sought.

After individual preferences are taken into account, and land classification and potential crop and pasture productivity assessed, the animal carrying capacity can be estimated and the infrastructure requirements should become clear. Subdivision fencing, laneways, holding pens, run-off areas and watering facilities will be needed to allow appropriate grazing management (see the section on strip cropping as an example of subdivision).

Considerable facilities will be required if it is obvious that high quality pastures can be produced, and beef or sheep breeding and finishing enterprises carried out successfully. These may include, for example, holding and drafting yards, cattle crush, weighing equipment, shearing shed.

A significant area on the farm of lower quality soil with low grade pasture potential would indicate that breeding and fattening enterprises are unlikely to be economic, and the most appropriate enterprise could be Merino wethers for wool, or slowly growing out bullocks.

Strip cropping as an example of subdivision

Most strip-farming situations occur on high quality Class I or Class II agricultural land where continuous grain cropping can be reasonably sustainable if appropriate crop sequences, stubble retention and suitable fertiliser programs are used. Depending on the relative economics of livestock enterprises and grain crops at the time, a pasture phase may be neither economically desirable nor environmentally necessary in the most favourable of these situations. However, there may be significant long-term benefits from a pasture rotation in many situations.

Fencing

On land with a slope or soil condition necessitating use of crop strips, the inclusion of a pasture phase poses the difficulty and cost of a very large amount of livestock fencing and efficient provision of watering points for multiple pasture strips.

Electric fencing is the most efficient option because the cost of materials and construction is low. Many farmers, such as those on the Liverpool Plains, successfully graze cattle on strips using semi-permanent, single wire electric fencing. Commonly used materials include 2.5 mm medium tensile wire with plastic insulators and star posts at 20 metre intervals. Costs per 500 m in 2004 are estimated at $476 for materials and $250 for labour. A laneway and water trough are constructed at one end of the strips. The large number of paddocks resulting from fencing strips allows for rotational grazing management and pasture spelling which maximises feed efficiency and pasture performance.

Stock handling

On farms with inadequate or no animal handling infrastructure, the cost of setting up, for

example, sheds, yards, handling facilities, can be very high. Depending on the individual situation and economic climate, however, there is likely to be a sound argument for the expenditure required for introducing livestock and pasture phases into strip-farming operations. Obviously the costs and returns must be evaluated conservatively before undertaking any significant capital investment in livestock and infrastructure.

DIVERSIFICATION AND COMPLEMENTARITY

Just as an investor on the stock exchange diversifies a portfolio of shares to reduce the risk associated with the inevitable fluctuations of the financial world, so the farm should be diversified across as broad a range of enterprises as management and conditions permit.

Over time the diversification of farm enterprises into animal as well as cropping options spreads risk and tends to reduce income fluctuations. Diversification allows more rapid response to market signals, enhancing economic viability.

The enterprises on mixed crop and animal farms can have a mutually complementary effect such as described in the weed control section. Animals graze useful weeds from fallows and crop residues, efficiently salvage high quality feed from failed crops, and optimise the labour and capital resource on mixed farms, significantly enhancing overall economic performance.

There are sound biological and sustainability reasons for combined cropping and pasture based livestock grazing systems on most Northern NSW farms. Well managed, legume based pasture can impact beneficially on crops in many ways:

- High quality pastures produce cost-effective forage for breeding and fattening throughout most of the year, increasing marketing options for livestock.
- Pasture legumes such as lucerne, clovers and medics, can provide substantial amounts of 'free' nitrogen for following crops (Figure 1).

Legume pasture species and cultivar trials, such as at Tamworth Agricultural Institute and across NW NSW are refining pasture recommendations and producing better pastures.

- Pastures contribute organic matter as a food source for soil organisms. These organisms re-cycle plant nutrients and improve soil structure, water infiltration and water holding capacity.
- The pasture phase can effectively reduce crop insect pests and diseases by eliminating host plants.
- Tactical grazing during the pasture phase provides effective control options for serious weeds of crops such as wild oats (Figure 3), and an alternative control strategy against herbicide resistant weeds.
- Similarly, many pasture weeds can be conveniently controlled with the appropriate herbicide program during the cropping cycle. Reduced reliance on herbicides lowers the rate of increase of herbicide resistance.
- Introduced and native pasture species, particularly perennials, provide effective ground cover which prevents or minimises erosion, controls rising ground water and helps avoid soil salinity and acidity.
- Soil erosion is reduced.

PASTURE SUITABILITY

Pasture species

There are many useful native and naturalised pasture grass species in the region and most are described in the NSW Department of Primary Industries' Agfact P2.5.32 *Grasses - native and naturalised*. Grass pastures must include legumes to maximise production.

In the more eastern parts of the region, some of the more valuable native perennial species include Wallaby grass (*Austrodanthonia* spp), Weeping grass (*Microlaena stipoides*), Red grass (*Bothriochloa macra*), and Queensland Blue grass (*Dichanthium sericeum*). Many of these also grow on the plains where Curly Mitchell Grass (*Astrebla lappacea*) is one of the most important species. These species can be encouraged and extended with appropriate management such as lengthy spelling and self seeding, however, regeneration after many years of continuous cropping may be extremely slow. Native grass seed supplies are either prohibitively expensive, very scarce or unavailable, therefore it may be necessary to rely on exotic species at least in the short-term.

Species selection

Pasture quality and period of availability greatly influence the choice of livestock enterprises open to the producer. If high level breeding and fattening with rapid weight gains are required then pastures must have a good balance of legumes and grasses and be capable of producing adequate volumes of highly digestible, leafy green forage over an extended period.

Introduced species are often an improvement on natives which tend to mature rapidly and lose digestibility. Austrodanthonia is an example of a native grass species which maintains good quality fodder as it matures. A combination of introduced legumes and the more valuable native grasses can perform well. Livestock performance on these pastures depends largely on adequate legumes to provide nitrogen for the system, and tactical grazing to ensure grasses are grazed at a leafy highly digestible stage for as long as possible.

A huge number of pasture species are available, with widely varying characteristics and requirements. North western NSW has a wide variation in soils and environmental conditions. For successful pasture establishment and performance, the species must be well matched with the soil and climate of the location.

Tropical grasses and legumes are well adapted throughout much of the region particularly in hot areas to the west. Temperate species are preferred in the more easterly zones and those where aspect, soil, fertility and management are favourable.

Vigorous phalaris, lucerne and clover pasture sown into a prepared seedbed with an air seeder (near Gunnedah)

Author Ian Collett checking an excellent stand of Arrowleaf clover with Biserrula in spring on sandy loam soil west of Boggabri NSW.

Range of species available

New pasture species and cultivars are being evaluated constantly by NSW Department of Primary Industries and other organisations, sometimes with spectacular success, for example, the range of serradellas, biserrula, arrowleaf clover and barrel medics, as well as the tropical grasses including Bambatsi panic, Premier digit and Floren bluegrass.

A selection of some useful introduced pasture species is listed below. These are used in appropriate situations throughout the region, and the selection of other suitable species, and best adapted cultivars from within species, needs careful consideration.

The choice depends on important physical characteristics of each paddock including: amount, seasonality and reliability of rainfall, type, depth and fertility of soil, livestock type and performance requirements, and management requirements, to name a few.

Personal preference and local experience should also be a factor in the choice of pastures.

(Note that forage crop species are not part of this publication but are covered in specific NSW Department of Primary Industries Agfacts available on the web and/or as hard copies.)

Temperate Grass Species

Phalaris (*Phalaris aquatica*)

Cocksfoot (*Dactylis glomerata*)

Fescue (*Festuca arundinacea*)

Temperate Legume Species

Lucerne (*Medicago sativa*)

Snail medic (*Medicago scutellata*)

Barrel medic (*Medicago truncatula*)

Sub clover (*Trifolium subterraneum*)

Rose clover (*Trifolium hirtum*)

Serradella (*Ornithopus* spp.)

Biserrula (*Biserrula pelecinus*)

Disc/Strand hybrid medic (*Medicago tornata/ littoralis*)

Gland clover (*Trifolium glanduferum*)

Sulla (*Hedysarum coronarium*)

Arrowleaf clover (*Trifolium vesiculosum*)

Purple clover (*Trifolium purpureum*)

Tropical Grass Species

Panic (*Panicum* spp.)

Setaria (*Setaria incrassata*)

Rhodes (*Chloris gayana*)

Digit (*Digitaria eriantha*)

Lovegrass (*Eragrostis curvula*)

Buffel (*Cenchrus ciliaris*)

Bluegrass (*Bothriochloa* spp.)

Tropical Legume Species

Annual lablab (*Lablab purpureum*)

Perennial lablab (*Lablab purpureum*)

Atro siratro (*Macroptilium atropurpureum*)

Burgundy bean (*Macroptilium bracteatum*)

Cowpea (*Vigna unguiculata*)

Butterfly pea (*Clitoria ternata*)

Desmanthus (*Desmanthus virgatus*)

More details on pasture species and cultivars are available from sources such as NSW Department of Primary Industries' Agfacts, Agnotes and web-site, and various pasture guides such as *Pasture Production for Livestock*. These publications may be useful to match the species/variety with the specific conditions of soil, topography, and climate.

Examples of successful pasture mixes

It is not possible to cover the entire spectrum of choices in this publication and other sources are available for this purpose. However, the following are some examples of good mixes. Varieties mentioned are only suggestions and not necessarily the best or only choices available.

Serradella plus rhodes grass and Premier Digit grass on sandy, moderately acidic, well drained soils in the Coonabarabran, Warialda and Qld border areas.

Vigorous, dense Bambatsi panic with Arrowleaf clover (west of Boggabri)

Medic, lucerne plus Bambatsi panic and Purple Pigeon grass on grey clay near Narrabri.

Lucerne and sub clover with phalaris on red clay loam soil near Gunnedah.

Sub clover plus Premier Digit grass and rhodes grass on the less acid sandy to loam soils and light textured soils of the Dubbo area.

In many situations the pasture will be required to last for a relatively short period of 2–4 years before rotating back to crop. A legume such as lucerne may be the most suitable species for this situation. Pasture longevity is directly linked to appropriate matching of species with environment and grazing management. A mixed grass-legume pasture is recommended for long-term rotations.

The supply of adequate nutrition with fertilisers, combination of legumes with grass species and

Vigorous tropical grass-based pasture combination of Purple pigeon grass, Premier digit grass and Katambora rhodes grass with Serradella and Biserrula in north west NSW.

grazing systems which allow adequate spelling of pastures all contribute to highly productive and long lasting pasture.

Many varieties of pasture grasses, legumes and herbs are available in NSW and it is essential to select those which best match each environment, farm and even paddock for good results. To aid in selection, refer to your local NSW Department of Primary Industries office, or other pasture advisors.

PASTURE ESTABLISHMENT

Inadequate planning is the most common cause of pasture establishment failure. Planning should commence at least 12 to 18 months before sowing.

Climatic conditions on the North West Slopes and Plains are quite variable but are characterised by a summer dominant rainfall often with dry autumns and an erratic rainfall pattern. Large variations in daily and seasonal temperatures occur with severe winter frosts and high summer temperatures. These conditions provide a difficult environment to establish small seeded pasture species (which are delicate and slow growing compared to most crops) and thus greater care and attention to detail is essential to establish pastures successfully.

The following guidelines provide a sound basis for pasture establishment:

Maximise soil moisture storage

Having sufficient stored soil moisture allows timely sowing, greatly improves germination, early growth and survival. Volunteer vegetation must be controlled in the 'fallow' period to preserve soil moisture and reduce weed competition with young pasture.

Use effective sowing techniques

Pasture seed is intrinsically very small, seedlings are weak and unable to emerge from the deep placement (50 mm) commonly used for cereal crops. Pasture seed must be shallow sown – no more than 15 mm deep and even less for tropical grasses.

The most reliable method of establishing pasture is to sow into a weed free conventional seedbed. Direct drilling is the next most reliable method, and although it can be highly successful with good conditions, aerial or surface seeding into crop or stubble is the least reliable method. Surface sown seed should be treated with a registered chemical to prevent theft by ants.

Surface seeding onto cultivated fallow land with a properly calibrated broadcaster can be a very cost effective pasture establishment method.

Refer to other publications for more detail on specific pasture establishment methods. These publications include the Prime Pasture Program's reference manual, the NSW Department of Primary Industries PASTURES home study program land management series, and technical publications from other sources.

Use adequate seed

Sufficient seed is needed to establish a productive, competitive pasture in the first year that will limit weed growth and maximise stocking rates after establishment.

Sow adapted varieties

Research and practical experience are the best guides to the more successful pasture varieties for a particular situation. This information greatly improves the chances of successfully establishing a highly productive persistent pasture. Species and variety guides and recommendations are available from NSW Department of Primary Industries and appropriate advisors. To avoid introducing noxious and nuisance weeds, use certified seed or seed from known origins.

Provide adequate nutrition

It is essential that plant nutrient deficiencies are diagnosed and corrected where necessary if pastures are to perform well, especially on long-term farmland.

A ploughed paddock left in the rough ready for broadcast seeding near Boggabri.

Most soils on the North West Slopes require fertiliser to maximise production. Young pasture plants need a good supply of nutrients soon after germination. Some soils on the plains will also require fertiliser. Legumes require phosphorus and sulphur and may need molybdenum in some soils on the slopes. Grasses also need these elements but need adequate nitrogen as well for satisfactory establishment. A pasture with a good balance of legumes will eventually provide adequate nitrogen. Many soils require small amounts of starter nitrogen for good grass establishment.

Inoculation of all legume seeds is vital to ensure good nodulation and nitrogen fixation.

Other nutrients which can be limiting in certain situations include potassium, molybdenum and zinc.

Sow when conditions are best for germination and survival

Temperate species are best sown in autumn, from late April until the end of June. Early sowing within this period is preferred if soil moisture is adequate.

Tropical grasses are best sown in spring from late September until early November or in late January/early February when soil temperature and moisture are adequate and there is a reasonable probability of receiving good follow up rain. The late summer/early autumn sowing is generally more reliable in the far north and west of the area. Anticipated invasion by either summer or winter growing weeds is an important consideration when choosing the best sowing time.

Control weeds and insects

Weed competition is a major cause of establishment failure in pastures. Effective weed control in the seasons before sowing pasture, and attention to adequate seed rate and seed distribution at sowing will greatly improve the chances of good establishment.

The number of herbicides available for weed control in pastures is limited, especially for pastures containing a mixture of legumes and grasses, and they can be more expensive than those used for crops. Early identification of weed species and prompt application of appropriate herbicide during seedling growth of the susceptible weed stage is strongly encouraged.

Non-chemical weed control measures such as crash grazing or mowing can be effective in some situations. Manual hoeing is another option for isolated weed infestations

Insect infestations, such as blue oat mite, can severely damage young pastures. Young pasture must be monitored regularly to allow timely control measures when required. Resistant pasture varieties, such as aphid resistant lucerne, should be sown where available.

Herbicide residues

Pastures can be susceptible to herbicide residues from previous crops. Therefore, paddock records of herbicides used and knowledge of residues and plant back times is essential for successful pasture establishment after crops.

GRAZING MANAGEMENT

Pasture plants of different species and varieties vary greatly in their response to grazing. Management that promotes the wellbeing of a pasture usually benefits grazing stock and contributes to sustainability. Spelling at critical times (such as spring and autumn) can favourably affect pasture composition and persistence. Legumes need to be well adapted to the environment but also need correct management to maintain a suitable balance with grass species to fix adequate nitrogen in the pasture phase.

The means of reproduction in legumes varies considerably. Some are dependent on high soil seed reserves (e.g. sub clover and medic) whilst others spread by stolons and seeding (e.g. white

Cattle grazing improved tropical grass and temperate legume pasture near Boggabri.

clover). This variation can affect the grazing management as tactical grazing and spelling can have a dramatic effect on seed set. As a general rule, do not under-graze or over-graze established pastures. Keep pasture in the active growth phase to optimise production of high quality forage, enable quick regrowth, improve carrying capacity, and achieve efficient use of soil water.

As many pastures are sensitive to seasonal changes, management on a seasonal basis allows the producer to focus on the likely issues to address at a particular time. However, it is vital that optimum management requirements of the important species in the pasture mixture are considered. In the establishment year, grazing management should aim to ensure that perennials establish strong root systems and that annuals set adequate seed. In subsequent years annuals should be lightly stocked or rested for up to two months after germination to allow effective establishment.

Minimising soil compaction

Soils vary greatly in their susceptibility to compaction by cattle and sheep, however it is clear that all soils will suffer more severe damage when softened by wet conditions. Therefore, it is essential to have safe run-off areas available such as stony hillsides or sloping pasture areas that are well established and more resistant to hoof damage.

The static vertical pressure exerted on the soil by a standing beast is around 138 kPa, a standing sheep about 66 kPa, and by an unloaded, tyred tractor 74–81 kPa. Hoof pressure is significantly higher with a moving animal as its weight is carried on three and sometimes only two feet. Though most grazed pasture soils will be compacted, the magnitude of hoof compaction is usually small and, unlike compaction caused by heavy farm machinery, is limited to shallow depth in the upper 20 cm of the soil. This compaction is readily overcome with normal cultivation, however deep compaction caused by machinery can be almost irreversible.

TECHNIQUES TO REMOVE PASTURE SPECIES

Removing pasture species before the crop phase is important because pasture species and annual crops have a similar capacity to compete for moisture, nutrients and light. Lucerne in particular is very persistent when managed and grown under ideal conditions and can be difficult to remove. This is particularly the case when the stand is thick and healthy and relatively weed free. In no-till situations or where deep and thorough cultivation is undesirable, lucerne can be removed with an effective registered herbicide.

Perennial grass pasture species, such as phalaris, panic, and pigeon grass, are usually susceptible to cultivation especially in hot weather, and can be eradicated with appropriate knock-down or selective herbicides. Annual pasture grasses and legumes, such as medics and clovers, which regenerate from seed (and can have a high percentage of carry-over hard seed) can become part of the crop weed spectrum. They can be controlled in the fallow period with grazing or knock-down herbicides, and in the crop with selective herbicides.

ROTATION EFFECTS OF PASTURE

Well managed pastures can add to the soil's supply of organic matter and legume species can contribute large quantities of nitrogen for use by following crops. Legumes host the Rhizobia bacteria that fix atmospheric nitrogen into forms useful to plants. They fill a vital role in maintaining nitrogen levels in pasture and cropping soils. Over 120 kg/ha of fixed nitrogen per year has been measured in sub clover pastures in southern Australia where plant nutrition was good. Perennial legumes like lucerne are able to fix even greater amounts of nitrogen under correct management.

Organic matter is essential for a healthy level of soil organisms, for soil structure, and to provide plant nutrients after decomposition. Grasses are superior to legumes in raising organic matter levels and therefore grass-based pasture with legume should be sown in soils with low organic matter. The nitrogen produced by the vigorous legume stimulates the grasses.

Long-term rotation experiments at NSW Department of Primary Industries' Tamworth Agricultural Institute show direct benefits in wheat grain yield and grain protein following only 2 years of vigorous lucerne pasture. In these experiments the benefits on black soil and red soil were averaged over 3 years from 1991 to 1993. On black soil (Fig. 1) the grain yield after lucerne was more than double and grain protein was almost 50% higher than the continuous wheat treatment. On red soil (Fig. 2), grain yield increase after lucerne was almost four times and grain protein was almost 20% higher than the continuous wheat treatment.

Wheat yield and protein in all other legume rotations were also superior to those of continuous wheat. The long fallow (18 months) treatment held up better than continuous wheat but caused the most severe decline in organic matter. The improved wheat yields in fallow were due to better soil water accumulation during the long fallow treatment.

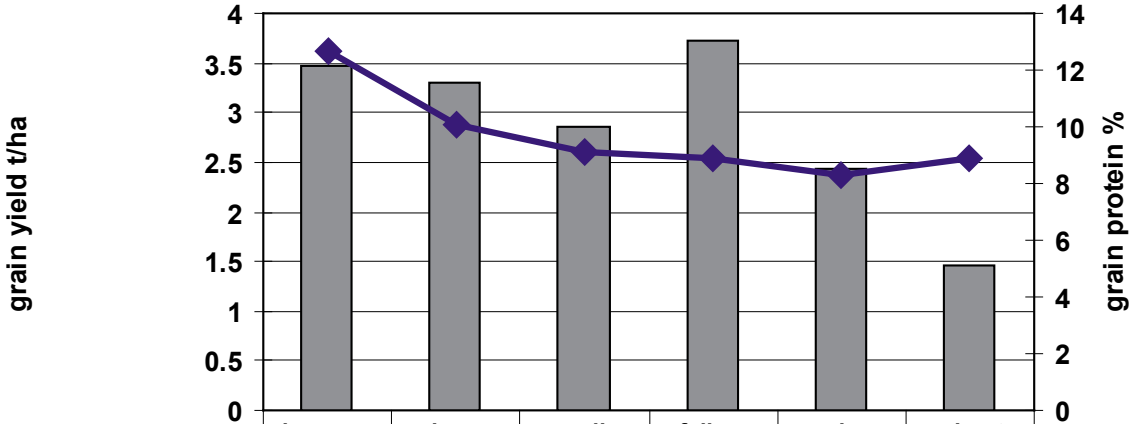
Note that grain protein was depressed in the chickpea rotation due to the effects of severe diseases including Luteovirus, Ascochyta and Phytophthora in 1991. Relatively high protein level of the continuous wheat was at the expense of the very low grain yields in this rotation. No nitrogen fertiliser was applied to any treatment.

The optimum length of the pasture phase depends on several factors which vary from farm to farm with environmental conditions, market forces and the specific rotation being followed.

A well managed lucerne phase of 2 to 3 years can provide a highly significant benefit to the following wheat on heavy textured black soil, however 3–4 years may be required on lighter red soils. In the Tamworth rotation trial the legume pastures, particularly the lucerne and the sub clover, provided the best source of active organic matter which best maintained an open soil structure and resulted in maximum water infiltration. A video report on tape or CD of this trial is available from NSW Department of Primary Industries, Tamworth.

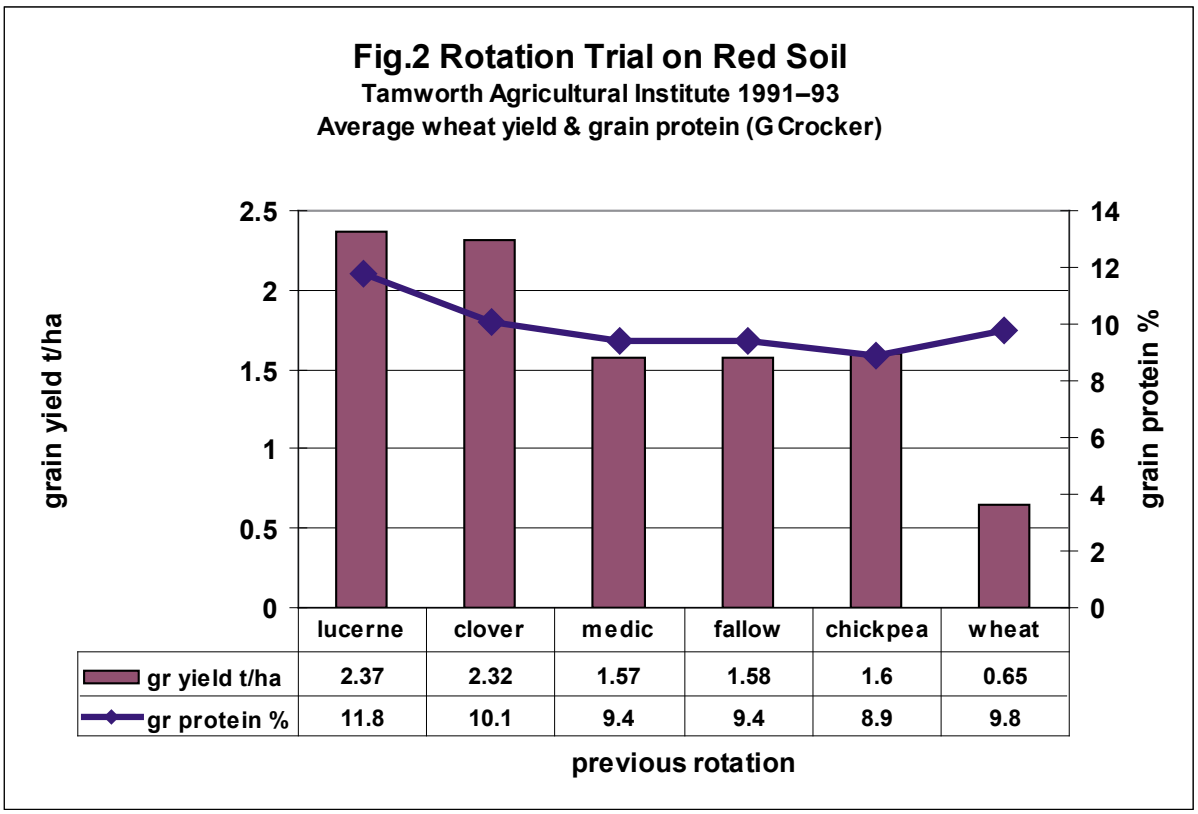
In the summer rainfall environment of northern NSW, lucerne is a superior source of biological nitrogen to that of annual legumes such as sub clover and medic. This is because the deep-rooted perennial nature of lucerne allows

Fig. 1 Rotation trial on Black Soil
Tamworth Agricultural Institute 1991–93
Average wheat yield & grain protein (G Crocker)



	lucerne	clover	medic	fallow	pulse	wheat
gr yield t/ha	3.47	3.31	2.86	3.73	2.44	1.45
gr protein %	12.7	10.1	9.1	8.9	8.3	8.9

previous rotation



nitrogen to be fixed at greater depth which slows the rate of mineralisation, and subsequent loss by leaching and denitrification. This reservoir of fixed nitrogen provides a relatively stable and long lasting source of nitrogen. Summer growing grasses and legumes utilise this nitrogen thereby minimising the acidification of soils, which is a significant problem with legume pastures in southern NSW.

Length of pasture phase

There is no set recommendation for the length of the pasture phase as it depends on several variables which need to be evaluated for each paddock and farm situation. Some variables include:

- The rate of N accretion (linked to the effectiveness of nitrogen fixing species present and rate of removal by grasses and weeds)
- Relative profitability of the cropping and livestock enterprises
- The occurrence and severity of pests and diseases

With average conditions lucerne pastures usually extend from 3–7 years and perennial grass-based pastures 5–7 years. This period may be reduced if weed invasion, disease or drought intervene.

As a rule of thumb, every tonne of dry matter (DM) top growth produced by the legume pasture or crop contains about 15 kg of nitrogen. A similar amount is produced in the roots. A typical rain grown lucerne pasture producing say 4.5 t/ha of DM and 4.5 t/ha of roots would therefore produce a total of about 135 kg/ha N each year. Under rotational grazing and 'average' conditions, about 50 % of this N will be carried over in the soil for following crops.

In a lucerne phase the maximum amount of nitrogen is produced in about three years under normal circumstances. Under average Northern NSW dryland conditions moisture in the soil profile will be considerably decreased after the lucerne phase. For this reason it is necessary to remove the lucerne in spring to allow soil moisture to accumulate before sowing a winter crop.

Nitrogen fixed by shallow rooted annual legumes is mineralised more rapidly than nitrogen fixed by deep-rooted species like lucerne. For this reason the nitrogen produced by annuals is more vulnerable to leaching and denitrification during the fallow period. Thus (except for short rotations) annual legumes should be sown with tropical grass species in northern NSW. This practice has the benefits of converting mineralised nitrogen to an organic form, allowing organic carbon fixation,

minimising soil erosion and increasing water infiltration in summer, the period of high intensity rainfall.

The rate of nitrogen accumulation from this pasture depends on the proportion of legume and is slower than that of lucerne. However, the mixed pasture would have a more beneficial effect on soil structure. This annual legume/grass pasture is more suitable for a longer term rotation. As with lucerne, it is necessary to remove the mixed pasture in time to allow soil moisture to accumulate during the higher rainfall summer months if yields are to be maximised in the following crop.

Where cereal diseases may carry over in grasses to infect the following cereal crop, it may be necessary to remove the pasture earlier or plant a crop not susceptible to the diseases.

VAM

Legume and grass pastures generally do not harm the soil organism vesicular-arbuscular mycorrhizae (VAM) enabling a wide choice of crop type to be grown after the pasture phase.

WATER USE EFFICIENCY

Water has possibly the greatest single influence on pasture production but farmers have no control over the rainfall received. However, management practices that maximise the infiltration capacity of the soil enable more rain to soak in and be available for use by the pasture or crop. Conversely, if the infiltration capacity of the soil is reduced (such as by compaction, surface crusting or reduced ground cover) runoff will be increased, soil water storage decreased, potential for erosion and nutrient loss increased, and pasture growth reduced.

Therefore, the first objective in water use efficiency is to keep surface infiltration capacities high by maintaining good soil structure and effective surface cover. Tactical grazing with appropriate spelling periods can be effectively used to maintain ground cover and minimise deep drainage below the plant roots. Deep drainage of water past the root zone of plants and into the water table is not only lost to pasture and crop production but can raise the water table and be a major cause of salinity. It also removes nutrients from the root zone by leaching, and can contribute significantly to soil acidity.

SOIL ACIDITY, SALINITY AND SODICITY

All three problems are strongly influenced by management of soil moisture and water on the farm, and can have a major impact on soil health, pasture establishment and production.

Highly acidic soil interferes with the availability of plant nutrients and the growth of sensitive plants. Saline soil reduces pasture production and can sterilise soil, whilst sodic soils can have severe structural problems which restrict water infiltration, increase run-off, cause crusting and compaction.

Parts of the region are already affected, or at risk of being affected by excessive soil acidity, salinisation and/or sodicity. Identification of these problems is essential and it is necessary to understand their causes and effects to avoid them, and to apply corrective management where appropriate.

SOIL COMPACTION

Introducing grazing animals into cropping systems has major advantages but it may adversely affect soil structure and this must be considered. Many of the red and black clay soil types in Northern NSW are susceptible to compaction by grazing animals when wet, which can damage structure of the all-important top soil layer.

Compaction by animals can occur very quickly on susceptible clay based soil which becomes soft or 'plastic' when wet. Cattle can exert ground contact pressure of up to 250 kPa when walking. This type of compaction is usually limited to a depth of up to 20 cm but can cover a large proportion of the paddock, damage the surface soil structure and significantly interfere with water infiltration, physically damage pasture plants, especially lucerne, reduce pasture production, accelerate diseases such as crown rot, and create a very uneven soil surface. This leads to poor aeration, poor infiltration and ponding which worsens the problem unless stock are removed. This has particular implications for crop establishment in no-till and minimum-till cropping situations where compaction can nullify the soil benefits of

no-till and the farmer may not have access to the powerful machinery needed to restore seedbed tilth.

In comparison, soil compaction under wet conditions by heavy machinery can penetrate to 50 cm or more and is very difficult to repair especially in non-cracking soils.

Cattle tend to be more damaging to soil structure and pasture than sheep, however during wet conditions when soil is soft, it is essential to move all livestock onto sacrifice or run off areas with firmer ground. This needs to be planned for in all grazing situations.

Harmful effects can be minimised by avoiding set-stocking and removing stock when soil is wet and near its plastic limit.

WEEDS AND DISEASES

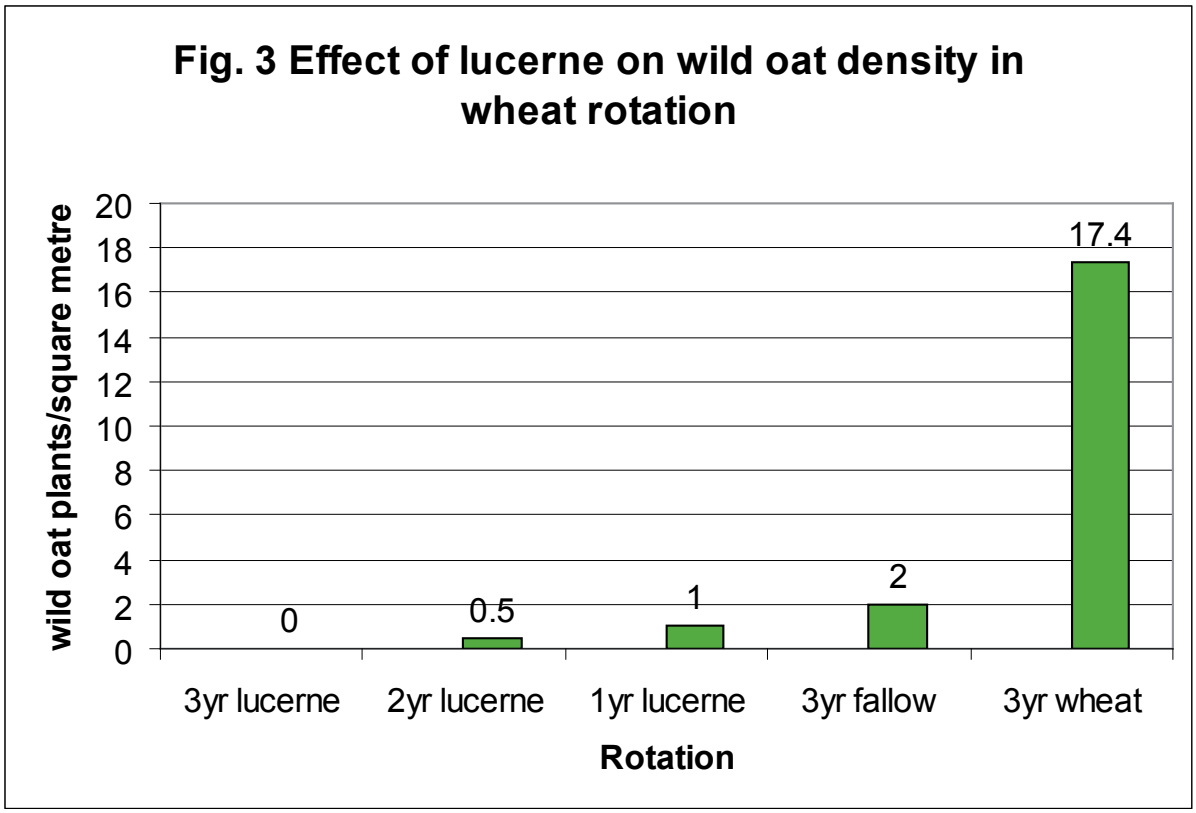
Grazing livestock can become a valuable part of the integrated weed control program on many farms. Alternate phases of crop and pasture can significantly reduce pasture weeds in crops and crop weeds in pastures. During the pasture phase strategic grazing can effectively remove palatable weeds by systematically preventing seeding.

For example in a trial at Tamworth (Fig. 3), three years of well managed lucerne pasture fully controlled wild oats in the following wheat crop and even one year of lucerne reduced wild oats to just one plant per square metre. Three years bare fallow also reduced the wild oats to two plants per square metre. However, when three more crops of wheat were produced the wild oat population increased to 17 plants per square metre in the third crop.

Fallow weed control by grazing reduces the need for herbicides, but at the cost of some nutrient tie-up, lost fallow moisture, potential increases in the weed seed bank, and soil compaction from the animals. The grazing option works best in dry conditions when soil is firm, plants are stressed and feed may be scarce. Livestock grazing intensity should be high enough to remove weeds within three or four days. The class of grazing animal must be matched to the quality of feed on offer in the fallow.

Annual weeds such as wild oats can be eliminated by grazing during a pasture phase.

During the crop phase, chemical fallow or cultivation can eliminate difficult pasture weeds. Grassy weeds can be conveniently removed from broad leafed crops such as canola and



pulses using selective herbicides, and similarly, broad-leafed weeds removed from cereal crops.

Cereal crop diseases such as crown rot and take-all, and pulse and oilseed crop diseases such as ascochyta and blackleg can be reduced by a pasture phase as long as host weeds are controlled in the pasture.

ANIMAL HEALTH

The incidence of animal health problems may increase with better quality pasture and increased stocking rates. Bloat and enterotoxaemia (pulpy kidney) are the most important potential problems in clover, medic and lucerne dominated pastures.

Deaths from bloat are caused by compression of the lungs by the rumen expanding with gas from fermentation being produced faster than it can be belched up, or in the form of foam which is hard to bring up; and compression of the blood supply from the expanding rumen. There is no control measure for frothy bloat that is 100 percent effective but there are a number of practical control measures that greatly reduce the risk of bloat. Livestock officers (beef cattle) and veterinarians can advise on bloat control.

Lush pastures often predispose to pulpy kidney and producers should ensure that cattle are effectively inoculated with the appropriate vaccination.

Producers should be aware of a number of other potential disorders so they can familiarise themselves with symptoms and preventative measures for these conditions. The following is not a comprehensive list of pasture species that have the potential for causing animal health problems. Growers need to enquire about potential animal health problems that may arise from any pasture species they intend sowing. Animal health problems which may be encountered include clostridial diseases, Redgut, internal parasites, nitrite/nitrate poisoning and photosensitisation. Other animal health problems caused by particular grasses include phalaris poisoning, ryegrass staggers and cyanide (prussic acid) poisoning in sorghum species. Oxalate poisoning can also be caused by buffel grass and purple pigeon grass. Information is available from NSW Department of Primary Industries on animal health issues and the management of specific pasture species that may cause animal health problems.

Consult your veterinarian for more information on animal health.

TROPICAL GRASS SEED PRODUCTION

Tropical grass seed is expensive and often in short supply, but where Plant Breeders Rights will not be contravened, the seed cost of pasture rotations can be reduced by harvesting viable grass stands with brush type or other appropriate harvesters.

A number of landholders on the North West Slopes and Plains have harvested tropical grasses. This can be a difficult job but by using modified machinery and improved technology for drying and storing seed farmers can significantly improve harvest efficiency. If considering seed production farmers should choose a paddock that is as weed free as possible and control weeds before sowing and during the growth stage. The greatest seed losses can occur from cleaning after harvest.

Timing and method of harvest greatly affect the yield and quality of seed recovered. Harvest decisions are complicated by the continual ripening of seed in the crop and by the spread in maturity in the individual seed heads.

Well grown tropical grass seed crops can produce over 1 t/ha of seed but because the production of new seeds and shedding of old seeds is continuous only about 25 to 50% of this seed potential is presented for harvest at any one time. Quality of the seed harvested will also be below the potential because some immature seeds will always be present.

The timing of harvest will vary with different grass species. It will also depend on the weather conditions as wind and rain can quickly strip ripe seed from the standing crop. Autumn is generally the preferred harvest time in this area.

Harvest of tropical grass seed should commence before all seed is fully ripe. This gives the best compromise between maximum seed yield and maximum seed quality.

Crops should generally be harvested when the bulk of seed is almost shedding. Changes in colour of the ripening seed can also be a useful guide.

Recommendations to time harvest when a certain amount of seed has been shed (say 15–20%) are generally unreliable.

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Region pasture planner in pasture work on NSW DPI website www.agric.nsw.gov.au

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Pasture improvement cautions

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

The *Native Vegetation Act* (2003) restricts some pasture improvement practices where existing pasture contains native species. Inquire through your office of the Department of Infrastructure, Planning and Natural Resources for further details.

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