Chapter 2
Perennial pasture management

2.1 Grazing method .............................................28
Paul Sanford

2.2 Animal production from extensive grazing systems ............................................32
Hayley Norman and David Masters

2.3 Animal toxicity ..............................................39
Jeremy Allen

2.4 Internal parasites of livestock and perennial pastures ..........................................42
Brown Besier

2.5 Perennial pastures, plant diseases and the ‘green bridge’ ..........................................44
Roger Jones and Dominie Wright

Grazing method is a critical factor in efficient pasture and animal management. For perennial pastures the choice of grazing method is particularly important to ensure plant persistence while maximising pasture utilisation and livestock performance.

With most perennial species some form of rotational grazing is essential to ensure persistence in the medium- to long-term. A number of studies have demonstrated that the density of perennial pastures declines rapidly under set-stocking. Kikuyu is an obvious exception as it persists under set-stocking and can respond to high grazing pressure. There are a number of species including tagasaste and some of the temperate perennial grasses that persist under set-stocking with cattle but not with sheep.

There is considerable interest among livestock producers in using different grazing methods to improve productivity, maintain desirable pasture species and reduce land degradation. Historically set-stocking was the only grazing method used with annual pastures. Under this system, stock were moved from paddock to paddock on an ad hoc basis, remaining in each paddock for varying periods and in some cases months. In contrast, rotational grazing involves the frequent movement of large groups of stock through a series of paddocks. The difference between the methods is that set-stocking largely enables the animal to control where, when and which plants it eats whereas the higher grazing pressure of rotational grazing, means the animals have less ability to choose. Rotational grazing allows the producer to decide when and for how long a pasture will be grazed and rested.

This section briefly discusses how different grazing methods impact upon the productivity and persistence of perennial pastures, livestock production and land degradation.

Different grazing methods
Grazing method is a procedure or technique of grazing management used to achieve a specific objective. Set-stocking and rotational grazing are examples of grazing methods, but there are many more. Farmers can become confused when confronted with the large range of grazing methods, e.g. set-stocking, rotational grazing, strip grazing and cell grazing, etc. However, all these grazing methods fall on a continuum between the two extremes of (strict) set-stocking and intensive rotational grazing.

Under (strict) set-stocking animals remain in one paddock for the whole year and the pasture receives no rest. However, very few producers use this grazing method in its strictest sense but rather leave stock in the same paddock for long periods, especially during the growing season. Intensive rotational grazing involves moving stock daily and in some cases more than once per day with pastures receiving a long rest between grazings.

With rotational grazing stock are either moved on the basis of time (e.g. four paddock lucerne system with two weeks grazing followed by six weeks rest), or variable recovery time under the ‘Savoury’ approach, plant growth stage (e.g. three-leaf stage), animal intake (e.g. maintain maximum intake) or feed-on-offer (FOO).

Another key factor in rotational grazing is the number of paddocks in a rotation. As the number of paddocks increases the:
• grazing period for each paddock decreases
• stocking pressure during grazing increases
• rest period for each paddock increases
• animals’ ability to graze selectively is reduced
• average stocking rate (i.e. grazing days/ha) stays the same.

Some farmers use an intensive rotational grazing method developed by ‘Savoury’, the principles of which are to:
• control rest to suit the growth rate of the plant
• adjust stocking rate to match carrying capacity
• plan, monitor and manage the grazing
• use short grazing periods to increase animal performance
• use maximum stock density for the minimum time
• use a diversity of plants and animals to improve ecological health
• use large mob size to encourage herding.

In reality, no single grazing method can meet every animal and pasture objective. The best approach is to use different grazing methods...
Perennial pastures for Western Australia

Perennial pasture management tactically on the basis of seasonal conditions and livestock and pasture requirements.

For example, in situations of feed deficit rotational grazing allows better control over the regrowth period than set-stocking and can be used to restrict livestock intake. Conversely, in a situation of feed surplus set-stocking at high stocking rates can be used to control FOO and allow animals to select a high quality diet.

Pasture production

Optimising pasture production depends on controlling two variables: the residual FOO following grazing and the length of time pastures are allowed for regrowth. In general, the higher the leaf area the higher the potential growth (FOO provides an estimate of leaf area).

If residual FOO is too low, pasture growth will initially be slow due to the low leaf area available for photosynthesis. If the period of regrowth is short, then pastures will only experience high growth rates for short periods or not at all. Conversely, feed quality declines as plants mature, so there can also be a trade-off between biomass production and quality.

All grazing methods with the objective of maximising production involve monitoring pasture growth and using indicators to maintain the optimum FOO for pasture growth for the longest possible time, e.g. grazing at the three-leaf stage.

When FOO is plotted against pasture growth rate for kikuyu (Figure 2.1), it becomes apparent that the fastest growth rate increases occur up to a FOO of about 1400 kg DM/ha, after which pasture growth rates continue to increase but more slowly. Grazing systems that enable a kikuyu pasture to be maintained >1400 kg DM/ha have the potential to increase production.

An application of this principle is to defer kikuyu pastures at the break of season until they reach ~1400 kg DM/ha then graze and maintain at 1400 kg DM/ha throughout autumn and winter. In spring allow FOO to fluctuate between 2000 and 3000 kg DM/ha to optimise pasture growth and liveweight gain in stock. Another example is rotational grazing systems that maintain the majority of paddocks, cells or strips at ~1400 kg DM/ha or higher.

For other perennial pastures with a more upright growth habit than kikuyu (e.g. lucerne), the minimum levels of FOO are likely to be lower.

Cows on setaria pasture on the south coast. All of the sub-tropical grasses except kikuyu require some form of rotational grazing to persist.

Figure 2.1 Pasture growth rates versus feed-on-offer (FOO) for kikuyu at Manypeaks.
Perennial plant persistence

Most perennial species require rest following grazing to allow plants to replenish below-ground reserves and to complete seed set, retain protective sheaths under moisture stress and regenerate from dormant buds. The key to the long-term persistence of perennial pastures is to manage the carbohydrate reserves. Perennial plants store carbohydrate in their crown, tap-root, stolons and/or rhizomes and use this energy for the initial regrowth following grazing (or defoliation), to persist through periods of stress (e.g. drought, cold) and for regrowth in autumn for summer-dormant species. If the carbohydrate reserves are continually exhausted and not fully replenished, then the stand density will gradually decline.

The response of perennial pastures to different grazing methods can be considered in terms of their requirements for strategic rest from grazing, the timing of the rest period and grazing pressure. For example, the response of perennial grasses falls into four broad categories:

(a) Some species like cocksfoot require rest during a period of stress (e.g. drought) when growth rates are low. Rest is most likely required during these periods to retain active root systems and buds with low dormancy. A rest in summer also enables sterile tillers to complete their lifecycle.

(b) Some species require a strategic rest during periods of active growth, particularly when regenerating from buds in autumn and during the reproductive phase (e.g. phalaris). These species have limited resources for regrowth if grazed during these periods probably because they have a low density of tiller buds.

(c) Species that respond to additional grazing pressure (e.g. kikuyu). These species exhibit rapid growth following defoliation and have many tiller buds close to the ground. Many possess rhizomes and/or stolons.

(d) Some species show minimal impact from different grazing methods (e.g. wallaby grass). There is some uncertainty regarding these plants as their lack of response may be the result of light grazing pressure.

Research has shown that perennial grasses, when set-stocked, persist better under cattle than sheep, most likely because sheep are more selective and graze more closely than cattle. In summer, selective close grazing by sheep results in a greater loss of perennial plants than cattle at a similar stocking rate (DSE/ha).

The appropriate grazing method(s) for each perennial species are discussed in their respective descriptions (Chapters 4 to 9).

Animal production

It is commonly thought that rotational grazing results in more pasture dry matter production and as a consequence allows higher stocking rates. In recent comparisons between set-stocking and rotational grazing in which production was optimised, the stocking rate was 5-15% higher with rotational grazing. The liveweight gain per head was lower under rotational grazing in the prime lamb studies, but there was little or no difference in wool cut per head in trials involving Merino wethers.

In general, when pasture availability is non-limiting, livestock production per head will be higher with set-stocking as it allows animals to select a high quality diet. However, this may lead to the loss of the most palatable / highest quality species in the pastures so that in the medium- to long-term animal production will decline. The combination of high stocking rates and set-stocking can lead to an increase in the subterranean clover content, which can also improve performance per head. In contrast rotational grazing usually leads to an increase in the grass component, which increases production per hectare.

Most farmers are likely to see similar or smaller increases in stocking rate with rotational grazing than those measured in research trials unless scale is important. Large paddocks often contain areas of pasture that are ungrazed or grazed infrequently. If large paddocks are subdivided and rotationally grazed, pasture that was previously under-utilised will be consumed – leading to an increase in production. A similar result can be obtained by grazing large paddocks with big mobs, thus reducing selective grazing by livestock.
During lambing most producers prefer to set-stock to reduce mis-mothering particularly with Merino ewes. However some farmers successfully rotate lambing ewes by allowing them to ‘drift’ between paddocks (i.e. gates are left open so the ewes that have just lambed can catch up to the mob when ready). Set-stocking is also preferred during joining and birth by producers who are single sire mating and who need to identify progeny carefully.

Rotational grazing can be used as a tool to assist in the control of internal parasites, either by using cattle to clean up a pasture for sheep or ensuring that livestock are not exposed to heavy worm larvae pick-up. This requires planning and an understanding of larval survival patterns. In set-stocked situations clean paddocks can be prepared (Section 2.4 Internal parasites).

Large mobs associated with rotational grazing can increase the spread of certain diseases (e.g. footrot) or make control difficult. On the other hand, rotational grazing with large mobs can reduce a farmer’s work-load as there are fewer mobs to check and manage compared to set-stocking.

**Land degradation**

Deep-rooted summer-active perennials reduce groundwater recharge and subsequent salinisation and can also reduce soil erosion. Most perennial pastures reduce soil erosion to some extent as they increase the surface cover. However, when lucerne is grazed hard in summer or autumn there is insufficient groundcover (~250 kg DM/ha) to control either wind or water erosion.

Rotational grazing can result in more groundcover than set-stocking and therefore less soil erosion. Set-stocking was compared with an eight-paddock rotation at Walebing in the northern agricultural region. The rotationally grazed paddocks had 2 t/ha more groundcover at the start of summer than those that were set-stocked at the same stocking rate (8 DSE/ha).

Saltbush requires rotational grazing for long-term persistence and productivity.
2.2 Animal production from extensive grazing systems

Hayley Norman and David Masters

A large component of the productivity of extensive grazing systems is determined by plant herbage production (both quantity grown and time of production) and the feeding value of this herbage. Feeding value is defined as ‘the animal production response to grazing a forage under unrestricted conditions’ and is a function of voluntary feed intake and nutritive value. Grazing ruminants require a high feed intake because:

- the gross energy of herbage is generally low
- 15-60% of ingested energy is lost via faeces
- up to 18% of the energy released through ruminal fermentation is lost through heat and gas production
- the process of grazing and ruminating can incur a high energy cost.

To achieve maximum profitability from extensive grazing systems, livestock production (value of meat, wool or milk) must be considered in relation to efficiency of production per unit of feed versus a number of costs. Direct costs include livestock health and processing, pasture establishment and maintenance and feed conservation costs. Indirect costs are environmental outcomes and opportunity costs.

This section discusses the factors influencing the productivity of ruminants from extensive grazing systems including the time of feed availability, quantity of herbage production, voluntary feed intake and nutritive value of herbage. It concludes with a discussion about some of the opportunities perennial pastures offer to livestock production systems.

Factors influencing the value and productivity of pastures

Time of feed availability

The cost of carrying stock through periods of feed shortage is a major limitation to the profitability of mixed farming systems in southern Australia. In Mediterranean-type environments this scarcity occurs during the late summer/autumn/early winter period. Figure 2.2 shows the herbage available from a subterranean clover-based annual pasture set-stocked at 10 DSE/ha from September until March. At the start of September only 1 t DM/ha of herbage had been produced. Two months later the pasture contained over 5 t DM/ha despite continuous grazing by 10 sheep/ha. By March only 1 t/ha of dry, low quality pasture remained. As a result of this autumn/winter feed gap, producers must conserve excess spring herbage, reduce stock numbers, feed costly supplements or fail to fully use the spring biomass production.

Pasture available in autumn or early winter therefore has a higher marginal value than herbage produced in the spring, i.e. a small change in pasture availability in autumn has a higher impact on whole farm economics.
Economic modelling indicates that an additional kilogram of pasture produced in the wheatbelt in May has 10 times the value of a kilogram of equivalent quality feed in October. Therefore, perennial pasture species that provide a relatively small quantity of biomass when the marginal value of pasture is high could be more profitable than annual species that provide a larger number of total grazing days but with most of the production in spring when there is a surplus of feed.

**Quantity of herbage production**

Herbage production depends on the genetic potential of the pasture plants in that environment, competition between plants, rainfall amount and distribution, temperature, soil type, soil fertility, disease and the grazing intensity.

In contrast to annual pasture systems, some of the biomass produced by perennial plants is not available to livestock. For instance, some may be inedible, such as woody stems (stems >2-5 mm in diameter are usually considered inedible for sheep), while some may be out of reach of animals without cutting.

**Voluntary feed intake**

Variation in voluntary feed intake accounts for at least 50% of the variation that is observed in feeding value of forages. Voluntary feed intake is not easy to predict. Characteristics that influence voluntary feed intake include: gut fill; clearance rate of digesta from the rumen (influenced by digestibility); energy; protein content; palatability; feeding behaviour and species; and class and physiological state of the animal. Other related factors include the amount of time the animal grazes and ease of grazing reflected by bite mass and bite frequency. Plant morphology also plays a role, for example, browsing from sparse shrubs is more time consuming than eating from a dense sward.

**Physical and metabolic control mechanisms**

A conceptual model for the regulation of pasture intake by the grazing animal based on a combination of physical and metabolic signals has been developed. Digestibility of herbage has a large influence on voluntary feed intake as it determines the rate that plant material can be cleared through the rumen. Put simply, animals can only eat as fast as the rumen clearance rate will allow. Low clearance rates are associated with increases in the generation of satiety signals from the rumen to the central nervous system. This limitation represents a physical constraint to intake that is particularly important for feed sources with a low digestibility. There are also metabolic signals, for example, an energy deficit generates hunger signals, relative to the size of the deficit. Conversely, high levels of energy within the animal causes the generation of satiety signals. These metabolic signals are more significant for animals consuming highly digestible feeds. Intake by the animal is regulated through the central nervous system based on a combination of hunger and satiety signals generated by physical and metabolic responses to the feed.

With very low quality feeds, grazing animals can reach a stage where the rate of digestion is so slow that they are simply unable to consume enough feed to grow. Under these conditions, the physical signals override the hunger signals generated through low energy levels within the animal.

The predicted relationship between digestibility and voluntary feed intake for a three year old,
Perennial pasture management

50 kg dry Merino ewe is illustrated in Figure 2.3, using the ruminant nutrition model GrazFeed. Assuming that all diets contained 15% crude protein, an average ewe of this size, condition and age requires the digestibility of the feed to be above 60% for growth. Generally, crude protein is lower in feeds of low digestibility, in which case the line in Figure 2.3 would be steeper.

**Palatability**

Palatability (or feed preference) depends on any characteristic of the feed that increases or inhibits intake of forage whether the forage is offered alone or as a mixed sward. If an animal rejects forage then clearly that forage will be of reduced feeding value even if its nutritive value is high. Palatability is also likely to be regulated by the central nervous system through a combination of pre- and post-ingestive feedback signals. The physical and metabolic signals described above fit within this framework, but so do others such as taste, odour, texture, where the learned behaviour has often been developed in response to either nutrients or toxins.96

Evidence for nutrient signals has been reported in experiments under a range of environmental conditions. Under normal circumstances, ruminants prefer foods with high digestibility and avoid those with low digestibility and high fibre.96, 303 Growing lambs will select from a range of different crude protein levels to obtain a mixture of feeds that meet their crude protein requirement, but will avoid the excessive intake of degradable protein.92, 303

However, there is also clear evidence that these nutritional signals may be overridden by others related to the presence of toxins and other anti-nutritional factors. For example, compounds such as tannins, oxalates, coumarins and nitrates, which are all commonly found in grazed plants can depress feed intake and alter dietary selection. Many perennial plants generate a range of compounds as a deterrent to grazing and to improve persistence in their environment. Annual plants tend to focus resources on the production of seed as a persistence mechanism.

**Nutritive value**

Nutritive value refers to the responses in animal production per unit of voluntary feed intake and is a function of the digestibility of nutrients and the efficiency with which the nutrients are used for maintenance or growth. It is influenced by plant maturity, genetic variation, environment and management.69

**Metabolisable energy**

Metabolisable energy (ME) is the amount of energy available for absorption by the animal after digestion and fermentation of the feed consumed. The energy value of feeds can be characterised as the megajoules (MJ) of ME/kg of DM at the maintenance level of feeding (M/D). The dry matter digestibility of a feed (DMD) is often used to predict the ME. DMD is simply the difference between the quantity of feed eaten and the quantity that is excreted as faeces, expressed as a percentage of total DM eaten. Insoluble minerals (ash) and acid detergent fibre (ADF) represent the bulk of the indigestible material excreted.

Minerals that are soluble and absorbed by the animal have no energy value, however, they may contribute to the DMD. If feeds have a high ash content (e.g. saltbush), digestible organic matter in the dry matter (DOMD) is the most appropriate method for comparison with other feeds. Figure 2.4 illustrates the relationship between DMD, DOMD and metabolisable energy for feeds within the normal ash range (90-120 g ash/kg DM).369

Measurements of in vivo DMD are time consuming and expensive as they involve studies with penned animals. A number of laboratory (in vitro)
techniques have been developed to predict DMD by determining modified ADF or by measuring DM disappearance in a rumen fluid or pepsin/cellulase digestion system. More recently, techniques have been developed to predict in vitro and in vivo DMD using Near Infrared Reflectance Spectroscopy (NIRS). It is important to note that laboratory-based predictions have been developed for a narrow range of “typical” forage species. Predictions of DMD or ME for novel forages may be unreliable until there has been more extensive animal house in vivo calibration.

Figure 2.5 illustrates how the digestibility or energy value of herbage impacts on liveweight changes. The data were generated using the ruminant nutrition model GrazFeed by ‘offering’ ad lib roughage with 45-85% DMD and 15% crude protein. The classes of stock were:

- three-year old, dry Merino ewe weighing 50 kg (same as Figure 2.3)
- 50 kg pregnant ewe carrying twin lambs, 100 days after mating
- 50 kg lactating ewe with twin lambs, 25 days after lambing
- three-year old, dry Merino ewe weighing 50 kg subject to cold temperatures (0-15°C) and 5 mm of rainfall.

Figure 2.5 illustrates that the feed quality required for maintenance of liveweight for a 50 kg ewe depends on the ewe’s physiological state and on the climate. A dry ewe is predicted to maintain bodyweight on hay of 60% DMD (8.6 MJ/kg DM), however a lactating ewe with twin lambs is unable to maintain bodyweight even with a diet of 85% DMD (12.7 MJ/kg DM) because she cannot

- three-year old, dry Merino ewe weighing 50 kg
- 50 kg pregnant ewe carrying twin lambs, 100 days after mating
- 50 kg lactating ewe with twin lambs, 25 days after lambing
- three-year old, dry Merino ewe weighing 50 kg subject to cold temperatures (0-15°C) and 5 mm of rainfall.
eat enough to meet her energy requirements. When these requirements are compared to the DMD of subterranean clover (Figure 2.2), it becomes apparent that annual pasture residues in summer and autumn contain insufficient energy for maintenance of liveweight for any of the ewes. Sheep will only maintain weight through selection of the highest energy components of the feed or through supplementation. Table 2.1 presents DMD values of a range of annual and perennial pasture species in spring and autumn. Most, but not all of the pastures would provide enough energy for the dry and pregnant ewes in spring, however few species provide enough energy in the autumn. Table 2.2 is an estimate of the quantity of dry matter in autumn required to provide the same energy as 1 tonne of lupins.

**Protein**

Ruminants have a minimum protein requirement for maintenance, growth and reproduction. The figure of 7-9% crude protein (CP) is often used as the minimum requirement for an adult animal that is not reproducing or growing. For growing ruminants, dietary requirements are 14-16%. Protein requirements are often presented as a range for different classes of ruminant livestock, due to the unique relationship between the ruminant, the microbes within the rumen and the diet which makes defining more specific requirements impossible. A proportion of all protein consumed is degraded by the microbes in the rumen (rumen degradable protein). Depending on the amount of energy supplied by the diet, some of this degraded protein is converted back to microbial protein by the microbes and then passes down the digestive tract for absorption as amino acids. Within most diets, a component of the protein is resistant to microbial breakdown (undegraded dietary protein). This passes through the rumen and is either absorbed lower down the gastrointestinal tract or excreted in the faeces. Therefore the amount of protein available for absorption depends on the type of protein consumed, the energy available for microbial protein synthesis and the protein content of the diet.

Protein deficiency has been associated with grazing sub-tropical perennial grasses during the dry season and with grazing dry annual pastures in summer. Table 2.1 demonstrates the low protein

**Table 2.1 Dry matter digestibility (DMD) and crude protein (CP) of a range of annual and perennial pasture species sampled in spring and autumn**

<table>
<thead>
<tr>
<th>Lifecycle</th>
<th>Species</th>
<th>Spring</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In vitro DMD (%)</td>
<td>CP (%)</td>
<td>In vitro DMD (%)</td>
</tr>
<tr>
<td>Annual</td>
<td>Annual ryegrass</td>
<td>67 (48-78)</td>
<td>10 (4-18)</td>
</tr>
<tr>
<td></td>
<td>Subterranean clover</td>
<td>72 (69-75)</td>
<td>23 (20-29)</td>
</tr>
<tr>
<td>Biennial</td>
<td>Melilotus alba</td>
<td>74 (70-77)</td>
<td>16 (13-20)</td>
</tr>
<tr>
<td></td>
<td>Sulla</td>
<td>60 (52-71)</td>
<td>17 (17-18)</td>
</tr>
<tr>
<td>Perennial</td>
<td>Lucerne</td>
<td></td>
<td>63 (61-66)</td>
</tr>
<tr>
<td></td>
<td>Dorycnium hirsutum</td>
<td>52 (45-55)</td>
<td>12 (11-14)</td>
</tr>
<tr>
<td></td>
<td>Lotus corniculatus</td>
<td>69 (55-75)</td>
<td>16 (12-19)</td>
</tr>
<tr>
<td></td>
<td>Setaria</td>
<td>65 (60-72)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Puccinella</td>
<td>59 (56-61)</td>
<td>6 (4-8)</td>
</tr>
<tr>
<td></td>
<td>Tall wheat grass</td>
<td>61 (58-64)</td>
<td>8 (6-10)</td>
</tr>
<tr>
<td></td>
<td>Paspalum</td>
<td>74 (67-80)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rhodes grass</td>
<td>65 (50-71)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Veldt grass</td>
<td>56 (50-60)</td>
<td></td>
</tr>
</tbody>
</table>

Data from CSIRO Livestock Industries laboratory database (unpublished, E. Hulm, D. Henry, L. Bell and H. Norman).
content of perennial grasses (in autumn and spring) and annual ryegrass (in autumn). Introduction of annual or perennial legumes or improved nitrogen nutrition would alleviate the protein deficiency in a perennial grass system. Alternatively protein could be provided through grain legume supplements (such as lupins) or a protein lick.

Crude protein is estimated by analysing a pasture sample for nitrogen content and multiplying the resulting figure by 6.25 (as protein generally contains 16% nitrogen). However, this crude calculation may over-estimate the true protein in feeds due to the presence of some non-protein nitrogen compounds (e.g. nitrates, betaines). These non-protein compounds may be converted into microbial protein in the rumen, but the extent to which this occurs depends on the availability of energy from the diet. In the absence of sufficient energy, the compounds are converted to ammonia in the rumen, which is absorbed by the animal, converted to urea and excreted in the urine.

Sulphur is primarily used along with nitrogen for the production of microbial crude protein in the rumen. The recommended dietary N:S ratio for sheep is 12.5:1. Perennial pastures such as saltbush provide high levels of sulphur.

Table 2.2 Quantity of feed in autumn required to provide the same energy as 1 tonne of lupins

<table>
<thead>
<tr>
<th>Feed source</th>
<th>Dry matter (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat grain</td>
<td>964</td>
</tr>
<tr>
<td>Lucerne</td>
<td>1415</td>
</tr>
<tr>
<td>Typical dry annual pasture</td>
<td>1800</td>
</tr>
<tr>
<td>Cereal straw</td>
<td>2509</td>
</tr>
</tbody>
</table>

Vitamins and minerals
Livestock also have minimum requirements for a range of minerals and vitamins. In summary, naturally occurring deficiencies of copper, selenium and cobalt (vitamin B12) will occur in some regions if supplements are not provided or pastures have not been fertilised with the appropriate trace elements. For selenium and cobalt, deficiencies are most likely in the medium to high rainfall areas in spring. Deficiencies will result in reduced growth and wool production and in extreme conditions incapacitation and death. Deficiencies of calcium can also result if livestock are fed high levels of grain supplements. Responses to zinc supplements have been reported in grazing sheep.

Of the essential vitamins, only vitamin E deficiency is consistently of commercial importance. Vitamin E (α-tocopherol) is a powerful antioxidant present in green plants. Deficiency can cause nutritional myopathy in weaner sheep, especially when they have grazed dry feed for an extended period. Sub-clinical nutritional myopathy is not detrimental to liveweight gain or wool production and can often go unnoticed, but clinical deficiency may cause the death of the animal. Perennial pastures offer significant opportunities to supply young animals with vitamin E when they remain green over the summer and autumn. Weaner sheep grazing saltbush have been found to have significantly higher vitamin E levels in their muscle and liver tissues than sheep grazing stubbles.

Additional secondary compounds that impact on intake and nutritive value
Increasing sodium chloride (salt) in the diet decreases feed intake, digestibility, liveweight gain and wool growth significantly. This is particularly relevant to plants growing in saline soils where the salt content of the leaves of halophytes can be up to 35% of DM.

Condensed tannins (CTs) are a large and diverse group of compounds, present in a number of species including tagasaste, sulla, Lotus and Acacia spp. They may have a positive contribution to animal production at low concentrations (0.2% or less of dry weight) through resistance to plant disease and pests and bloat control. They are also thought to assist in the control of internal parasites in lambs, but this is yet to be demonstrated under Australian conditions.

However, at concentrations of more than 1% CTs bind protein – protecting it from ruminant digestion. At concentrations more than 5% CTs reduce the voluntary feed intake and digestibility of the herbage. Tannin concentrations in herbage vary with plant genotype, season, soil fertility, soil acidity, water stress and temperature.
Principles of feed budgeting and grazing management

Feed budgeting at its most complex takes into account all of the factors that influence pasture intake and use. Feed budgeting is the process of matching feed supply with the demand of the grazing animal. In practice, estimates of feed-on-offer, pasture growth rates and dry matter digestibility provide the information required to calculate stocking rate and the length of the grazing period. This information needs to be adjusted to take account of the required pasture cover at the end of grazing and the proportion of pasture that is used. Pasture utilisation is never 100% due to losses from trampling, selective grazing and natural decay. Feed budgeting can be used tactically to improve pasture utilisation and meet livestock targets in the short-term (e.g. strip grazing) or strategically to assess the ability of the feed base to meet livestock requirements over a full year.

There is now a range of tools and options available to improve the efficiency of production from grazing systems. Extension programs such as PROGRAZE focus on tactical grazing management to meet livestock targets. Satellite images can be used to provide real time information on feed-on-offer and pasture growth rates at the paddock scale. Computer programs such as GrassGro can be used for longer term strategic planning to simulate pasture and livestock production under different grazing regimes, while optimisation models such as MIDAS can be used to evaluate options for changes in whole-farm enterprise structures.

Opportunities offered by perennial plants in extensive grazing systems

Significant opportunities exist to improve the profitability of extensive animal production systems through strategic use of perennial plants within a farming system. In this context the perennial plants may have a higher value when considered as a contribution to total farm feed resources than when considered on their own.

Opportunities for perennial plants include:
- Summer-active perennial plants have the capacity to fill the autumn feed gap by producing biomass and responding to summer rainfall when annual plants have died. The biomass produced usually has higher ME and CP than dry crop and pasture residues. Increased feed availability outside of the winter/spring growing season provides the opportunity to develop novel animal production systems that reduce the impact of seasonality of annual pastures on meat and wool production and quality.
- Perennial plants could also provide components of the diet that are lacking in dry autumn feed, such as crude protein and vitamin E.
- Tannins and other secondary compounds could help to reduce parasite burdens and reliance on chemicals.
- Small amounts of high quality feed in summer and autumn could improve the use of dry crop and pasture stubbles. For example, the high crude protein and low fibre in saltbush complements the high fibre and low protein content of crop stubbles, which can improve the use of the total feed resource.
- Selective plantings of perennials could be used to meet special animal nutrition needs such as high energy for colostrum production to improve lamb survival or to increase ovulation rate in breeding ewes.
- At lambing time the tussock growth habit of some perennial grasses (e.g. tall wheat grass) or the hedge formation of some shrubs will provide shelter and nutrition. This will protect the newborn lambs from wind and rain. At the same time, a close supply of feed allows the mother to graze close by and decreases the likelihood of mis-mothering.
- Mixed annual and perennial pastures provide animals with the capacity to manage their diet, offering both increases in profitability and environmental sustainability.
Most herbaceous perennial pastures and shrubs used for livestock production provide a valuable and good quality food source. However, occasionally some of these plants can poison livestock. Even though you may never encounter such a situation, it is worthwhile to be aware of the possibility. This will enable prompt action and minimise losses should poisoning occur.

For many of these plants there are reasonably well known predisposing factors involved in the development of toxicity. These will vary with the particular plant and type of toxin involved. However, with most plants, the risk of poisoning is increased if the plant is the dominant pasture species available.

Several clinical syndromes are involved in the poisoning of livestock following consumption of herbaceous perennial pastures and shrubs.

**Photosensitisation**

Photosensitisation occurs after exposure to sunlight and is essentially an inflammation of the skin (dermatitis) and sometimes an inflammation of the conjunctiva and cornea of the eye (conjunctivitis/keratitis).

Photosensitisation is caused when light sensitive molecules, usually derived from plants, are deposited in the skin and cornea. These are activated by exposure to sunlight to cause considerable local damage. Access of sunlight to these molecules is blocked or diminished by pigmentation in the skin or long hair or wool. For this reason, the physical changes of photosensitisation are most apparent in areas with white hair or wool and those least covered by hair or wool, such as eyes, eyelids, ears, lips, face and coronets. Photosensitisation is not the same as sunburn. It is caused by exposure to visible light and does not require prolonged exposure. Sunburn is caused by ultraviolet light and requires prolonged exposure.

Animals showing clinical signs of photosensitisation might:
- appear restless
- seek out shade
- shake their heads, or
- rub against other objects.

Affected parts become swollen due to fluid accumulation under the skin (oedema) and this might cause the ears to droop. This will progress to weeping of the oedema fluid though the skin, death of the skin, formation of hard scabs and sloughing of the dead skin to leave raw wounds. It is likely there will also be discharges from the eyes and the cornea may become opaque. In many cases animals may appear lame because the coronets become inflamed. If animals are removed from the source of the problem and into shade as soon as the early behavioural changes or signs of oedema are noticed, they will recover well.
However if removal is delayed, extensive damage may occur and some animals may die.

There are two types of photosensitisation:

(a) Primary photosensitisation occurs when plants contain light sensitive molecules and these are absorbed unaltered by the animal eating the plant. This is very rare in perennial pastures but has been reported in lucerne and birdsfoot trefoil.

(b) Secondary photosensitisation occurs when ruminants and occasionally horses suffer damage to their liver and then graze green pasture. A plant toxin is the most common cause of the liver damage. Chlorophyll from green pasture is metabolised by bacteria in the alimentary tract to phylloerythrin, a very potent light sensitive molecule. When this is absorbed it is normally extracted from the blood by the healthy liver and excreted, however a damaged liver is unable to remove all the phylloerythrin from the blood and its concentration increases, causing photosensitisation. A number of sub-tropical grasses can cause secondary photosensitisation including signal grass, bambatsi panic and panic grass.

Acute oxalate poisoning
Plants containing more than 2% soluble oxalate (DM) have the potential to cause acute oxalate poisoning in ruminants, however poisoning is normally associated with much higher concentrations (e.g. >10%). The effect on stock depends on ‘pre-conditioning’, i.e. whether stock have had previous exposure to plants containing oxalate, and whether the stock are hungry or not when given access to the plant.

The soluble oxalate is absorbed and combines readily with calcium to form insoluble calcium oxalate crystals within the body. Death is usually due to hypocalcaemia but can also result from damage caused by the calcium oxalate crystals in the kidneys, rumen wall and lungs. Clinical signs include difficulty in breathing, staggering, collapse and a quiet death. Perennial pastures and shrubs reported to occasionally cause acute oxalate poisoning include saltbush, small leaf bluebush, setaria, buffel grass and panic grasses. Ensuring these species are not the sole feed source and that pasture with a low oxalate content is also available to stock will minimise the risk.

Big head in horses
If most of the calcium in plants is in the form of insoluble calcium oxalate, then horses grazing such plants will be at risk of developing calcium deficiency. This does not occur with ruminants as the rumen bacteria breakdown the calcium oxalate, releasing the calcium for absorption. As a result, pasture that may be excellent for ruminants can be dangerous for horses. Plants that have a calcium to total oxalate ratio less than 0.5 and more than 0.5% total oxalate content (DM) are considered hazardous. Clinical signs include weight loss, lameness, fracturing of long bones and swelling of the bones of the face and jaw; hence the term ‘big head’. Perennial pastures and shrubs reported to cause big head in horses include: buffel grass, setaria, panic grass, kikuyu, signal grass, small leaf bluebush and saltbush.

Cyanide (hydrogen cyanide or prussic acid) poisoning
Many plants contain cyanogenic glycosides that act as deterrents to snails and insects. Within the plant the cyanide-containing compound is linked to a sugar and is harmless. When the plant is damaged (e.g. by chewing), hydrogen cyanide is released by hydrolysis. In the body the cyanide blocks cellular respiration and in most situations results in sudden death. Affected animals may be seen to stagger for a short time before they collapse. Perennial pastures that occasionally produce cyanogenic glucosides include birdsfoot trefoil, white clover, couch grass and greater lotus, but it is a very rare condition.
In WA an extremely unusual situation occurred where goats fed branches of *Acacia saligna* died from cyanide poisoning. This fodder tree is normally considered safe and not to contain cyanogenic glycosides. However, the branches fed had been pruned because of gross malformations due to a heavy thrip and virus infection and these processes had induced the infected branches to produce cyanogenic glycosides. The normal (uncut) branches contained no cyanogenic glycosides.

**Stagger syndromes**

There are a number of stagger syndromes involving different plants. In all cases, clinical signs are brought on or exacerbated by exercise. The conditions ‘perennial ryegrass staggers’, ‘phalaris staggers’, ‘paspalum staggers’ and ‘tagasaste staggers’ are specific to these species and are described under livestock disorders in the relevant species description (Chapters 3 to 9).

**Poisoning by ergot alkaloids (ergotism)**

Ergot alkaloids are produced in the ergots of the fungus *Claviceps purpurea*, which can be found in the seed heads of some of the perennial grasses (couch, *Paspalum dilatatum*), or by the endophytic fungi *Neotyphodium coenophialum* in tall fescue and *N. loli* in perennial ryegrass. Ingestion of these alkaloids results in three prominent clinical syndromes – hyperthermia (pathologically high body temperatures), gangrenous ergotism (affecting peripheral parts of the body such as ears, tip of tail and hooves) and agalactia (substantially reduced or non-secretion of milk)/extended gestation/abortion. Generally, hyperthermia occurs in association with warmer temperatures and gangrenous ergotism with cooler temperatures.

**Nitrate poisoning**

As a general rule, any plant containing greater than 1.5% potassium nitrate equivalent (DM) is considered at risk of causing nitrate poisoning, however the concentrations associated with clinical disease are frequently more than 5%.

Nitrate is converted in the rumen to nitrite, which when absorbed oxidises the iron in haemoglobin, rendering it ineffective in carrying oxygen around the body. This results in rapid and deep breathing, muscle weakness, coma and rapid death. Nitrate poisoning appears similar to cyanide poisoning. Pregnant ruminants that survive a clinical episode of nitrate poisoning will often abort. Long-term intake of nitrate at levels just below those likely to cause clinical nitrate poisoning have been associated with, but not proven to cause, abortion, congenital abnormalities, reduced production and goitre. Perennial pastures that have the potential to cause nitrate poisoning include lucerne, perennial ryegrass, kikuyu, small leaf bluebush and saltbush.

**Specific plant associated conditions**

There are several conditions associated with specific pasture species: phalaris sudden death syndromes; kikuyu poisoning; ‘red gut’ (twisted intestine) in sheep grazing lucerne; and bloat in cattle grazing lucerne, strawberry clover and white clover. These conditions are discussed under livestock disorders in the relevant species descriptions (Chapters 3 to 9).
2.4 Internal parasites of livestock and perennial pastures

Brown Besier

Internal parasites (nematodes or worms) are a major cost to the grazing industries and effective worm management is an essential part of profitable livestock production. The continual presence of worm burdens in most grazing animals causes reduced animal production, outbreaks of parasitic disease and occasional deaths. In addition to the effects of worm infections and the necessary control costs, increasing levels of resistance by worms to drenches further threatens the effectiveness of chemical-based worm control.

Pasture management is an important aspect of worm control programs, as the egg and larval stages of the common worm species spend some time in the external environment. The microclimatic conditions within the pasture have a major influence on the worm numbers and types present at a particular time and location.

**Worm lifecycles**

Moisture at ground level is essential for the worm lifecycle. Adult worms produce eggs that are excreted onto the ground in the faeces. Providing that suitable environmental conditions are present – adequate moisture and mild temperatures – the eggs develop to larvae within the faecal mass. The larvae migrate onto pasture – again, providing sufficient moisture is present – where they may be ingested by grazing animals and over a few weeks, develop into adult worms, which then complete the lifecycle (Figure 2.6).

**The effects of pasture on worm populations**

Worm eggs and larvae are highly vulnerable to extremes of climatic conditions while on the pasture. During very hot and dry periods, such as in summer in WA, most eggs die quickly after deposition onto the ground, and larvae which have developed on the pasture also die as conditions become more extreme. However, where there is sufficient moisture at ground level, both eggs in faeces and larvae on the herbage can survive, unless temperatures reach very high levels.

The state of the pasture is a good way to gauge the likelihood of worm larvae being present to infect grazing livestock. Green pasture – indicating moisture or at least higher humidity at ground level – is highly correlated with the ability of worm eggs to develop and the larvae to survive. On irrigated pastures and in tropical situations, worm larval development can continue year-round, and is only affected by extremes of temperature. In more seasonal environments, the worm risk to livestock is mostly restricted to the green-pasture period. However, in these environments, areas of perennial pasture such as kikuyu have been shown to support worm larvae when none were present on dry annual pastures.

**Perennial pastures and worm burdens**

The good relationship between green pasture and worm larval survival increases the risk of worm infections in grazing animals. The likely effects of an expansion of perennial pastures into environments where annual species are presently dominant include:

- An increase in the length of the ‘worm season’, as worm pick-up by livestock will continue outside the traditional risk period.
- The risk of greater worm problems and the need for more complex management, due to the continual presence of worms.
- Introduction of the highly pathogenic barbers pole worm (*Haemonchus contortus*) into areas where it does not exist at present. This worm is a major cause of sheep and goat deaths in summer rainfall regions, as it requires warm and moist conditions, but does not presently occur in inland WA.

**Management of worms on perennial pastures**

The increased risk of damaging worm burdens in young (worm-susceptible) animals and greater production loss in all classes of stock due to continual worm burdens complicates worm management strategies. In particular:

- Traditional programs based on removing worms during the summer period are less effective on perennial pastures. More drenching is usually necessary to keep burdens at acceptable levels, especially in young stock.
- More frequent monitoring of faecal worm egg counts is necessary, to detect impending worm problems.
• Pasture rotations can play a major role in ensuring that livestock are not exposed to heavy worm larval pick-up. This requires forward planning and knowledge of larval survival patterns, but can be highly effective in avoiding parasitic loss.

Worm control benefits of perennial pastures

Although there is a higher worm risk on perennial pastures, they can also have some benefits over pastures based on annual species:

• Animals in good nutritional condition are better able to resist the effects of worms. The higher levels of protein nutrition provided by perennial pastures during the summer-autumn periods of winter rainfall regions are likely to help offset the effects of greater worm burdens.

• The development of drench resistance by worms is lower on green pasture. The highest levels of drench resistance occur where worms which survive summer drenching are not diluted by further worm pick-up. Even though more frequent drenching is typically necessary in green-pasture systems, the continual larval intake reduces the dominance of resistant worms. This may be a significant benefit in developing sustainable worm management strategies which maintain the effectiveness of drenches.

Changes to worm control strategies will be necessary where large areas of perennial pastures are grown in regions previously dominated by annual species. In particular, worm egg count monitoring will be an essential basis for ensuring that excessive burdens do not develop. In the longer term, research into parasite ecology will produce systems to deliver the nutritional and environmental sustainability benefits of perennial pastures while providing effective worm management.

Figure 2.6 Lifecycle of sheep worms
2.5 Perennial pastures, plant diseases and the ‘green bridge’
Roger Jones and Dominie Wright

The benefits provided from sowing perennial pastures need to be balanced against problems that may arise from their widespread use. One potential problem is the development of a continuous herbaceous ‘green bridge’ for legume and cereal pests and pathogens that would otherwise be unable to persist over summer. Such a ‘green bridge’ is absent with annual pastures, which senesce in late spring and only regenerate following the autumn rains. Also, pathogens and pests which are able to survive over summer without a ‘green bridge’, e.g. inside dormant seed, in trash or those in diapause, could continue to build-up in perennial pastures. With annual pastures, epidemics of such pathogens and outbreaks of such pests cease at the end of the growing season and then start again from a low base when the pasture regenerates in autumn.

In WA, the seasonally dry conditions, which can extend from late spring through to late autumn, ensure a substantial, continuous bridge of green foliage is rarely present away from isolated ‘wet’ spots. Even in years with good out-of-season rainfall the perennial pastures dry off and/or drop leaves in response to moisture stress. The summer dry period extends for four to seven months in any year. While this reduces leaf diseases, which only survive on green foliage (e.g. rust), it has less impact on viruses, which can persist in the root system of plants.

Another issue is that many perennial legume pastures are being sown with untested seed from regions where a number of seed-borne diseases of legumes occur. The widespread sowing of untested seed risks the potential large-scale introduction of seed-borne diseases. A survey of commercial lucerne seed entering WA from the eastern States showed 80% of the samples were infected with AMV (levels of 0.1-4%) and 11% were infected with CMV (0.1-0.3%), although no CMV was detected in survey samples taken at random in the field.\textsuperscript{77}

Diseases reduce herbage production and seed yields of legume and grass pastures, reducing their persistence and favouring the build-up of weeds. In addition, diseases spread from legume pastures to nearby grain legume crops and annual legume pastures, or from perennial grass pastures to cereals.

If straightforward control measures are implemented, the disease risks from growing perennial pastures can be reduced.

**Virus diseases**

In WA, detailed surveys of virus occurrence have been undertaken in perennial pastures of lucerne,\textsuperscript{77} irrigated white clover, perennial ryegrass and kikuyu,\textsuperscript{72, 252, 253} with less detailed studies on irrigated perennial grass pastures containing couch grass.\textsuperscript{145, 183, 251} These surveys revealed widespread infection with AMV in lucerne and white clover, WCMV in white clover, RyMV

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*Alfalfa mosaic virus (AMV) on lucerne. It is readily seed-borne and commercial stocks can be infected, so ensure disease-free seed is always sown*

*Alfalfa mosaic virus (AMV) on white clover*
### Table 2.3 Virus diseases of perennial pastures and susceptible annual crops and pastures

<table>
<thead>
<tr>
<th>Virus (acronym)</th>
<th>Mode of transmission</th>
<th>Susceptible perennial pasture plants</th>
<th>Susceptible annual crops and pasture plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEED-BORNE VIRUSES THAT INFECT LEGUMES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa mosaic virus (AMV)</td>
<td>Seed-borne and non-persistently aphid-borne</td>
<td>Lucerne (readily seed-borne and many commercial seed stocks infected); white clover (susceptible but not seed-borne). Reaches very high incidences in lucerne and white clover pastures.</td>
<td>Annual medics (readily seed-borne), annual clovers (often seed-borne) French serradella, chickpea, lentil, faba bean, field pea, lupin</td>
</tr>
<tr>
<td>Bean yellow mosaic virus (BYMV)</td>
<td>Seed-borne and non-persistently aphid-borne</td>
<td>Lucerne - commercial seed not found infected,177 white clover not a host Sulla – highly resistant254</td>
<td>All annual clovers, annual medics and other annual pasture legumes (often seed-borne at low levels). Biserrula very sensitive Lupin, field pea, faba bean, lentil</td>
</tr>
<tr>
<td>Cucumber mosaic virus (CMV)</td>
<td>Seed-borne and non-persistently aphid-borne</td>
<td>Commercial lucerne seed sometimes infected at low levels177 Sulla - moderately resistant198</td>
<td>Annual medics and sub. clover (seed-borne), chickpea, lentil, balansa clover, crimson clover, other clovers</td>
</tr>
<tr>
<td>Subterranean clover mottle virus (SCMoV)</td>
<td>Seed-borne and contact transmitted</td>
<td>Lucerne – low level111</td>
<td>Subclover, arrowleaf clover (seed-borne at low levels) Annual medics and many other annual clovers are hosts</td>
</tr>
<tr>
<td><strong>NON-SEED-BORNE VIRUSES OF LEGUMES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White clover mosaic virus (WCMV)</td>
<td>Contact-transmitted</td>
<td>White clover – survey showed 52% of irrigated white clover infected with levels up to 83%253 (lucerne – low level)</td>
<td></td>
</tr>
<tr>
<td>Clover yellow vein virus (CYVV)</td>
<td>Non-persistently aphid-borne</td>
<td>White clover – survey showed 84% of irrigated white clover infected with levels up to 23%253</td>
<td>Faba bean, field pea, lentil, chickpea</td>
</tr>
<tr>
<td>Bean leaf roll virus (BLRV)</td>
<td>Persistently aphid-borne</td>
<td>Lucerne – low level177</td>
<td>Faba bean, field pea, lentil, chickpea</td>
</tr>
<tr>
<td>Beet western yellows virus (BWYV)</td>
<td>Persistently aphid-borne</td>
<td>Lucerne – low level177</td>
<td>Canola, chickpea, field pea, faba bean, lentil, all pasture legumes</td>
</tr>
<tr>
<td>Subterranean clover red leaf virus (SCRLV)</td>
<td>Persistently aphid-borne</td>
<td>White clover – survey showed 33% of irrigated white clover pastures infected with levels &lt;12%252 Lucerne also infected at low level177</td>
<td>Subclover, other annual clovers, chickpea, field pea, faba bean, lentil</td>
</tr>
<tr>
<td>Barley yellow dwarf virus (BYDV)</td>
<td>Persistently aphid-borne</td>
<td>Perennial ryegrass – survey showed 77% of irrigated perennial ryegrass infected with levels up to 5%253 (kikuyu – low level)72 Also cockfoot, tall fescue, couch grass, lovegrass, Rhodes grass</td>
<td>Wheat, barley, oats, many annual grasses</td>
</tr>
<tr>
<td>Cereal yellow dwarf virus (CYDV)</td>
<td>Persistently aphid-borne</td>
<td>Cocksfoot, perennial ryegrass, tall fescue, couch grass, lovegrass, kikuyu, Rhodes grass</td>
<td>Wheat, barley, oats, many annual grasses</td>
</tr>
<tr>
<td><strong>MITE TRANSMITTED VIRUS OF PERENNIAL GRASSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryegrass mosaic virus (RyMV)</td>
<td>Mite-transmitted</td>
<td>Perennial ryegrass – survey showed 60% of irrigated perennial ryegrass infected with levels up to 34%253 Kikuyu grass also occasionally infected72</td>
<td></td>
</tr>
</tbody>
</table>
Perennial pastures for Western Australia

in perennial ryegrass and BYDV and CYDV in various perennial grasses. Seed-borne infection with AMV was common in commercial lucerne seed stocks (Table 2.3).

Symptoms caused by viruses in pasture species vary in intensity and type depending on the combination of virus and plant species infected. Mottle, pallor, vein clearing, reduced size and deformation are common leaf symptoms, while dwarfing is a common whole plant symptom.

Factors that favour virus build-up and the risk of epidemics and increased production losses include long-term perennial pastures, the removal of non-host pasture species, e.g. grasses from legume pastures and legumes from grass pastures and a range of other factors that depend on the mode of transmission of the virus (Table 2.4).

Control measures for viruses
The aim with control measures is to minimise the build-up of virus infection and consequent losses to reduce the potential for the perennial pasture to be a source of infection to adjacent annual crop and pasture paddocks. The potential damage from infecting crops is sometimes greater than the direct damage to the pasture. The incidence of virus infection increases with the age of a stand. Economic loss is likely when incidences are high.

With viruses that are not seed-borne, rotation with a crop after about three years will reduce disease build-up, but this is only possible with phase farming. Other control measures vary with the mode of transmission of the virus (Table 2.4).

Fungal diseases
The principal fungal diseases of pastures can be divided into leaf diseases and root diseases. The major leaf diseases cause leaf spotting, which reduces the area for photosynthesis. These diseases are caused by a number of pathogens including common species such as Phoma, Leptosphaerulina, Puccinia and Bipolaris spp. These fungal pathogens are important because they also infect cereal and legume crops and annual pasture species. Perennial pastures act as a source for these fungal pathogens to survive over summer (‘green bridge’). The risk may be reduced during summer when there is minimal green leaf material present on herbaceous perennial pasture plants.

The biggest problem is when Leptosphaerulina and Phoma spp. are allowed to persist. These pathogens are widespread in WA and can cause major crop losses through defoliation.

Table 2.4 Factors that favour virus build-up and control measures in relation to the mode of transmission

<table>
<thead>
<tr>
<th>Mode of transmission (viruses)</th>
<th>Pasture management and conditions which favour virus build-up</th>
<th>Control measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact-transmitted (WCMV, SCMoV)</td>
<td>Frequent mowing, heavy grazing and trampling, rotational grazing, frequent driving of vehicles and machinery over pastures, lush soft growth.</td>
<td>Reduce mechanical damage by lowering grazing pressure and closing up for hay production, stop driving over paddock, increase the proportion of non-host grass species in a legume pasture.</td>
</tr>
<tr>
<td>Seed-borne (AMV, BYMV, CMV, SCMoV)</td>
<td>Sowing untested seed stocks that introduce new sources of seed-borne virus.</td>
<td>Sow new pastures with seed stocks that have been tested and found to be healthy in a 1000 seed test. For perennial legumes like lucerne select aphid resistant varieties.</td>
</tr>
<tr>
<td>Aphid- and mite-borne (AMV, BYMV, CMV, CYVV, BLRV, BWYV, SCRlv, BYDV, CYDV, RyMV)</td>
<td>Heavy grazing which prevents the infected (source) plants from being shaded over, which results in increased exposure of infected plants to aphids and eriophyid mites. Warm conditions that allow a rapid increase in aphid numbers.</td>
<td>Smother source plants by reducing the grazing pressure and closing up for hay production. Infected plants will be smaller and less vigorous and will be shaded by healthy plants in spring, which will restrict access by aphids and eriophyid mites. Kill vectors by applying a pesticide. Increase the proportion of non-host species in the pasture.</td>
</tr>
</tbody>
</table>
The major fungal root diseases found on perennial pasture plants: Rhizoctonia solani, Fusarium spp., Gaeumannomyces graminis var. tritici (take-all) and Sclerotinia sclerotiorum, are common to many crops in WA, although some are host-specific. These pathogens cause root diseases in most of the perennial pasture species as well as providing a source for diseases to spread to cereal and grain legume crops. The pathogens can survive in soil and crop debris for many years. The risk is reduced because most perennial pastures, with the exception of lucerne are managed as permanent pastures and are not grown in rotation with annual crops.

Control measures for fungal diseases
There are four approaches to disease control in annual pastures that are also useful for controlling diseases in perennial pastures:

(a) Cultural control
Grazing management, rotations, cultivation and sowing healthy seed stocks provide potential control of some leaf disease pathogens. A limitation is that most cultural practices are often determined by production imperatives, rather than disease management. This is the main method used to control leaf and root diseases in pastures. Grazing management offers the best control options for most fungal leaf diseases while rotation is important for fungal root diseases. Unfortunately, heavy grazing can exacerbate root diseases, as the damage caused by grazing and trampling allows fungal pathogens to enter the crown and cause a rot that leads to plant death.

(b) Chemical control
Provides good short-term control of some leaf diseases, but provides poor long-term control for herbage diseases. The limitations include pollution, toxic effects on grazing animals, pathogen resistance and the cost.

(c) Host resistance
The benefit gained from durable, effective, multiple resistance is that there is little further cost once such varieties are established. The limitations from this approach are the lack of availability of such resistance and the time and cost of developing resistant varieties, which could soon become outmoded.

(d) Integrated control
The benefit from this approach is the complementary effect of methods operating in different ways. Examples include: partial resistance + grazing, or partial resistance + fungicides.

Nematode diseases
A number of nematodes are pathogenic to perennial pasture plants (Table 2.5). Most have a wide host range and their population density can increase, especially under perennial grasses. These nematodes can adversely affect cereal yields, e.g. cereal cyst nematode causes heavy losses in cereal crops and is hosted by many grasses. However, it is easily controlled by crop rotation that ensures the paddock is free of cereals and other grasses. Triticale is an alternative option, as it is resistant to both root lesion nematode and cereal cyst nematode. The perennial grasses are rarely grown in rotation with crops. Lucerne is often grown in a phase rotation with crops, and nematodes are not a common pathogen of lucerne in WA.

Among the greatest risks is the introduction of the stem nematode (Ditylenchus dipsaci) through pasture seed. Currently, there are no records of stem nematodes having been detected in crops in WA. This nematode would have a devastating impact on crops and could also affect the export of seed as it is seed-borne. Oats and canola are highly susceptible and introduction of this nematode would adversely affect the export hay industry as well as the canola industry.
### Table 2.5 Nematode species that are pathogenic to perennial pastures

<table>
<thead>
<tr>
<th>Nematode (Latin name)</th>
<th>Presence in WA</th>
<th>Perennial pasture host</th>
<th>Crop host</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root lesion nematode (Pratylenchus spp.)</td>
<td>Common pathogen, depends on nematode spp.</td>
<td>Range of sub-tropical and temperate grasses, lucerne</td>
<td>Wheat, barley, oats, chickpeas, faba beans (MR*), lentils (MR), field peas, canola</td>
</tr>
<tr>
<td>Cereal cyst nematode (Heterodera spp.)</td>
<td>Endemic</td>
<td>Perennial ryegrass</td>
<td>Wheat, barley, oats</td>
</tr>
<tr>
<td>Burrowing nematode (Radopholus spp.)</td>
<td>Endemic</td>
<td>Buffel grass, kikuyu, kangaroo grass</td>
<td>Wheat, barley, oats</td>
</tr>
<tr>
<td>Stem nematode (Ditylenchus spp.)</td>
<td>Seed-borne nematode not present in WA, (quarantine pathogen)</td>
<td>Buffel grass, couch grass, lucerne</td>
<td>Oats, chickpeas, faba beans, lentils, field peas, canola</td>
</tr>
<tr>
<td>Dagger nematode (Xiphinema spp.)</td>
<td>Endemic</td>
<td>Buffel grass, Rhodes grass, couch grass, kikuyu, perennial ryegrass, kangaroo grass</td>
<td>Lucerne</td>
</tr>
<tr>
<td>Root-knot nematode (Meloidogyne spp.)</td>
<td>Endemic, but prefers warmer climates where soil moisture is non-limiting</td>
<td>Rhodes grass, kikuyu, <em>Panicum</em> spp.</td>
<td>Lucerne (wheat, barley, chickpeas, faba beans) – depends upon nematode spp.</td>
</tr>
</tbody>
</table>

*MR – Moderately resistant*