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How to use this manual

The purpose of this manual was to summarise local and national feedbase management strategies relevant to the northern dairy industry focusing on forage, water and nutritional management. It contains the important principles of developing tropical feeding systems in order to provide a perspective of how different feeding systems may apply to individual farms.

Detailed information has been provided on each part of the various systems, including each pasture or forage species used, cow management and nutrition, irrigation and soil management, and other aspects such as animal health in relation to their effects on feeding systems. The factors which drive profitability of the various systems have been reviewed throughout the manual, and in the final chapter, key performance and economic parameters are discussed and related to the choice of feeding system.

The document has been published as a web-based technical manual. The manual is comprised of two sections; Section 1 describes the types of dairy production systems operating in the sub-tropical environment of northern Australia and summarises feedbase management. Section 2 provides information and data on forage species, and guidelines for managing forages, irrigation, soils and animal nutrition.

There are a number of ways in which you can find information in the manual. If you are searching for specific information you can search for a word or term. If your search is on a particular theme you can search by theme.

Where information has been drawn from other publications, and when data is presented in tables and figures, the source has been acknowledged. References have been cited at the beginning of the text according the Chapter they were cited in. Where possible electronic links to references was provided.

This manual is aimed at providing a broad audience – farmers, contractors, advisers, agribusiness and students with information to understand and confidently manage a successful dairy enterprise in the sub-tropics of northern Australia.
Section 1
Dairy production in the sub-tropics
Chapter 1. Sub-tropical dairy systems

Feedbase systems
Dairy feeding systems are comprised of forages, supplementary feeds, animal genetics and associated activities which ultimately drive stocking rate, milk production and profit. Traditionally, cows calved during spring onto tropical pastures and cows were dried off during winter. A relatively common and simple feeding system in northern Australia today is grazed tropical grasses during summer, grazed temperate pasture during winter, conserved feed fed out in autumn and grain based concentrate in the bails throughout the year.

In more complex systems cows calve all year round and feeding ration formulation and feed-out systems, and use crops and pastures for grazing and conserve forages, usually with some irrigation. The goal of modern feeding systems is to maintain a high intake of quality feed by cows to achieve a constant supply of milk, high in components and with a low somatic cell count, all year.

Studies to better understand the feeding system in terms of improving forage production, forage utilisation and animal nutrition has dominated dairy research and extension in northern Australia for more than 10 years. The premise is simple, the more a cow eats the more milk she will produce, and the better the diet quality the greater the feed conversion efficiency of milk yield and milk components. Whatever the complexity of the feeding system, dairy managers instinctively strive to increase diet quality and feed intake. Each manager has experiences where milk yield fell after feed supply was interrupted.

There are also examples of rapid increases in milk yield when feed supply was suddenly increased, as with the high production M5 herds at Mutdapilly where milk yield increased by more than 2000 L/cow in the first year of the study. There are also examples where managers are opportunistic and source exotic by-products such as distiller’s grain, sorghum syrup, pineapple pulp, biscuits, fruit-cake and chocolate.

It is relatively simple to achieve high milk production. A much greater challenge is to ensure the feeding system is profitable. Thus income from milk sales must be substantially higher than the feeding costs. Income must cover feed costs, as well as herd, shed, administration, labour and management, depreciation and finance costs. In subtropical Australia, feed costs are typically 50-60% of milk income and this proportion of costs has steadily increased from about 35% in the 1980’s. In fact, in intensive feedlot operations feed costs are often about 75% of milk income. The reasons for this trend are complex, but an underlying influence are market signals for milk production and decreased marginal return per litre of milk produced. This necessitates
higher milk output through higher stocking rate and feed intake by cows. Increasing feed intake invariably increases unit costs as the proportion of home grown forage falls and other costs occurs from growing crops for ensilage, increased capital outlay on feed-out, feed commodities and irrigation infrastructure. Consequently, feeding systems are undergoing a process of constant change to keep increasing milk yield and income and overcome reduced margin over feed costs.

Adoption of technology
Feeding systems in northern Australia have been influenced by ongoing changes in technology, markets for milk, environmental issues and climate variability (Table 1.1). In many respects the area has been a pioneer front in developing milk production in the tropics and there has been a steady improvement in technology of feeding systems, both in the feed itself and the associated machinery and equipment. The dominant aspect of market change has been the gradual withdrawal from manufacturing milk to an almost total focus on the local fresh milk market (Table 1.1). The fresh milk market grew with local population growth, against a background of a well established industry based on export of butter. Initially, some farmers close to Brisbane were offered attractive quotas to attract their milk away from manufacturing.

Over the next 40 years the price differential between market and manufacture milk increased and quotas expanded to almost all farmers and for most of the milk.

Following deregulation of milk price in 2000 this process was complete, with 93% of milk now going to the fresh milk market under individual contracts with milk processors.

The most notable change in technology up to the nineties was a series of developments in pasture management which resulted in progressive increases in pasture production and quality. In the sixties there was optimism for the potential of tropical pastures and the Dairy Pasture Subsidy Scheme resulted in huge areas of planting in coastal and subcoastal regions. These pastures were somewhat disappointing, but provided impetus for subsequent developments in irrigated temperate pastures, use of nitrogen fertiliser and ensilage of crops, particularly maize.

The wide spread adoption of herringbone dairies in the seventies and eighties enabled many farmers to spend more time on pasture improvement.
Table 1.1. A schematic demonstration of the major technology and market changes influencing feeding systems on northern dairy farms, showing the periods of most active change.

<table>
<thead>
<tr>
<th>Major events</th>
<th>Decade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1950’s 60’s 70’s 80’s 90’s 00’s 10’s *</td>
</tr>
<tr>
<td>Market milk quotas</td>
<td></td>
</tr>
<tr>
<td>Dairy pasture subsidy scheme</td>
<td></td>
</tr>
<tr>
<td>Irrigation/ryegrass</td>
<td></td>
</tr>
<tr>
<td>Dairies - Herringbone - Robotic</td>
<td></td>
</tr>
<tr>
<td>Nitrogen fertiliser</td>
<td></td>
</tr>
<tr>
<td>North American cow genetics</td>
<td></td>
</tr>
<tr>
<td>Silage</td>
<td></td>
</tr>
<tr>
<td>Partial mixed rations</td>
<td></td>
</tr>
<tr>
<td>Environmental issues and climate variability</td>
<td></td>
</tr>
</tbody>
</table>

* Projected changes

The change from Jerseys and British Friesians to Holstein Friesian cows was linked to the market milk quotas and also the much higher cull price for Holstein cattle, and some farmers with large quotas had gone this way in the seventies. By 2000 Holstein Friesian was the dominant breed.

Environmental issues associated with effluent, creek bank management, nutrient runoff and greenhouse gas emissions emerged in the eighties as a consequence of the increase in stocking rate and feed intake. The effect of climate variability on forage production and animal comfort was a significant factor in redefining feeding systems for many dairy enterprises during the 2000’s. Unreliable rainfall and decreased irrigation water promoted the widespread adoption of crops for ensilage because of their potential to use water more efficiently than pasture. Covered feed out structures have been installed on some farms to improve cow comfort to mitigate heat stress and mastitis. As a consequence, the proportion of farm systems feeding cereal-based partial mixed rations has increased substantially.

**Industry production**

Nationally the number of farms has fallen by 66% over the past three decades, whereas in Queensland this reduction has been 80%. Milk production per cow in northern Australia has increased from 70% of the national average in 1980 to 90% in 2010. Total milk production in 2010 was 530 ML from 583 farms with a farm gate value of $272M. The average farm gate milk price is ~54 cents/L, compared with ~41c/L in Victoria in 2012 ([www.dairyaustralia.com.au](http://www.dairyaustralia.com.au)), and recent good seasons have seen a return to profitability after 10 years of drought. Although >90% of milk in Queensland is used for local fresh milk markets and the major issue facing the industry is the alignment of production with markets. During winter and spring there is 5 to 7 ML milk each month above the market demand, and during summer and autumn there is a 2 to 6 ML/month shortfall. There is also intense competition among milk retailers for market share and this has resulted in further reductions in milk price to farmers. In 2012, the number of farms was 540 and total milk production was 485 ML. In addition, processors and retailer expect farmers to have much greater control over the production pattern whilst increasing milk components and decreasing somatic cell count.
Change in production system

A primary way of managing milk output, and increasing total production is the intensive use of cereal-based silage in feeding systems. Current data demonstrate that farms which have adopted intensive silage and associated feedout facilities (PMR) are able to increase stocking rate and milk more cows and achieve higher milk production per cow than grazing herds (Table 1.2). On the Darling Downs, an area well suited to such a feeding system, adoption of this system has seen substantial increases in production with substantial economic benefit.

Table 1.2. Production and economic parameters for dairy farms in south east Queensland (SEQ) and the Darling Downs (DD) using feeding systems dominated by grazing or the use of intensive silage feeding (Murphy and Simpson 2010).

<table>
<thead>
<tr>
<th>Dairy system parameters</th>
<th>SEQ Graze</th>
<th>SEQ PMR</th>
<th>DD Graze</th>
<th>DD PMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows milked</td>
<td>228</td>
<td>253</td>
<td>118</td>
<td>244</td>
</tr>
<tr>
<td>Milk (ML/farm/year)</td>
<td>1.267</td>
<td>1.529</td>
<td>0.717</td>
<td>1.872</td>
</tr>
<tr>
<td>Milk (L/cow/year)</td>
<td>5558</td>
<td>6048</td>
<td>6102</td>
<td>7673</td>
</tr>
<tr>
<td>Milk price (c/L)</td>
<td>58.5</td>
<td>56.8</td>
<td>56.4</td>
<td>57.9</td>
</tr>
<tr>
<td>Feed related costs (c/L)</td>
<td>25.6</td>
<td>28.1</td>
<td>28.2</td>
<td>33.4</td>
</tr>
<tr>
<td>Dairy operating profit ($/cow/year)</td>
<td>943</td>
<td>772</td>
<td>908</td>
<td>1082</td>
</tr>
<tr>
<td>Return on assets (%)</td>
<td>5.4</td>
<td>4.4</td>
<td>4.1</td>
<td>7.5</td>
</tr>
</tbody>
</table>

The dominant climatic issue influencing the feeding system is the combination of high temperatures and rainfall. In northern Australia, the high rainfall is associated with high temperature. Although this combination is ideal for growth of tropical grasses and crops, there are penalties in terms of continuity of forage supply and forage quality. The warm conditions promote a high fibre content of grasses and crops and a very high biomass which cannot be fully utilised by grazing during the growing season. Attempts to reduce the fibre content and redistribute the biomass have not been successful. Converting forage into silage has been more effective with crops, such as maize and barley, than tropical grasses. Irrigation is usually required to grow temperate grasses and forages such as ryegrass and lucerne during winter and spring, and this system has been so successful that surplus milk supply now occurs in that period. Consequently there has been a move away from tropical pastures in the feed systems and more towards ensiled maize and irrigated temperate pastures.

The high temperatures also have a direct effect on the cow. Holstein Friesian cows have been shown to cease grazing once temperatures exceed 27°C, and at temperatures above 32°C, a common occurrence during spring to autumn, require shade and cooling to maintain appetite. Many farms now have covered feed out structures where cows eat a silage mix while shaded and cool. The heat stress on cows, measured using the THI index, is evident for 9 months of the year in lowland north Queensland
and 3 to 4 months in southern NSW and elevated areas (www.coolcows.com.au). The effects of heat stress is greater in northern areas with high humidity such as Beaudesert and Gympie compared to lower altitudes west of Toowoomba.

Summary
Dairy farmers have been very active in adapting to new markets and incorporating new technology into feeding systems. These changes have resulted in a relatively consistent level of high quality milk in each month of the year, and milk production per cow is now similar to that in the temperate dairy regions of southern Australia. Holstein Friesian cows have been widely adopted and the environment, including feeding and cooling, altered to enable these cows to be productive in a tropical environment. Although it is unlikely that the genetic potential of this breed will be realised until the environmental constraints to milk production are minimised by housing animals in free stall barns. Over the last 30 years irrigation has gone from a small level on the majority of farms to being the main driver of productivity on approximately 75% of farms. The continued development of subtropical feeding systems is closely linked to the continued supply and it efficient use of irrigation water.

Current feeding systems in Australia range from grazed pasture with low purchased feed input, to grazing and feeding of conserved forages, to a system based solely on conserved cereal-based forages. The majority of northern farmers are in systems 2 and 3, which involve grazing for most of the year and complementing this with conserved forages directly or as part of a Partial Mixed Ration (PMR). However, approximately 9%, have ceased grazing altogether and adopted a Total Mixed Ration (TMR) where cows are confined continuously and offered their entire ration as a mix, usually on a concrete feed pad. The move to more intensive feeding has been prompted by drought over the last 10 years. In northern Australia since the drought farmers find the management and high productivity of such systems attractive.

At Mutdapilly Research Station five feeding systems, very similar to the five described nationally, were run independently for four years (Walker et al. 2007). All systems were productive in the subtropics, but results clearly showed the importance of forage quality and land productivity (stocking rate) in achieving profitability. Irrigation was essential to maintaining a supply of high quality forage and land productivity was maximised when this was used to grow conserved forages. Farm profit was subsequently increased with these high input systems compared with lower input, grazed pasture systems.

This manual describes the feeding systems in northern Australia and their productivity. The important principles of the feeding systems are described. The description includes pasture or forage species and cow management and nutrition, irrigation and soil management. Other aspects of management, are covered in relation to feeding systems. The profitability of the various systems is continually reviewed, and in the final chapters key performance and economic parameters are discussed and related to the choice of feeding system.
Chapter 2. Principles of feedbase management

Feeding systems

The feeding systems employed in tropical and subtropical Australia are relatively unique with a substantial dependence on both tropical and temperate forage species for grazing. In most tropical areas tropical forages are used in cut and carry systems. Many countries with large dairy industries, such as India and Pakistan, do not have large land areas available to graze dairy cows, and forage is harvested and collected by hand or purchased off farm and carried to the cows. However South Africa, Brazil and some other tropical countries have also developed successful production systems based on similar combinations to those used in Queensland and New South Wales and such systems are expanding throughout the tropics and subtropics.

In the temperate latitude of southern Australia, temperate species are predominantly used for grazing. Even within an area such as northern Australia there is substantial variation in the details of feeding systems, associated with rainfall, soil type and irrigation supply, but there are many issues in common related to the establishment, growing, utilisation and nutritional quality of tropical forages. From a pioneering industry of spring calving cows onto dryland tropical grass pastures there has been consistent innovation in the feeding systems over time which transpired into increased farm productivity (Figure 2.1). These initial systems had very low productivity, a very different situation to today where subtropical systems can demonstrate productivity equal or higher than that seen in temperate areas.

![Graph showing milk production from 1997 to 2011](image)

Figure 2.1. Total milk production/year (ML) averaged for all QDAS farms and for the top 10% based on operating profit margin per cow from 1997 to 2011 (Forage Plus project).
The key driver of change has been economics, as in common with most other agricultural industries milk has undergone a steadily declining terms of trade. This means a litre of milk has less purchasing power now than it did in previous years e.g. it now takes 10 times as many litres of milk to purchase a Holden car as it did in the 1950s.

Associated with this change has been a rise in family expectations for living standards. Together these factors have caused dairy farms to steadily grow in cow numbers (Table 2.1).

Table 2.1. Key factors within feeding systems, household economics and milk markets that have lead to the intensification of dairy enterprises.

<table>
<thead>
<tr>
<th>Feeding systems</th>
<th>Household economics</th>
<th>Milk markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow numbers</td>
<td>Living costs</td>
<td>Terms of trade</td>
</tr>
<tr>
<td>Farm capacity to grow feed</td>
<td>Labour cost</td>
<td>Seasonality</td>
</tr>
<tr>
<td>Control of feed supply</td>
<td>Overhead costs</td>
<td>Quality payments</td>
</tr>
</tbody>
</table>

**Northern feeding systems**

The feeding system is that mix of feeds and associated methods of procurement and delivery to animals. The nutritional needs of the animals are often the focus of the feeding system, though these can be altered to fit a desired feeding system. For example where monthly milk production targets are reasonably fixed the feeding system must deliver required amounts of specified quality parameters each month, whereas in more flexible marketing conditions batch calving is often used to alter the annual pattern of needs by cows to more closely match the natural growth cycle of pastures. Feeding systems in northern Australia have moved very strongly from batch calving (predominantly in autumn and spring) to calving all year round. Now most farmers need to manage the annual feed supply ahead so that anticipated demand each month is met.

The objective of feeding systems is to support a profit under sustainable conditions. Total feed supply is the major cost on dairy farms, representing approximately 60% of gross income, and variation in cost of feeding has a large effect on farm profitability. The processes of growing and utilising feed and increasing stocking rate are also the primary factors linked to environmental damage, such as the potential for soil erosion, movement of fertiliser nutrients off farm and manure contamination of waterways. Consequently the management of feeding systems is a major occupation of dairy farmers and the major focus of dairy RD&E in northern Australia.

The main control over production and feed costs is home grown forages. The old saying 'home grown feed is the cheapest source of feed' is often the case. Whilst purchased feeds whether grains, forages or by-products form an important part of the total ration, but there is limited opportunity to alter price and quality. There are much greater opportunities to change the price and quality of home grown forages through species selection and improvements in agronomy and utilisation by cows. The level of home grown forage utilisation is consistently correlated with economic margin over feed costs in farm accounting data such as QDAS, and thus is a useful measure of farm efficiency. Present levels of home grown forage utilisation are in the order of 4 to 7 t DM/ha/year, with the lower values being in the low rainfall zones (Figure 2.2). Farm accounting data also show that these
values are almost doubled where irrigation is applied to forages and as feeding systems have become more productive irrigation has become an integral part of the system. Another factor associated with increased forage production is herd size, or total milk output. Large farms, producing over 1.4 ML milk annually, recorded a mean home grown forage utilisation of 8.5 t DM/ha/year, compared with 4.5 t DM/ha/year on small farms with total milk output of less than 0.7 ML/year.

![Bar chart showing regional variation in home grown forage utilisation on northern dairy farms (Forage Plus project).](image)

**Figure 2.2.** Regional variation in home grown forage utilisation on northern dairy farms (Forage Plus project).

**Potential of subtropical feeding systems**

Faced with the challenges of increasing milk production from tropical forages, there have been a number of controlled studies of the potential of feeding systems in the tropics and subtropics. In the 1970’s it was demonstrated that irrigated, nitrogen fertilised pangola grass pastures in a tropical environment supported up to 8 Holstein Friesian cows/ha and produced in excess of 20 000 L milk/ha/year (Chopping et al. 1976). Production per cow was relatively low and subsequent research demonstrated this could be improved by over-sowing ryegrass into the tropical grass pasture each autumn. In a tropical upland environment a combination of a tropical grass during summer and irrigated ryegrass during winter, with 6 kg concentrates/cow/day supported milk yields of 7000 L/cow/year (Walker et al. 1992).

In northern New South Wales, kikuyu grass pastures oversown with irrigated ryegrass each autumn supported 3 cows/ha year over 5 years. High genetic merit Holstein Friesian cows given 1.7 t concentrate each lactation averaged 6400 L milk/cow/year (Fulkerson et al. 2006).

In south east Queensland, high levels of productivity were substantiated in a four year project which examined five different feeding systems considered
to have relevance to northern Australia (Chataway et al. 2010b). The systems varied widely in the use of tropical forages, irrigation amount, pasture and crop species, and it was clearly demonstrated that all have relatively high potential for production (Table 2.2). The most intensive systems, full irrigation and feedlot, produced levels of milk production as high as or higher than anywhere in the world.

Similar levels of productivity have been recorded more recently in central New South Wales using a combination of kikuyu oversown with ryegrass each autumn (65% of land area) and a triple cropping program based on maize for silage and brassicas and legumes for grazing (35% of land area). The feeding system supported 5 cows/ha and recorded 27800 L milk/ha/year (Future Dairy – Farina et al. 2011).

Taken together, these results clearly show the high productivity of mixed tropical and temperate forage systems which are suited to the tropics and subtropics. A recent survey of Queensland dairy farms showed a substantial number of farms are moving towards similar, intensive systems of production. These farmers were more confident of further expansion into the future than those who were not interested in adopting such intensive systems. Farms with relatively high production of over 2 ML milk/year had higher inputs of irrigation, silage and concentrate than farms producing less than 1.0 ML/year (Chataway et al., 2010a). Stocking rate was almost doubled on the large farms and yet milk production per cow was increased by 50% to 6500 L/cow/year (Table 2.3).
Table 2.2. The potential of five feasible milk production systems in Northern Australia as measured by the M5 project over 4 years (Walker et al. 2007).

<table>
<thead>
<tr>
<th>System</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage type</td>
<td>Tropical grass</td>
<td>Tropical grass, irrigated winter temperate pasture</td>
<td>Forage cropping, irrigated winter temperate pastures</td>
<td>Irrigated temperate pastures</td>
<td>Maize, lucerne and barley silage, feedlot</td>
</tr>
<tr>
<td>Calving</td>
<td>Spring</td>
<td>Spring and autumn</td>
<td>Spring and autumn</td>
<td>Spring and autumn</td>
<td>Year round</td>
</tr>
<tr>
<td>Forage base (% area)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical grass</td>
<td>78</td>
<td>80</td>
<td>13</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Forage crops</td>
<td>22</td>
<td>0</td>
<td>76</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Temperate pastures</td>
<td>0</td>
<td>20</td>
<td>11</td>
<td>91</td>
<td>0</td>
</tr>
<tr>
<td>Silage crops</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Stocking rate (cows/ha)</td>
<td>1.9</td>
<td>2.7</td>
<td>1.4</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Grain mix (t/cow/year)</td>
<td>2.7</td>
<td>2.9</td>
<td>2.8</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Water use (ML/cow/year)</td>
<td>0</td>
<td>0.34</td>
<td>0.3</td>
<td>1.31</td>
<td>1.0</td>
</tr>
<tr>
<td>Milk (L)</td>
<td>6330</td>
<td>6730</td>
<td>7078</td>
<td>7617</td>
<td>9457</td>
</tr>
<tr>
<td>(/ha/year)</td>
<td>12 030</td>
<td>18 840</td>
<td>9830</td>
<td>22 850</td>
<td>40 670</td>
</tr>
</tbody>
</table>

A common feature of all these high production systems is the dependence of tropical and temperate forage species. The environment is suited to growing tropical species during summer and temperate species during winter. The combination of temperate and tropical forages results in large amounts of home grown forage to be produced annually. The base feeds are the tropical pasture grasses or a maize crop for summer and irrigated ryegrass pasture during winter. These are complemented on most farms by a selection of other forages suited to the environment including sorghum, millet and barley crops, cool- and warm-season legumes, brassicas and herbs. Lucerne is a temperate legume of high value to the dairy industry.

Home grown forages are invariably complemented with purchased feeds, predominantly grains, protein meals and by-products. As with forages, there is a wide range of tropical and temperate crops providing these feeds. Grains, especially barley, wheat and sorghum, are a primary source of purchased nutrients and are supplemented with protein meals such as soybean, chickpea and cotton crops. Sugar cane molasses is commonly used in feed mixes, and selections of whole cotton seed, brewers grains, sorghum syrup, palm oil and coconut by-products and rejects from the manufactured food industry are included on some farms if the opportunity arises.
Table 2.3. Characteristics of Queensland dairy farms with low, medium and high levels of milk output.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production (ML/farm/year)</td>
<td>0.48</td>
<td>0.99</td>
<td>2.20</td>
</tr>
<tr>
<td>Milk production (L/cow/year)</td>
<td>4460</td>
<td>5471</td>
<td>6474</td>
</tr>
<tr>
<td>Stocking rate (cow/ha)</td>
<td>0.69</td>
<td>1.00</td>
<td>1.23</td>
</tr>
<tr>
<td>Pasture dominant (%)</td>
<td>46</td>
<td>47</td>
<td>32</td>
</tr>
<tr>
<td>Crop dominant (%)</td>
<td>31</td>
<td>34</td>
<td>50</td>
</tr>
<tr>
<td>High concentrate input (&gt;8kg/cow/day)</td>
<td>0.03</td>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>Using pit/bun silage (%)</td>
<td>25</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>High use of feed pads (%)</td>
<td>3</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Intensive irrigation (&gt;0.1 ha/cow (%))</td>
<td>9</td>
<td>2</td>
<td>16</td>
</tr>
</tbody>
</table>

**Efficiency**

Experience on farm and in studies of feeding systems has demonstrated both the resilience of production systems and the importance of capable management in achieving efficiency. Resilient in the sense the cow will often compensate for variations in feed supply and quality. For example, a cow's intake may vary considerably from week to week, but over a full year the level of milk production will reflect the average level of food intake and body condition of cows. Similarly it has been found that the protein and energy contained in different forages and grains is used efficiently although these feeds may be offered to the cow up to 12 hours apart.

However there is a high level of management needed to procure and deliver these feeds to the cow. Each home grown forage has specific management needs and optimum production is achieved only if all these are met. Where fodders are conserved the decisions on yield, quality, ensilage method and feeding out are critical. Contrary to traditional belief, grazing management which achieves high production and utilisation is a highly skilled operation. Purchasing of grains, by products and forages require forward planning and skill in negotiations. Consequently managerial skills and training are perhaps the most important parts of preparing for an intensive feeding system.

**Models**

As noted above there have been many field demonstrations of the production capabilities of feeding systems. However these cannot be continually repeated and recently computer models have been developed to enable future scenarios to be tested before implementation. Dairy Predict brings together the feeding system with the herd and calving pattern to predict likely milk output and financial margin (Figure 2.3). Such analyses are important preliminary steps in modifying a feeding system.

**Risks**

As the feeding system is a major cost to the farm business and high levels of skill are needed to operate it optimally there is risk of failure in making substantial changes to the feeding system in response to decreasing water allocation, increased stocking rate and milk production. Experience shows that without the appropriate rate of change for each farm business, training or sound financial advice, the risk of failure is increased. Most successful have been farms where the feeding system was changed steadily over a number of years. By contrast a number of failures have occurred where rapid change was implemented over one or two years.

A major area of risk which is often not considered is in the transition from
managing the farm alone with minimal outside contact to managing through employed labour, and negotiations with feed suppliers and technical service agents. Experience has shown this change is critical to success. Successful change often occurs with a change in generation or extensive retraining of long term management.

**Overview**

Feeding systems in tropical and subtropical Australia are relatively unique in that they employ a mix of tropical and temperate pasture and crop species and a range of by products from both tropical and temperate crops. They have undergone consistent change over the past 50 years associated with declining terms of trade and rising family living costs, and this process of change is continuing. High productivity of home grown forage is the basis of success in feeding systems and research and farm practice have demonstrated that these systems are as productive as anywhere else in the world, in terms of milk output per cow and per hectare. There is a significant move on farms towards including more crops suited to conservation and more irrigation and purchased concentrates in the feeding system. Experience has shown there are risks in changing a feeding system too rapidly or without careful preparation, and success often results from consistent change over a number of years.
Figure 2.3. Summary of a dairy feeding system located in Harrisville using Dairy Predict (i) calving all year round and (ii) seasonal calving in spring. Repeating the model runs with different inputs assists in making a decision on the priorities in developing the current feeding system (DairyPredict).
Feeding system drives profit
Milk production is based on food resources that are available in a region and have the potential to be converted to milk in a sustainable and profitable way. The cow is the means of conversion. The type of cow, her genetics, and her level of production are determined by the quality of the feed which in turn is often determined by the ratio of milk to feed price. The priority is to optimise the conversion of feed to milk, rather than optimise the cows’ genetic potential, though as quality of feedstuffs increase these two aspects become complementary, and similarly high genetic merit will increase feed conversion efficiency.

The resources used to produce milk vary greatly, from low quality forages such as rice straw to medium quality tropical pastures to high quality temperate forages and starch-based grains (Table 2.4). Industrial and food by products are often converted to milk in peri-urban areas although the production of methanol on the Downs offers a cheap source of protein to farms in that region. The optimum levels of milk production reflect these differences in feedstuffs, varying from 3 to 30 L milk/cow/day, and tend to be associated with differences in digestibility (fibre content).

Table 2.4. Examples of different feed resources used to produce milk and indicative levels of milk production.

<table>
<thead>
<tr>
<th>Feed type</th>
<th>Location</th>
<th>Milk production (L/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical pasture only</td>
<td>North Queensland</td>
<td>10</td>
</tr>
<tr>
<td>Temperate pasture only</td>
<td>Tasmania/New Zealand</td>
<td>15</td>
</tr>
<tr>
<td>Pasture and grains</td>
<td>Australia wide</td>
<td>20</td>
</tr>
<tr>
<td>Rice straw/bran</td>
<td>Philippines</td>
<td>3</td>
</tr>
<tr>
<td>Browse</td>
<td>East Africa</td>
<td>2</td>
</tr>
<tr>
<td>Maize silage/alfalfa/corn</td>
<td>USA/California</td>
<td>30</td>
</tr>
<tr>
<td>Vegetable/food factory waste</td>
<td>Peri-Urban</td>
<td>25</td>
</tr>
</tbody>
</table>

A principle of feeding systems is that the level of milk production increases with cow intake and continues to increase until the limit of appetite is reached (Figure 2.4). This limit may be physical, where the fibre content of the diet fills the gut, or metabolic, where one nutrient becomes limiting and prevents further intake or utilisation of other nutrients. Usually the limits are set by energy or protein intake, though in some circumstances a mineral lack can limit further increases in milk production.
Figure 2.4. The relationship between crude protein and energy intake and milk yield. The dashed lines show the theoretical relationship, whereby milk yield increases linearly with protein intake until energy becomes limiting. The solid lines are from a collation of experiments with energy intakes of 100, 180 and 260 MJ ME/cow/day in mid lactation (Balch 1967; Cowan 1982)

In foraging systems, such as browse or pasture systems without supplements, cow intake is limited by eating rate and grazing time. Often management restricts the ability of individual animals to eat by increasing stocking rate, such that reductions in individual cow intake are more than compensated for by a greater harvest of forage per hectare. As the level of supplementary or complementary feeding increases the effects of higher stocking rates on individual intake are diminished. For example if pasture is half the diet, the cow is less impacted by a reduction in pasture available through an increase in stocking rate, as she has her normal grazing time (6 to 10 h/day) in which to forage for approximately half the pasture required where no supplements were fed. In this situation, it becomes possible to achieve high milk production per cow and high utilisation of grazed forage. In Australian experiments, there has almost always been a linear increase in milk output with greater total feed inputs per hectare, unless overgrazing compromises pasture production (Figure 2.4).
Figure 2.5. Milk fat and protein output increase with level of total dry matter intake per hectare. The dotted line represents the situation where high stocking rate, trampling or fouling reduce pasture production (Flaxley farmlets – Valentine *et al.* 2009).

The genetic merit of a cow for milk production becomes more important as the quality of the diet increases. In lower production systems genetic merit almost always exceeds the capability of feeds, and other aspects of the cow take prominence, such as environmental fitness and reproduction. As diet quality increases genetic merit for milk production becomes more important. Breed type may be altered, as in northern Australia where Jerseys and British Friesians have been replaced with Holstein Friesians. Cows of high genetic merit are more responsive to intake of high quality feed than those of medium genetic merit, with the response to 6.3 kg grain/cow/day in a four year trial at Wollongbar being 1 L milk/kg supplement for high genetic merit cows and 0.6 L/kg for cows of medium genetic merit (Figure 2.5) (*Fulkerson et al.* 2008).

A major reason for higher genetic merit cows being more efficient than those of lesser merit is the higher intakes they are able to achieve. Also for cows of a given merit there is an increase in efficiency as feed intake increases. As intake increases, for example from 2 to 3 times maintenance (Figure 2.6), the distribution of energy in the animal changes. With the higher intake diet quality often increases and loss of energy in faeces is a smaller proportion of intake than with lower feed intake. Similarly the maintenance needs are a lesser proportion of intake. By contrast the proportion of energy going to milk increases, in this example from 20 to 28% gross energy intake. This results in a higher ratio of milk output to feed intake in other words higher feed conversion efficiency.
Figure 2.6. The interaction of genetic merit and level of supplementary feeding (2.9 and 6.3 kg/cow/day) for Holstein Friesian cows grazing kikuyu pastures (Fulkerson et al. 2008).

Figure 2.7. The effects of feeding a cow at 2 and 3 times maintenance level of the distribution of gross energy intake (GEI) among maintenance, faeces, urine and methane, heat and milk (Fulkerson et al. 2008).

In farm practice a number of these relationships are operating together, often to enhance overall efficiency. As the capacity of a farm to produce or purchase greater amounts of high quality feeds increases herd size increases and the genetic merit of cows is upgraded. In Queensland dairy herds there is an association of herd size, milk yield per cow, and
economic return (Table 2.4). Almost always farms move through these stages in a series of steps, whereby production is increased until a limit prevents further growth. This may be feed related such as lack of irrigation, or infrastructure such as dairy and feeding facilities. If it is possible to overcome these limits the farm makes further growth.

Table 2.5. The relationship of total farm milk production to milk production per cow and key economic parameters (Murphy and Simpson 2010).

<table>
<thead>
<tr>
<th>Production and economic parameters</th>
<th>Farm milk production (ML/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk (L/cow/year)</td>
<td>5107 5473 6312 7227</td>
</tr>
<tr>
<td>MOFRC ($/cow/year)</td>
<td>1494 1457 1577 1975</td>
</tr>
<tr>
<td>Dairy operating profit ($/cow)</td>
<td>487 599 614 1138</td>
</tr>
<tr>
<td>Dairy operating profit ($/farm)</td>
<td>50 194 111 201 152 363 398 732</td>
</tr>
</tbody>
</table>

An example of the effect of a change in farm capacity to grow forage was well demonstrated in the Mutdapilly farmlet herds from 2002 to 2006 (Table 2.5). Similar farms systems using pasture were compared, with the same cow numbers, area and level of grain feeding, but one farm received a major upgrading to the irrigation capacity. This resulted in an increase in milk yield per cow, reductions in purchased feed and pasture costs, and increases in margin over feed costs and profit.

Table 2.6. Changes in key production and economic parameters with a major increase in irrigation inputs. Data from the M5 farmlet trial, Mutdapilly research Station (Chataway et al., 2010b).

<table>
<thead>
<tr>
<th>Production and economic parameters</th>
<th>Farm system M5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmlet 2</td>
</tr>
<tr>
<td>Farmlet area irrigated (%)</td>
<td>20</td>
</tr>
<tr>
<td>Cows</td>
<td>360</td>
</tr>
<tr>
<td>Milk yield (L/cow/year)</td>
<td>6534</td>
</tr>
<tr>
<td>Feed cost (c/L)</td>
<td>17.9</td>
</tr>
<tr>
<td>Purchased feed cost (c/L)</td>
<td>10.3</td>
</tr>
<tr>
<td>Gross margin ($/cow/year)</td>
<td>747</td>
</tr>
<tr>
<td>Return on assets (%)</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Overview

Milk production is based on feed resources available. The cow becomes more efficient at converting these resources to milk with increases in level of intake and quality of diet. In systems using low quality feeds or pasture only, a lower cow efficiency may be accepted to gain an efficient harvest of forage per hectare. As forage quality increases and complementary feeds are included in the diet, individual cow efficiency has greater relevance to production levels and economic success.
Chapter 3. The choice of forages

The choice of forages will be dependent on the agronomic suitability of particular forages to the local environment and on the ability of the farmer to alter the environment to meet the demands of a desired forage species. The forage selected also depends on the suitability of the forage to meet the nutritional requirements of the herd.

Local environment

The local environment exerts a dual influence on the choice of species. The predominant influence is on the establishment, growth and persistence of the forage, but it can also have a direct effect on the harvesting of that forage. With grazed pastures there is rarely an issue with harvesting, though as the industry adopts a greater proportion of crops into the feeding system weather constraints on successfully harvesting and conserving forage become important. In particular the ability to harvest maize silage has been challenged in high rainfall coastal environments. Though some farmers plant maize at the beginning of spring to avoid harvesting during the wettest months of the year.

Over the past 40 years the industry has experimented with many summer grasses, many of which are no longer seen on farms, but others have established in niches suited to the species and become mainstream pasture grasses. Kikuyu may have become the species of choice, and it thrives on deep volcanic soils in cooler environments. It is not well suited to many areas where soils are heavy, summer temperatures very high and rainfall low. In high rainfall areas setaria has demonstrated strong persistence, whereas in low rainfall areas Rhodes and panic grasses have established as permanent swards. In smaller niches other grasses such as bracharia spp, guinea grass and paspalum have become established.

Feeding experiments with milking cows have demonstrated there is no advantage in attempting to change any of these species to others less suited to the environment, as in the same environment the nutritional quality of the grasses is similar. It is more productive and efficient to fertilise those grasses suited to the local environment.

Purpose

As well as being suited to the local environment forages are chosen on the basis of intended contribution to the feeding system. The contribution can be in terms of total forage production, suitability for ensilage, add protein or starch to the ration, provide loafing area during extended periods of wet weather or extend the growing season.

To achieve higher total production the species is normally chosen in conjunction with changes in infrastructure and operations to suit that species, for example irrigation is needed to grow ryegrass pasture and storage and feedout facilities for using maize silage. These decisions are usually made once the current forage system is producing to its potential and higher milk output is desired.
Silage is used successfully to smooth out the milk production pattern over the year and in turn farmers can calculate the number of weeks feed ahead of the cows based on daily intake of the herd. Silage can also be used to increase total milk production per hectare when mixed in a nutritionally balanced diet. When choosing a crop species often sorghum is selected for dryland situations where rainfall and stored soil water is marginal, and maize and barley for irrigated summer and winter crops respectively. Most pasture is grazed directly by cows and only small amounts of ryegrass pasture haylage are made generally when pasture growth rates are high, feed on offer exceeds herd’s intake requirements and residual pasture following grazing increases.

Maize has the additional advantage of adding substantial amounts of starch to the diet, so complementing low starch pastures and potentially saving on purchased concentrates. On the other hand legumes are often chosen to boost the protein input from forages, often lucerne but also lablab, cow pea and soybeans. Protein is an expensive nutrient to purchase and boosting protein in forages can save on purchased feed costs. Frequently cultivars of species or novel species are chosen to extend the growing season of an established forage type or fill a feed gap. For example herbs are now often used to extend the growing season of irrigated winter pastures and provide autumn feed. White clover, prairie grass and perennial ryegrass are all used in some situations to extend the growing season into early summer or provide pasture growth during autumn before annual ryegrass is established. In forage cropping areas a combination of early and later maturing forage sorghums and lablab, and frequent grazing can be used to extend the summer forage season from September to May.

**Selection**

Local experience is usually the best guide to choosing forage species as there is a 20 to 40 year history of using many of the forage species available in northern Australia. Newer introductions are often tested against normal practice by seed companies before release and then after release their effectiveness becomes evident within two to three years.
There are also a number of forage selection tools available which can be very useful as a broad guide as to the types of species likely to be productive in the local environment. These are either booklets produced by seed companies or the state departments of agriculture or user friendly computer software programs. A summary of these is shown in Table 3.1

Table 3.1. Examples of booklets and software programs useful in selecting forage species suited to northern Australia.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Publisher</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture Picker</td>
<td><a href="http://www.tgs.asn.au">www.tgs.asn.au</a></td>
<td>Summaries of agronomic and nutritional characteristics of 42 tropical grasses and 47 tropical legumes.</td>
</tr>
<tr>
<td>Pasture Picker</td>
<td><a href="http://www.pasturesaustralia.com.au">www.pasturesaustralia.com.au</a></td>
<td>Geographically based enabling 128 tropical and temperate species to be selected on the basis of climate, agronomy and management.</td>
</tr>
<tr>
<td>Tropical Forages</td>
<td><a href="http://www.csiro.au">www.csiro.au</a></td>
<td>A comprehensive agronomic overview of 180 tropical pasture and forage species.</td>
</tr>
</tbody>
</table>

Overview

The selection of forage species or cultivars will largely be based on local experience and the purpose for which the forage is to be used. There are a number of sophisticated selection tools available to assist in screening of forages and obtaining details about selected forages. Regardless of the forage selected, the genetic potential to produce large amounts of quality biomass will not be achieved unless water, nutrients and defoliation practice are optimal.
Chapter 4. Forage combinations that work

Combinations of forage species are required to ensure a continuous supply of quality forage and sustainable land use.

Types of combinations

There are three types of forage combinations commonly used in the northern dairy industry. Firstly, many pastures contain a permanent mix of forage species. Secondly, different forage species are used during different periods of the year to take advantage of complementary growth rhythms. Thirdly, in the longer term, especially where crops are used in forage production, it is necessary to have a rotation of forage species.

Mixed pastures

Mixed pastures have traditionally been based on a grass and legume combination. Pioneering pastures often used a paspalum and white clover combination, and areas of white clover mixed with tropical grasses still persist on many dairy farms. White clover has been demonstrated to contribute up to 100 kg N/ha to associated grass, though typical values are much less in the order of 40 kg N/ha. The tropical legumes, such as siratro and glycine, fixed similar amounts of nitrogen for the associated grass when they were present at 30% or more of the dry matter in the sward. In addition to fixing nitrogen legumes enhance the diet of the animal as they are normally palatable and have higher crude protein and lower fibre content than the grass. White clover has also been shown to have a beneficial effect on rumen fermentation which results in a disproportionate improvement in the overall nutritional value of the diet.

In recent years herbs, such as chicory and plantain, and forage rape (brassica) have been used in mixtures with pasture grasses under irrigation. The combination extends the grazing season for these pastures by taking advantage of the deep rooting capabilities of the herbs and rapid establishment of brassica.

Complementary forages

The use of complementary forages in the annual feeding system has been a major development over the past 20 years, and the trend is continuing with an increased emphasis on using crops in the mix. The primary application has been to grow cool season forages during winter and tropical species during summer, but there are other aspects such as high starch forages such as maize complementing high protein forages such as soybean. Perennial ryegrass is not widely used in northern Australia because the hot and humid summers cause high plant mortality within the first year of establishment.

The use of irrigated annual ryegrass based pastures, either oversown during autumn into tropical grass or sown in separate areas of land, enhances the forage supply to cows during winter and spring (Figure 4.1). Such pastures consistently produce over 10 t DM/ha/year, and up to 20 t DM/ha/year on some farms. Combined production from summer and winter pastures has consistently been in the range 12 to 18 t DM/ha/year. The nutritional quality of such pastures is considerably higher than that of tropical grasses, being relatively low in fibre and high in crude protein content, and consequently milk production during early spring has changed from being the lowest to the highest output of the year. There have been many variations and improvements to this combination, such as incorporating herbs or clovers within the ryegrass pasture and replacing some of the ryegrass area with other species such as prairie grass or perennial ryegrass. Also methods have been evaluated to inhibit the growth of kikuyu by mulching or applying a desiccant to improve the establishment of ryegrass. A primary aim of these variations is to
increase the proportion of the temperate species relative to the tropical and lengthen the growing season for the temperate species.

Without irrigation in regions with mean annual rainfall less than 1000 mm, forage oats and barley are the preferred temperate forages to complement summer crops and pastures. Oats has been the traditional source of winter forage for dairy cows, but the reliance on rainfall means yields are extremely variable, making it difficult to schedule milk output for modern market demands. Under irrigation ryegrass pastures have been shown to be far more productive than oats.

There has been a substantial move towards cropping in the dairy industry, to increase total forage output, increase water use efficiency, maintain continuous forage supply, and to provide silage. Silage has increased in importance as the market has become dominated by fresh milk sales and the consequent demand for a consistent milk supply in each month of the year. As with pastures, summer and winter crops are used to complement each other and provide year round forage supply. The primary silage crop is maize, a summer growing crop with a high starch content. This ideally complements irrigated winter forages in terms of growing season and nutritional value for cows.

Combinations of summer maize and winter barley yielded 24 t DM/ha/year, and more intensive triple cropping of this combination yielded 30 t DM/ha/year (Forage Plus project – Callow 2010). Triple cropping of maize, brassicas and ryegrass yielded up to 40 t DM/ha/year in central New South Wales (Future Dairy Project – Garcia et al. 2007). The average ME content of these forage mixtures is consistently above 10.5 MJ ME/kg DM, substantially above the 9.0 MJ ME/kg DM for tropical grass pastures.

Summer crops are often useful in utilising residual water and nitrogen in the soil profile after irrigated temperate pastures, which can be considerable, and so remove any risk of nutrient movement into water ways during the high rainfall summer months. Sorghum is particularly effective in this regard, and it can then be either grazed or ensiled.
Figure 4.1. The annual feed system for a herd using dryland summer pasture and irrigated winter pasture, showing their complementary patterns of growth and their relationship to purchased concentrates and short term cropping (DairyPredict).

**Long term rotations**

Cropping programs require a long term rotation to maintain soil structure, prevent pest/disease build up and to optimise use of soil nutrients. On dairy farms this primarily relates to rotations with maize, though rotation of sorghum and lablab has been shown to be useful on dryland cropping areas. More recently soybean has been used as an alternative to lablab because it makes high quality protein based silage.

Maize is a highly specialised and nutrient and water demanding summer crop, and in the short term can complement winter barley or irrigated temperate pasture. In the longer term it may be necessary, especially if winter cropping is also conducted on that land, to rotate with completely different forages. The traditional rotation has been with lucerne in approximately equal periods, such as 3 years each (Walker *et al*. 2007).

By contrast pastures do not require such a rotation, and many tropical and temperate pastures have been grown on the same land for in excess of 30 years without any measured loss of productivity.

**Improvements measured**

**Efficiency**

Efficiency gains have resulted from increases in total production per hectare and from maintaining a flat milk production curve through the year. QDAS records over 40 years demonstrate that farmers who
increased home forage production had greater milk output and higher profitability than average. This is despite the fact that with changes to forage production, such as installing irrigation and planting temperate pastures each autumn or investing in machinery and expertise to grow and ensile crops, the level of investment increases. In each case the consequent increase in milk production more than compensated for these increased costs, and total milk production increased while cost per unit of milk output decreased (or to overcome a reduction in the in marginal return per litre produced).

Experimental comparisons have shown similar increases in efficiency. Increasing the application of N fertiliser combined with increasing the stocking rate increased milk production per ha, often correlating to a decline in milk production per cow and the decline in proportion of legume in the pasture (Cowan and Stobbs 1976). Incorporating annual temperate pastures into a tropical grass pasture increased annual milk production from 20% for Cynodon (couch) pastures in north Queensland (Chopping et al. 1982). Intensive irrigation increased gross margin by $400/ha/year compared with dryland farming. The use of maize, barley and lucerne silages in a feedlot farming system resulted in a doubling of both milk production per hectare and measures of profitability such as return on assets (M5 project - Walker et al. 2007).

The ability to manage milk supply and achieve a similar level of milk sales each month is greatly facilitated through the use of a combination of forages, particularly if one or more of those forages can be conserved as silage. Such control firstly makes farmers eligible for favourable milk sales contracts and provides the confidence for farmers to enter these contracts with relatively tight margins for deviation. Without the use of complementary forages it would probably be difficult to secure a milk supply contract given the current focus on the fresh milk market.

Cow nutrition
The increases in milk output are dependent on improvements in cow nutrition, primarily an increase in annual food intake but also concomitant increases in nutritional value of the diet where temperate forages or legumes are included in the mix. The use of irrigated temperate pastures lifted the milk production potential from pastures alone to 18 L/cow/day (Kaiser et al. 1993), compared with 12 L/cow/day for tropical pasture (Cowan et al. 1993). Including white clover in kikuyu pastures increased milk production to 15 L/cow/day (Davison et al. 1997). Intensive inputs of silage and concentrate lifted production to 30 L/cow/day (Chataway et al. 2010b).

Choosing combinations that work
The choice of forage combinations is dominated by three factors; (i) the pattern of milk supply required, (ii) availability of irrigation and (iii) targeted level of milk production per hectare. Other factors such as type of production system (i.e. grazing, partial mixed ration) rainfall zone, topography and soil type are relevant to the final selection of species.

The pattern of milk production required in northern Australia is a consistent supply each month of the year, and this can only be achieved using a combination of forages. Irrigation
enables forage production during summer and winter and increases the potential for total forage production. Within these constraints the options for increasing milk production per hectare will depend on current forage systems.

Grazed forage combinations enable milk production of 10 000 to 20 000 L/ha/year, though it is difficult to maintain an even production pattern without incorporating silage into the feeding system. At modest levels of milk production per hectare silage can be made from ryegrass or other pastures excess to requirements during the growing season. As the target level of milk production rises there is no excess pasture, yet the amounts of silage needed increase substantially. At this point cropping is often introduced into the feeding system, with the aims of increasing total forage production and increasing the amounts of silage available for cows. Feeding systems using crop silages have produced 20 000 to 40 000 L milk/ha/year.

**Overview**

A combination of forages is essential for ensuring a consistent pattern of milk production throughout the year. There is a wide choice of forages available in the subtropics, but the fundamental features are winter and summer growing, dryland or irrigated and grazed or cropped. Specific choices will depend on the amount of irrigation available, the requirements for cropping as a source of silage, ‘window’ of opportunity for planting, whether the land is arable and the nutritional requirements of the cows.
Chapter 5. The management of forages

Milk production is a function of the intensive management of feed production and animal husbandry programs. In large enterprises these functions are often separated, sometimes into independent businesses. However the vast majority of northern Australian dairy farms are family owned and managed and of moderate scale (mean annual milk production >1 ML of milk), and the two functions are managed by the same person or family. Each is critical to success. On the farm the main feed production activity is growing and utilising forages, and the productivity of these is dependent on management rules which, when followed, enable forages to grow to potential.

Growing

Table 5.1. A representative combination of forages grown on a west Moreton dairy farm through the course of a year (D dryland; I irrigated; G grazing; S silage).

<table>
<thead>
<tr>
<th>Forage</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhodes grass</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Kikuyu</td>
<td>✓ ✓</td>
<td></td>
</tr>
<tr>
<td>Native pastures</td>
<td>✓ ✓</td>
<td></td>
</tr>
<tr>
<td>Crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Forage sorghum</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Oats</td>
<td>✓ ✓</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>✓ ✓</td>
<td></td>
</tr>
</tbody>
</table>

Feed is required in the short term

To maintain productivity on a dairy farm it is important that the time between sowing and harvesting is minimised. The farm area is limited and the demand for forages as cow feed is high and constant, and it is not possible to allow extended periods of time for establishment. Some species which require a long establishment period, such as Pinto peanut (Walker 2003), has been difficult to incorporate into the feed program. Even with permanent pastures such as Rhodes grass or kikuyu it is important that cow grazing be managed carefully in the first 6 months after sowing. This is why when establishing kikuyu in autumn, it is recommended to plant it in a mix with oats and white clover. Annual pastures and forage crops are normally being grazed by cows 6 to 8 weeks after sowing when roots have established sufficiently to prevent the plant from being pulled out of the ground. Similarly it is imperative that silage crops produce a high yield to overcome the costs of harvesting, ensiling, feeding out and wastage.

This short term demand for feed means diligence is needed in establishment. Firstly timeliness is essential, each species has an optimum period of the year for planting and research has shown that earlier in this period is more productive than later. Seedbed preparation and
maximising stored soil water are critical, though the degree of preparation varies widely between species, tillage equipment, water availability and farm circumstances, varying from mulch striking annual ryegrass into tropical grass stubble to establishing maize with zero tillage.

Seeding rate is typically higher than would be used in dryland broad acre farming and beef production. A high seeding rate quickly establishes the dominance of the forage on the land, so reducing weed competition, and invariably results in a shorter time to first grazing than lower seeding rates. For short-rotation ryegrass, an additional 1 t DM/ha can be utilised within the first and second grazes by increasing the recommended seeding rate to 80-100 kg/ha. Dry matter production thereafter will be similar to the standard seeding rate as the plant population stabilises.

Inland from the coast, the seeding rate for dryland crops grown for silage is often much lower. The principle behind this strategy is firstly to provide more water per plant and increase the likelihood for the crop to reach physiological maturity and optimise dry matter production and forage quality. Secondly, reduce the establishment cost per hectare and increase the area planted. The use of seasonal fallows, fertiliser and weed control such as pre-emergent’s are aimed at promoting rapid establishment and growth.

Quality is a premium

Dairy cows are genetically able to produce milk well above the capacity of forages, so any improvement in quality will ensure higher milk production and possibly reduce the need for higher cost feeds. Conversely low forage quality will reduce milk production and income.

When forage management is optimised the primary difference in forage quality, measured as utilisable energy and protein, is between species. Where resources allow a higher quality forage to replace a lower quality one, it is often profitable to do so. Temperate, or winter growing, species are invariably of higher quality than tropical species, and legumes of higher quality than grasses (Figure 5.1). Though legumes have high quality their capacity for dry mater production is invariably less than for grasses, and similarly dry matter production of temperate species is lower than for tropicals. When forage management and growing conditions are less than ideal, the variation in forage quality within species is almost as large as between species.

The development of the tropical and subtropical dairy industry has paralleled the development of infrastructure and expertise for growing high quality forages. Irrigation has been the primary factor, enabling the use of ryegrasses, clovers and herbs, and lucerne. It also ensures the consistent yield of quality silage crops, such as maize and barley.
**Figure 5.1.** Comparison of neutral detergent fibre (NDF%) content between forages sampled on-farm across Queensland dairy regions during winter (July-August 2011) and summer (January-February 2012) (C₄Milk project).

Within species the predominant changes in quality occur with ageing. The rate of decline in utilisable energy and protein varies greatly between species, but all show a decline with age. The decline is less with legumes than grasses. A significant factor in this decline is an increase in stem content, as stem is lower in quality than leaf, and the aim of grazing management is often to maximise the harvest of leaf without a high proportion of stem in the diet. Tropical species have a greater propensity to produce stem than temperate species. Most rules on utilisation of individual species, both as grazing and silage and temperate and tropical species, relate to a compromise between increasing yield as plants mature and declining quality (Figure 5.2).
Nutrient supply to plants normally influences quality indirectly, by promoting faster growth and a higher leaf to stem ratio. The required inputs of additional nutrients are decided on the basis of expected forage yield and current soil nutrient content. The current levels of soil nutrients are calculated from periodic soil sampling and modelling of gains and losses from fertiliser inputs and crop removal. Potential gains from nutrient application are provided from local research response trials, experience on the farm, and decision support tools such as Whopper Cropper. In general these estimates are based on soil threshold values for phosphorus, potassium and sulphur, calcium to magnesium ratio and input–output calculations for nitrogen. Soil threshold values are those which ensure adequate growth of the plant but avoid a build up of excess nutrient in the soil or on the other hand avoid depleting nutrients.

Nitrogen is a more labile nutrient and its use can be calculated on a forage by forage basis, with the aim of equalising the sum of soil available nitrogen and applied nitrogen with nitrogen removal in the forage (Table 5.2). Soil available nitrogen can be directly measured before a crop is planted, but is more difficult to measure under a grazed pasture as large amounts of organic matter in the soil and on the surface directly affects the availability of nitrogen at any time. Nitrogen fertiliser history and pasture condition, with reference to local response trials, are more useful in adjusting nitrogen levels applied to pasture.

**Figure 5.2.** Changes in neutral detergent content (%) of temperate and tropical pastures with physiological development.
Table 5.2. Typical threshold values for nitrogen, phosphorus, potassium and sulphur for a maize crop with a target yield of 20 t DM/ha.

<table>
<thead>
<tr>
<th>Maize</th>
<th>CP</th>
<th>P</th>
<th>K</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient as % DM</td>
<td>8.1 (N 1.3)</td>
<td>0.23</td>
<td>0.73</td>
<td>0.1</td>
</tr>
<tr>
<td>Nutrient removed (kg)</td>
<td>259</td>
<td>46</td>
<td>146</td>
<td>20</td>
</tr>
<tr>
<td>Equivalent fertiliser*</td>
<td>Urea</td>
<td>Single</td>
<td>Muriate of</td>
<td>Sulphate of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Super</td>
<td>Potash</td>
<td>Ammonia</td>
</tr>
<tr>
<td>(kg/ha)</td>
<td>562</td>
<td>530</td>
<td>292</td>
<td>85</td>
</tr>
</tbody>
</table>

* Examples only of products which can be used to replace nutrients and doesn’t account for any preliminary nutrient deficiencies. Split applications are recommended.

**Utilisation**

Forage is utilised directly by grazing or indirectly through conservation as silage, haylage or hay (approximately 32 to 35%, 45 to 55%, and 90% DM respectively). Crop silage is an important part of the feed program on many subtropical dairy farms, and for each crop there are guidelines as to the optimum harvest stage generally based on the physiological stage of growth. These are almost always based on obtaining high quality and quantity of forage, and before quality falls below an acceptable level. Often this balance relates to leaf quality and stem elongation, as with lucerne and forage sorghum, though with maize the accumulation of starch is balanced against the decline in quality of leaf.

Once silage is in storage it is utilised as part of the total ration, usually in a partial mixed ration (PMR), based on the nutritional content. The ration is formulated to include the nutrients in silage and other sources of nutrients are used to balance the diet.

By contrast the utilisation of grazed pasture and crop is more complex, needing to take into account the contribution of nutrients in the grazed forage to the total ration and the effects of cows grazing on the harvested yield of forage. It is rarely possible to optimise both of these for long periods of time and in practice emphasis is placed on maximising the yield of home grown forage (Table 5.3); nutrient inputs from grains and protein meals are used to balance the diet. This approach is sound as invariably home grown forage is a cost effective way to feed cows.
Table 5.3  The relationship of farm operating profit to litres of milk per cow from home grown feed (Queensland Dairy Accounting Scheme, Busby et al. 2009).

<table>
<thead>
<tr>
<th>Key performance indicators</th>
<th>Milk from home grown forage (L/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;7.5</td>
</tr>
<tr>
<td>Milk from home grown feed (%)</td>
<td>26.6</td>
</tr>
<tr>
<td>Feed related costs (c/L)</td>
<td>37.7</td>
</tr>
<tr>
<td>Margin over FRC (c/L)</td>
<td>20.4</td>
</tr>
<tr>
<td>Margin over FRC ($/cow)</td>
<td>1207</td>
</tr>
<tr>
<td>Dairy operating profit ($/cow)</td>
<td>577</td>
</tr>
</tbody>
</table>

Where FRC is feed related costs

Grazed forages are normally harvested a number of times each season and the aim of grazing management is to graze during the growth cycle to optimise DM yield and forage quality, without compromising regrowth of the forage. Management can also be modified, particularly the grazing time, to assist in matching cow needs for nutrients with forage growth cycles.

In the subtropical dairy regions many farms include at least 40% of the ration as conserved forage and purchased feeds, to enable increases in herd numbers and levels of production. These components of the ration are often adjusted to enable grazed forage to be managed to potential and to avoid having forage in excess of cow needs. Also the use of various summer and winter growing forages results in a spread of forage peak growth rates through the year to match calving all year round. Consequently grazing and ration management are integrated and under continuous review (Table 5.4). The situation is quite different to that in many temperate areas of Australia where the growth peak is very concentrated in spring to match seasonal calving and there is less opportunity to use complementary feeds to manage the rotation.

The integration of ration and grazed forage management has on many farms replaced the traditional relationship of stocking rate with pasture utilisation. The incorporation of high levels of purchased feeds and crop silage has enabled stocking rates to be increased well above levels which could be sustained by pasture alone. Rather the objective is to fit the pasture grown, whilst maintaining utilisation, into the feed mix. An advantage is that other feeds can be used when necessary to maintain cow dry matter intake levels when pasture growth rates are slow allowing grazing to be suspended to allow pasture to grow to potential. Since other feeds can be stored there is wide flexibility to alter the short term stocking rate on
pastures to achieve the desired level of utilisation. In this way a planned schedule of feed is prepared for the year in advance and with it peace of mind for farmers.

Table 5.4. An example of changes to ration formulation to accommodate the changing growth rate of ryegrass between winter and spring.

<table>
<thead>
<tr>
<th>Season</th>
<th>Ration formulation</th>
<th>kg DM/cow/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>Silage (maize)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Concentrate (18 % CP)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Ryegrass pasture (25% CP)</td>
<td>5</td>
</tr>
<tr>
<td>Spring</td>
<td>Silage (maize)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Concentrate (12 % CP)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Ryegrass pasture (20% CP)</td>
<td>12</td>
</tr>
</tbody>
</table>

This situation contrasts strongly with those farms which choose to minimise the inputs of purchased and conserved feeds and are predominantly dependent on grazed forage. Here the aim is to set the stocking rate at a level which results in near maximum forage utilisation, a level at which pasture growth is not compromised by over stocking. Given the year to year variations in seasonal conditions it is advisable to be somewhat conservative in setting stocking rate. It is also important to have the capacity to make pasture silage, as it is not possible to completely match pasture growth with animal demand. Although in the dairy region of Milla Milla in far north Queensland, it is often too wet to make quality silage so farmers carry forward summer grown feed into winter as standing hay. In general across all dairy regions, at certain times of the year, typically spring for irrigated pastures, there will be an excess of forage which is more efficiently used if made into silage. At other times, typically autumn, there will be a lack of pasture and a short term supplement of hay or silage is needed to maintain cow production.

In both systems the optimum stage of the growth cycle at which to graze differs for the various plants, but is based on the stage of physiological development and the effect on leaf to stem ratio. The extent of leaf development has been found to be a reliable indicator of optimum yield for grazing and for other aspects such as leaf senescence, restoring of carbohydrate reserves, capacity to regrow after defoliation, and onset of senescence. The 3 leaf stage in ryegrass is a well recognised measure of optimum grazing time (Figure 5.3) (Fulkerson and Slack 1994). Leaf number is sometimes used for other plants, such as the 4 leaf stage in kikuyu (Reeves et al. 1996), 5 leaf stage in prairie grass (Slack et al. 2000), but various other measures include leaf height for forage sorghum, estimate of leaf yield for Rhodes grass and leaf cover for lablab.
Once grazing has commenced the object is to use as much of the forage as possible without compromising regrowth after grazing. An associated factor with tropical species is to avoid forcing animals to eat stems as this lowers the nutritional value of the diet and limits DM intake. The management rules differ for the various forages and they are less precise than for the commencement of grazing. Even for ryegrass, the most intensively studied pasture plant, there are differences of opinion as to whether residual leaf should be left after grazing or not. There is agreement that growth after grazing should not be compromised and various guides to assessing how to avoid this have been developed. A common measure with temperate pastures is stubble height, and for example ryegrass stubble should be at least 5 cm after grazing. Often with tropical species an estimate of leaf removal is used to judge the completion of grazing, such as 70% removal from Rhodes grass, forage sorghum or lablab. With irrigated forages and lucerne a back fence to prevent grazing of stubble more than 3 days old is universally recommended.

**Overview**

Optimum production from forages is dependent on applying proven management rules, many specific to individual forages but others which apply more broadly. Key areas are nutrient and water management in the growth of forages, and defoliation practice in their utilisation. The primary parameters in defoliation practice are stocking rate, stage of defoliation, and height of defoliation.
Chapter 6. Sourcing off farm animal nutrients

Combining off farm feed resources with home grown forage has the potential to increase the scale and profitability of milk production.

Feed into milk
Milk production is the process of using cows to convert local feed resources into a saleable product, milk. The origin of these feed resources maybe the farm area or local feed markets. In a substantial number of regions around the world all feed is imported to the cows from off the farm area, for example the milk production complexes based in urban areas of Pakistan and other countries. On the other hand there are many farms where all feed is produced on the farm, as forage in areas such as Tasmania and parts of New Zealand and as forage and grain in areas such as some farms on the Darling Downs. Most northern Australian farms sit between these extremes, typically importing 40 to 60% of total feed requirements. A majority of the imported feed is grains, protein and conserved forage, though as the human population increases and the number of dairy cows reduce there are increasing amounts of by-product available for feeding to cows.

Imported feeds
Importing feeds onto a dairy farm can increase profit through increasing stocking rate, total milk output and by balancing the ration of cows, so increasing efficiency of use of home grown forages.

Total milk output
Increasing total milk output has the effect of diluting the cost of fixed overheads and operating costs and is the traditional way of maintaining profit. It can readily be achieved by importing substantial amounts of feeds and adding these to the feeds produced on farm, and provided the cost of imported feeds is appropriate the total margin over feed costs increases rapidly even though the margin over feed costs per litre decreases. Sometimes the importation of feeds also avoids the need for additional investment on farm, such as in hay or silage making equipment.

A simple demonstration of this effect, using average farm data (QDAS report) is shown in Figure 6.1. In this example farm input of imported feed is increased from 30 to 50% of total feed used. Assumptions are made that milk price remains the same and that importing additional feed does not increase the costs of non feed items, namely administration, depreciation, and labour. However non feed costs are diluted by the extra milk production and fall from 20 to 15 c/L. Overall operating profit increases by an additional 400 000 L and 4 c/L multiplied by total production or $84 000/year. The effect is clearly sensitive to the cost of imported feed, as if the cost of this feed is very high relative to current feed costs the increase in cost can exceed the savings in non feed costs. An initial assessment of this effect is usually done using a marginal economic analysis.
Figure 6.1. A demonstration of the effects of increasing total milk output through the use of imported feeds on feed and non feed costs and dairy operating profit.

Balancing the ration

Often in dairy cow nutrition feeding two or more different types of feed each day increases efficiency of milk production. Almost all individual feeds are nutritionally imbalanced in some way, either having an excess or deficiency of particular nutrients, and a combination of feeds enables these differences to be balanced out and for the total intake to be consistent with the cow’s nutritional requirements. Typically well managed pastures have an excess of crude protein and more mature pastures an excess of NDF. Grains and maize silage contain high starch, but low protein. Protein meals contain low levels of starch. By mixing these and other ingredients together a diet close to optimum in crude protein, starch, NDF and other nutrients can usually be achieved.

Balancing rations is thus an important technical skill for the dairy manager. A knowledge of the nutrient content of the feeds being used, an ability to estimate intake by the cow, and details of dairy cow nutrient requirements are necessary to calculate a balanced ration. It is also essential to understand the economics of feeding, as in many situations profit may be optimised despite inefficiency in the use of a particular nutrient. Perhaps the most common example is excess crude protein in pasture, but if pasture is plentiful it is usually more profitable not to feed high amounts of starch and allow the cow to excrete excess nitrogen in the urine. Details of these calculations are shown later in this manual.

Sometimes combining feeds can have a different effect to the simple average, referred to as associative effects. Normally in balancing rations
it is assumed that 1+1=2, but it is important to be aware that in some cases it may equal 1.8 or 2.2. This is referred to as feed conversion efficiency. Often a modest amount of one feed has a disproportionate effect on the rumen or overall gut. Practical examples include,

- Small amounts of starch may stimulate rumen bacteria and increase fibre digestion and turnover in the rumen (large amounts of starch depress fibre digestion).
- Excess oil in the diet (>5% DM) tends to coat fibre particles in the rumen and slow digestion.
- Where the diet is protein deficient addition of protein can stimulate dry matter intake as well as balance the diet. This is more often encountered with growing stock than milking cows.
- Addressing mineral deficiencies, especially phosphorus, may stimulate dry matter intake and digestion.

**Marginal economic analyses**

Marginal economic analysis is a useful tool for initial assessment of a feed that is available for import to the farm. It is a four step calculation of likely milk response, economic value and comparison with cost.

**Step 1** Calculate **LOSSES** due to the proposed change – this includes extra costs and revenue foregone, in this case primarily the feed and handling costs. It may include additional equipment, such as feed troughs.

**Step 2** Calculate **GAINS** due to the proposed change – this includes additional revenue and components, and any cost savings.

**Step 3** Calculate “**NETT GAIN**” = GAINS - LOSSES

**Step 4** List “**NON-DOLLAR**” factors due to the proposed change – increased management skills, time, risk.

In marginal analyses for feed imports the most important factor is the likely milk response to additional feed. This can vary depending on pasture conditions, being higher when pasture is in short supply and lower when pasture is plentiful, and the nutritional balance of the diet. A nutrient deficiency can restrict response to added feed, for example a protein deficiency will restrict response to added starch. However under normal commercial conditions average response rates generated from experience are often used in economic assessment and have proved reliable. The response to grain based concentrates is taken as 1.1 L milk/kg as fed, 0.9 L/kg DM for high quality pasture or silage (temperate species, maize silage) and 0.7 L/kg DM for lower quality pastures (tropical species, sorghum silage). Often the responses to other feeds are expressed relative to grain, with molasses as fed at 70%, pineapple pulp 85%, whole cotton seed 100% and palm kernel extract 80%.

A number of imported feeds, especially byproducts, have limits to the amounts that can be fed each day. The primary feeds such as maize silage and grain do not have limits as long as the ration is balanced and cows are able to consume extra feed. However high potassium levels limit the amount of molasses that can be fed efficiently and high oil content limits the level of whole cotton seed.
Purchasing feed imports
Planning ahead is vital to successful use of imported feeds. Feed requirements need to be predicted well ahead of time, based on the target level of milk production, feed availability and the mix of these feeds needed to maintain a balanced diet. Feeds can then be purchased or contracted well ahead of the time when they are to be fed. Forward purchasing is necessary firstly to ensure supply as the quantities needed by the average dairy farm are large and may not be available at short notice. Also it is usual for the price of feeds to be lower when they are forward purchased, though this is not always the case. The purchasing of imported feeds is a highly skilled activity and where large quantities are needed, the successful acquisition will require extensive negotiations and research. In very large enterprises this activity becomes the major task of the owner/manager.

Overview
In tropical and subtropical Australia there are viable opportunities to expand dairy businesses by combining home grown and purchased feeds. The use of purchased feeds can expand the scale of the business, balance the ration and ensure continuity of supply. The purchasing of imported feeds depends on forward planning, and if large quantities are required extensive research and negotiation are required to optimise economic outcomes.
Chapter 7. Irrigation principles

Water is a natural resource which can greatly increase the profitability of milk production using relatively simple management rules.

Profit
The ratio of milk price to water price is invariably high, for example in a well managed system 5 cents value of water produces one litre of milk worth around 50 cents. The profit in using irrigation is much more influenced by the irrigation system adopted and the management of irrigation than the water price. There is an extremely high range in the efficiency of water use on farms (Figure 7.1), as much as a six fold difference, associated with the cost and appropriateness of the system of water distribution and the application of management rules to ensure high efficiency.

Figure 7.1. The variation measured in water use efficiency for milk produced from home grown feed on 13 northern Australian dairy farms (Callow 2011).

Key factors
In gaining optimum efficiency from irrigation there are some key factors which need to be taken into account before the process of water application is decided upon. The soil type is very important as there is large variation in the amounts of water stored in different soils and the rate of water infiltration is also very variable. Measuring or predicting the amounts of water a forage will use is important in deciding on how much water to apply and how often, and this will be strongly influenced by the type of forage being grown and the environment. A method of monitoring efficiency is important so changes can be made before the forage is severely stressed and rate of photosynthesis is inhibited.
On the individual farm the water supply can sometimes be unsuitable for certain crops, usually due to salt content. Water is often a limited resource and a means of choosing and prioritising where to apply that water will assist production. The added cost of irrigating from rising electricity tariffs places more emphasis on the importance of allocating water to forage that has the greatest return.

A substantial proportion of rainfall moves through the soil profile or off the forage area and the nutrients carried in this water need to be considered for their effects on catchment areas and waterways.

**Soil types**

Soils are characterised by the ratio of large (usually sand) to small particles (usually clay or organic matter) and the nature of the vertical profile (soil horizons). Air occupies the spaces between soil particles and water clings to the surface of those particles. Water in the spaces drains away. For a given volume of soil small particles provide a much greater surface area than large particles (Figure 7.2) and are therefore able to hold more water. On the other hand small particles hold water more tightly than large particles and as the water content falls it becomes harder for the roots to extract this water. Loam to clay loam soils, with approximately 50% clay, tend to have the greatest amount of plant available water, which is the amount of water between wilting point and a full soil water profile (Figure 7.3).

**Figure 7.2.** A diagram of soil particles showing the pore spaces and water adhering to the particles. Clay particles provide approximately twice the surface area compared with sand particles (Dalgliesh and Foale 1998, Figure 1.1).
The plant available water is extracted by roots in a different manner for sandy and clay soils. Sandy soils give up the water very quickly (low suction) whereas clay soils release the water more slowly (high suction) over an extended period of time. This means that sandy soils reach wilting point more quickly than would be expected for the amount of plant available water, and so irrigation frequency needs to be increased more than proportionally to the plant available water content.

The ability of plants to take up water depends on the nature and extent of roots. These vary widely between plants and growing conditions, but a key feature is the ability of roots to move through the soil profile and seek water. The water demand of the crop also has a strong influence on the rate of water uptake while there is available water in the soil.

Soil organic matter content has effects well beyond water holding capacity and is sometimes referred to as the biological powerhouse of the soil. It provides energy and nutrients to both soil microorganisms and roots. Organic matter is usually measured as organic carbon content, and is often in the order of 2 to 4% under undisturbed vegetation. Higher levels are found in the more fertile soils such as Kraznosems and prairies, and lower values under open forest grassland. Cultivation has repeatedly been shown to reduce organic carbon content of soils, to less than 1%, though modern techniques of minimum tillage and adequate fertilisation have been shown to arrest this decline. Restoration of soil organic matter can usually only be achieved by a number of years under well fertilised grassland or by applying manure or compost.

In tropical and subtropical Australia there are many different soil types used on dairy farms. However soils receiving irrigation are generally alluviums or better quality volcanic soils such as kraznozems, black...
earths and prairie soils. Each of these soil types has a sandy loam to clay texture and a deep rooting zone of at least 60 to 70 cm. Main differences between soils are likely to be in the plant available water stored, and consequent frequency of irrigation needed to achieve optimum yield.

**Plant water use**

Water moves from the soil to the atmosphere either directly from the soil surface by evaporation or indirectly through the leaves of plants as transpiration. The rate of evaporation depends on the water content of the surface soil, the humidity gradient from the soil to the atmosphere, ambient temperature and the level of exposure of the soil surface to solar radiation. The primary management control of evaporation is in intercepting the solar radiation before it reaches the soil surface, by maintaining a stubble or forage cover. With irrigated annual pastures and forages evaporation is highest in the period from planting to full cover.

Once forage attains full soil cover much of the water moves from the soil through transpiration and the proportion of total water loss occurring as transpiration rises (Figure 7.4). This may vary from 10% during seedling establishment to in excess of 80% during the mid growth stage of the crop. Approximately 1% of water is retained by the crop; the remaining 99% carries nutrients through the plant and is evaporated through stomata on the underside of leaves. A leaf area index of 3, where the total surface area of green leaves is three times the area of land, is associated with maximum transpiration, though the rate is also dependent on soil water level, relative humidity and ambient temperature.

![Figure 7.4](image)

**Figure 7.4.** Changes in the partitioning of water between evaporation and transpiration with growth of the crop and increasing leaf area index (Adapted Allen et al. 2004, Figure 22)

An estimate of evapotranspiration (ET) has traditionally been made from open pan water evaporation, a readily accessible measurement using a simple water pan. However, differences between open pan evaporation and ET from different crops and pastures have led to the
The development of a more complex formula to estimate ET referred to as the Penman-Monteith equation, using data on net radiation, soil temperature, air density, water vapour content and specific heat, and resistance factors for soil and air (Allen et al. 2004).

The Bureau of Meteorology provides calculated ET values determined using the Penman-Monteith equation at different sites across Australia (BoM). ET can be calculated for locations away from weather stations by interpolating climate data from the closest stations. The Penman-Monteith calculates ET₀ for a reference grass grown in a standard climate not short of water and under optimal agronomic conditions. As a result, it is recommended to multiply ET₀ by a crop coefficient (Kc) to distinguish between different water requirements between plant species and stage of growth (LAI).

\[
ET \text{ for a specific forage} = ET₀ \times Kc
\]

Typical ET values for a ryegrass pasture and maize crop are shown in Table 7.1, showing seasonal changes and differences between forage types. Total water required during the growing season for maize was 573 mm and for annual ryegrass 793 mm.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (mm/mth)</td>
<td>168</td>
<td>141</td>
<td>133</td>
<td>105</td>
<td>85</td>
<td>64</td>
<td>74</td>
<td>97</td>
<td>125</td>
<td>153</td>
<td>161</td>
</tr>
<tr>
<td>Average (mm/d)</td>
<td>5.4</td>
<td>5.0</td>
<td>4.3</td>
<td>3.5</td>
<td>2.7</td>
<td>2.1</td>
<td>2.4</td>
<td>3.1</td>
<td>4.2</td>
<td>4.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Kc Maize</td>
<td>0.5</td>
<td>1.2</td>
<td>1.2</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize (mm/mth)</td>
<td>62</td>
<td>184</td>
<td>193</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kc Rye</td>
<td>0.5</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
<td>1.0</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye (mm/mth)</td>
<td>53</td>
<td>76</td>
<td>64</td>
<td>74</td>
<td>107</td>
<td>137</td>
<td>153</td>
<td>128</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Plant types**

Plants differ in the production response to irrigation and also in the application regime most suited to them. Tropical grasses (C₄ plants) often have a higher potential growth ceiling than temperate grasses and legumes (C₃ plants) and although greater amounts of water need to be applied the total dry matter production and plant efficiency of water use are increased (Table 7.2). Crops often have a higher production potential and water use efficiency than pastures, partly due to the selection of crops for high productivity, but also due to the continual defoliation of pastures during the rapid growth phase. This means pastures have a greater proportion of their growing time in the initial and early development phases of growth compared with crops.
Table 7.2. The total dry matter production and water use efficiency of selected temperate and tropical crop and pastures plants in south east Queensland (Callow 2011).

<table>
<thead>
<tr>
<th>Forage</th>
<th>Production (kg DM/ha)</th>
<th>Water use efficiency (kg DM/mm)</th>
<th>Water use (mm/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass</td>
<td>12 977</td>
<td>11.7</td>
<td>2.35</td>
</tr>
<tr>
<td>Forage oats</td>
<td>8 695</td>
<td>9.2</td>
<td>2.39</td>
</tr>
<tr>
<td>Lucerne</td>
<td>18 112</td>
<td>10.7</td>
<td>1.71</td>
</tr>
<tr>
<td>Rhodes grass</td>
<td>10 662</td>
<td>15.2</td>
<td>5.30</td>
</tr>
<tr>
<td>Maize</td>
<td>18 365</td>
<td>47.0</td>
<td>3.33</td>
</tr>
</tbody>
</table>

**Monitoring water use**

A primary measurement in monitoring irrigation is the water use efficiency (WUE), which is the result of many factors including plant, infrastructure and operations. The irrigation system design is as important as management and operations in achieving target performance. The three primary steps in monitoring an irrigation system are;

- Assessing the water supply and distribution, which includes losses and impediments to the movement of water until it reaches the paddock.
- Assessing the water application to the forage, particularly in terms of uniformity and adequacy.
- Assessing performance in terms of WUE, often focusing on the method of water supply, such as below ground or overhead.

With a well designed system a major decision is in how to schedule water application, to minimise stress on the plant and optimise production without overwatering. There are four broad methods of doing this,

- Experience of the farmer, drawing on successes and failures from previous years.
- Plant assessment for visible signs such as wilting and indirect measures such as temperature of the leaf and stomatal resistance to water movement.
- Soil assessment for water content using direct observation of dug soil, drying a sample of soil or estimating soil water content using devices that measures resistance to water movement through soil, such as tensiometers and gypsum blocks.

In practice, quantitative methods use either estimates of water removal as evapotranspiration, based either on crop and pasture calculations or monitoring of soil water content. The ET₀ value can be multiplied by a crop coefficient specific to a plant and so provide a sound estimate of water removal, which is then compared with water inputs. Soil water content can be monitored by taking soil cores and drying, but is most often done using calibrated indicators of soil moisture levels, referred to as neutron probes and EnviroScans®. These measurements account for both water input and water removal (Figure 7.3).
Figure 7.5. The water balance of a forage system is a complex balance between various water inputs and outputs.
Chapter 8. Forage conservation

A forage conservation program enables control of the annual pattern of milk production and can markedly increase the total milk output.

**Reasons for conservation**

There are two reasons for including a fodder conservation program on a dairy farm, either to redistribute pasture supply to another time of year or to increase total farm milk output. Often the two are linked as redistributing pasture may increase total pasture utilisation by the herd or better complement purchased feeds such as grains.

The traditional reason for fodder conservation was to redistribute some of the grass from the spring and summer to winter feeding of housed cattle. This is not an issue in northern Australia but where there is a very marked seasonal pattern of pasture production overall efficiency is often increased if the excess pasture grown at the peak is conserved and fed back when pasture growth is very low. This has been done successfully when large areas of irrigated ryegrass are grown and was often tried unsuccessfully where large areas of rain grown tropical pastures were used.

However the substantial changes in feeding systems in northern Australia have markedly reduced the opportunities for redistribution of pasture. This is because a mix of forages is used during the course of the year and so a number of smaller peak growth rates are seen, and the import of approximately 40% of the diet provides the confidence to increase stocking rate. As stocking rate increases there is less surplus pasture available for conservation. The combined effect is that the vast majority of pasture is eaten by grazing, the most efficient way to harvest pasture (Figure 8.1).

![Figure 8.1. As stocking rate increases the amount of excess pasture available for conservation is reduced (Top Fodder adapted Figure 1.4).](image-url)
Special purpose silage crops have become the primary means of providing conserved fodder. These have several advantages to farm management, including increased yield of conserved fodder and improved planning of fodder production, increased water and nutrient use efficiency, and fewer conservation events during the year. It also means pasture management is less complicated if fodder conservation does not have to be integrated with pasture grazing.

Experience has shown that when special purpose crops are grown for fodder conservation there must be sufficient scale to ensure their inclusion in the feeding system boosts milk production, either directly through the extra forage or indirectly through improved pasture utilisation. Many early attempts at fodder conservation from crops, particularly maize, resulted in disappointment to the farmer as the extra cost and work was not rewarded with a significant change in annual milk output or profit. Studies of farms which successfully implemented and maintained fodder conservation from crops suggested a 20% increase in milk production may be needed to make the operation profitable, equivalent to approximately 200 t DM for the average farm.

As a consequence of these changes on farm, fodder conservation is primarily used as a means of increasing total farm milk output through increased feed supply, more consistent feed supply, and more efficient use of pasture and purchased feeds (Table 8.1).

### Table 8.1.
Indicative measurements of increases in scale associated with inclusion of conserved crops into the feeding system in Queensland. Data compares grazing farms with those using a feedpad (PMR) (QDAS 2010).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Grazing</th>
<th>Feedpad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow number</td>
<td>173</td>
<td>249</td>
</tr>
<tr>
<td>Milk output (ML/year)</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Milk yield (L/cow)</td>
<td>5800</td>
<td>6860</td>
</tr>
<tr>
<td>Dairy operating profit ($/year)</td>
<td>160 000</td>
<td>230 000</td>
</tr>
</tbody>
</table>

**Link to milk marketing**

Almost all milk produced in northern Australia is used for fresh, bottled milk sales. To service this market milk processors require almost the same amount of milk in each month of the year, commonly referred to as a flat production curve. Meeting this requirement on farm is greatly assisted by an ongoing program of conserving substantial amounts of forage.

Normally the calving pattern of the herd is spread throughout the year, with the exception that cows may not be mated during the hottest months. If the feeding program is also planned so that grazed and conserved forage combined provide a consistent supply of forage to cows in each month of the year a flat production curve can be obtained (Figure 8.2).
Figure 8.2. An example of a flat production curve showing the role of conserved forage complementing grazed pasture to main a consistent supply of forage throughout the year (DairyPredict).

**Silage versus hay**

Silage has major advantages over hay when the amounts of conserved fodder are large, whereas hay is often preferred when small amounts of conserved fodder are needed. Hay is convenient to feed out in small quantities, whereas opening a silage pit for small amounts is likely to cause spoilage. However when large, regular amounts of forage are to be fed silage offers the following advantages:

- Harvesting and ensilage are less weather dependent than hay making, and the crop can often be cut closer to optimising forage yield and quality. Where on-farm comparisons have been made, primarily with ryegrass in temperate areas, silage has consistently been of higher digestibility than hay and yields have been slightly higher.
- The most productive crops for conservation are not suited to hay making, the most notable example being maize. Other crops such as barley are also more easily ensiled than hayed. On the other hand lucerne can make excellent hay, but studies have shown that lucerne silage is of higher quality than hay, due to greater opportunity to cut at the appropriate time, reduced loss of energy and protein from respiration and drying, reduced weather damage while drying and less leaf loss from decreased tedding (Table 8.2).
- Large amounts of silage can be stored in less expensive facilities, usually pits or buns.
Chopped silage is well suited to mechanical handling at feeding out, using buckets to move silage to feed pads or mixer wagons. Chopped silage mixes easily with other feeds in a mixed ration.

Table 8.2. Average milk yield of cows in seven comparisons where lucerne silage or hay made from the same crop was offered in a total mixed ration diet with 42% concentrates (T. Cowan per. comm.).

<table>
<thead>
<tr>
<th>Conserved fodder</th>
<th>Milk yield (L/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silage</td>
<td>32.0</td>
</tr>
<tr>
<td>Hay</td>
<td>30.2</td>
</tr>
</tbody>
</table>

Taken together these advantages mean the annual feed program can be scheduled so that large amounts of high quality conserved forage are made at relevant times of the year and then be available for feed out throughout the year.

Quality of silage

The quality of silage is primarily related to the plant species being ensiled and the stage of growth at ensilage, and the processes of ensilage.

Though most silage is made from a small number of plants, especially maize, sorghum, lucerne and barley, there is a variety of plants that are at times made into silage in northern Australia and they vary markedly in nutrient content (Table 8.3). Broadly there are high starch silages, usually maize, high digestibility silages, usually temperate grasses, legumes and crops, and high protein silages, usually legumes. Associated with these differences in quality are large differences in yield, and the combination of these factors, yield and nutritional content, needs to be considered when planning a fodder conservation program.

Table 8.3. Pastures and crops used for silage production in northern Australia showing variation in yield and nutrient content (T. Cowan per. comm.).

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Yield (t DM/ha)</th>
<th>ME (MJ/kg DM)</th>
<th>CP (%DM)</th>
<th>Usual reason for ensilage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>20 (1 cut)</td>
<td>11</td>
<td>6</td>
<td>High yield and high starch content</td>
</tr>
<tr>
<td>Lucerne</td>
<td>18 (6 cuts)</td>
<td>10</td>
<td>20</td>
<td>High palatability and protein content</td>
</tr>
<tr>
<td>Sorghums</td>
<td>12 (3 cuts)</td>
<td>9</td>
<td>12</td>
<td>High dry matter yield without irrigation</td>
</tr>
<tr>
<td>Barley</td>
<td>6 (1 cut)</td>
<td>11.5</td>
<td>18</td>
<td>High digestibility</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>3 (1 cut)</td>
<td>12</td>
<td>24</td>
<td>High digestibility and protein content</td>
</tr>
<tr>
<td>Cowpea and lablab</td>
<td>4 (1 cut)</td>
<td>9</td>
<td>16</td>
<td>Opportunity ensilage</td>
</tr>
<tr>
<td>Tropical grass</td>
<td>4 (1 cut)</td>
<td>8</td>
<td>12</td>
<td>Opportunity ensilage, bulk forage</td>
</tr>
</tbody>
</table>

All these plants change in quality with age, and the plant stage of growth at harvest has a major effect on quality. Invariably the forage digestibility and crude protein contents decline, though the rate of decline differs between species. Starch or sugar content of crops such as maize and barley increase with age, and for maize the optimum stage of growth for harvest is determined from the starch content rather than the leaf digestibility. For each plant species there is an optimum stage for harvest, based on
likely yield, and one or more of digestibility, protein and starch content (Figure 8.2).

<table>
<thead>
<tr>
<th>ME</th>
<th>CP</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-bud</td>
<td>Budding</td>
<td>10% Flower</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>21</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>27</td>
</tr>
</tbody>
</table>

Figure 8.3. The effect of stage of growth on yield, metabolisable energy (ME) and crude protein content of lucerne (Top Fodder Figure 4.5).

There is potential to lose yield and quality during the ensilage process, through poor harvest and removal from the field, and inappropriate compaction of silage or feeding out. Each crop or pasture has specific risks, for example very wet pasture like ryegrass may lose dry matter and quality during wilting in the field, whereas with chopped crop there can be losses when blowing into trucks.

The variation in quality within a forage species can be just as substantial as between species as clearly demonstrated by the on-farm survey in Queensland which tested the quality of silage fed to milkers (Figure 8.3).
Figure 8.4. The dry matter content, neutral detergent fibre and starch content of collected on dairy farms across Queensland in 2011 and 2012. Shaded area indicates ideal level for silage production (C4Milk project).

The most serious losses usually occur due to poor fermentation of silage in the storage place, due to either inadequate compaction which can be compounded if the silage is too wet or too dry or if the chop length is incorrect and therefore excess air in the silage or low sugar levels limiting acid formation. Failed silages will contain butyric acid and moulds and will be unpalatable to cows. Palatable silages are described as lactic or acetic acid silage (Table 8.5). Silage which has adequate sugar content and is compacted well usually produces lactic acid, is well preserved, maintains quality and is very palatable. Silage which have low sugar content and are more difficult to compact, such as tropical grasses, have a slower fermentation and acetic acid is produced rather than lactic acid. The silage is well preserved and eaten by cows, but has lost some quality due to
the slower fermentation process and is often a lower quality material than those which make lactic acid silage.

Table 8.4 The pH, lactic and acetic acid contents of silages which have undergone successful and poor fermentation (TopFodder Tables 2.3 and 2.4). All silages are readily eaten by cows.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Lucerne</th>
<th>Temperate pasture</th>
<th>Kikuyu*</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successful</td>
<td>4.8</td>
<td>4.5</td>
<td>-</td>
<td>4.9</td>
</tr>
<tr>
<td>Poor</td>
<td>7.0</td>
<td>4.7</td>
<td>5.2</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>Lactic acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successful</td>
<td>7.5</td>
<td>8.0</td>
<td>-</td>
<td>4.9</td>
</tr>
<tr>
<td>Poor</td>
<td>1.3</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td><strong>Acetic acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successful</td>
<td>2.5</td>
<td>2.0</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Poor</td>
<td>11.4</td>
<td>4.8</td>
<td>4.2</td>
<td>0</td>
</tr>
</tbody>
</table>

* Tropical grasses rarely make lactic acid silage.

Estimating needs

Silage making is much more than a process to be used when there is a surplus of forage. It is a planned and substantial part of the annual business operation. The starting point for the plan is calculating the annual forage requirements for the cows and other stock. The adequacy of grazed pasture to meet these needs is assessed, and length and extent of periods of deficiency identified. These deficiencies are expressed as tonnes of dry matter which will need to be provided from silage.

The choice of forage for ensilage will depend on a number of factors, related to the farm capacity and nutritional needs of cows (Table 8.6). The farm capacity includes arable land area, available water, soil type, and storage area, these will set the limits for potential crops that can be grown and their yields. The amount of stored silage and nutritional requirements of the cows will influence the choice of forage to be ensiled. If there is minimal stored silage (<2 months), forages high in yield tend to be chosen instead of those high in quality.

Silage will be used to complement other forages and purchased feeds in a balanced ration, forages that boost total intake by providing either starch, protein or digestible dry matter will take preference when there is sufficient stored feed.
**Table 8.5.** A decision process for assessing the sources of silage in an annual feeding system.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surplus pasture or grazed crop</td>
<td>A priority for ensiling as it is already grown</td>
</tr>
<tr>
<td>Ability to crop</td>
<td>Suitable land area and machinery.</td>
</tr>
<tr>
<td></td>
<td>Availability of irrigation</td>
</tr>
<tr>
<td></td>
<td>Yes – maize, barley, lucerne</td>
</tr>
<tr>
<td></td>
<td>No – sorghums, lablab</td>
</tr>
<tr>
<td>Yield required</td>
<td>Tonnage required from cropping area</td>
</tr>
<tr>
<td></td>
<td>High – maize, sorghums</td>
</tr>
<tr>
<td></td>
<td>Modest – choice of crops</td>
</tr>
<tr>
<td>Complementing grazed forage</td>
<td>Nutrients required at time of feed out</td>
</tr>
<tr>
<td></td>
<td>Complementing high protein pastures – maize</td>
</tr>
<tr>
<td></td>
<td>Boosting forage intake – maize, sorghums, barley</td>
</tr>
<tr>
<td></td>
<td>Complementing low protein intake – lucerne, lablab</td>
</tr>
<tr>
<td></td>
<td>Total ration – maize and lucerne, barley</td>
</tr>
</tbody>
</table>

**Efficient systems of storing and feeding**

There are various methods of storing silage, including above ground buns and bunkers, in ground pits, stretchable bags, wrapped bales and tower silos. In practice wrapped bales and aboveground bunkers or buns have proved most suited to northern situations.

![Wrapped bales](image)

Wrapped bales are an expensive, short term method of storage, but have great versatility for harvesting small quantities of silage at opportune times and for feeding out small quantities over an extended period. They are ideally suited for use in ensiling excess temperate pasture or lucerne, and feeding this back later in the same year.

Above ground bunkers or buns are practical as they are low cost, can store large quantities of material and are suited to medium term storage of 1 to 2 years. They are also well suited to modern feed out facilities where silage is handled in tractor buckets. Bunkers hold 600 to 700 kg wet silage/M³, and can be built to size depending on the anticipated tonnage of silage to be used. Dimensions are set at least 1.8 times tractor width to allow for rolling and feeding out, and such that at least 0.2 m is removed daily from the face during the feeding phase. Location of bunkers is impacted by the following.

- Suited to feeding out, with access for tractors and close proximity to mixer wagons or feed troughs.
- Clear of power lines, telephones and other infrastructure with potential for accidents or damage.
- Above the water table and water drainage sites. The water movement can be diverted above the bunker to ensure silage is not contaminated.
As far away from neighbours as is practicable to avoid potential for odours to drift across properties.

Feeding of wrapped bale silage is normally done in round bale feeders located in the paddock or by unrolling the bale on a short pasture area, often near a fence line to avoid excessive treading. Bales can also be unwrapped and added to mixer wagons, though this is time consuming.

Silage is normally taken from bunkers using buckets and placed into side delivery carts or mixer wagons, for later delivery to feed out areas. This method does damage the silage face, resulting in up to 10% loss due to aerobic spoilage, but is much less expensive than more sophisticated cutting devices.

Feed out is often on a concrete floor, with cows reaching over a nib wall, and below a shoulder rail, to access feed. Feed troughs of various types are also used but are more difficult to clean out. Using concrete floors and troughs result in low wastage of 2 to 4%, compared with up to 28% for feeding on a pasture area (Dairy Australia 2009).

**Overview**
Silage use in northern Australia is moving towards the use of crops, bunkers and feed pads, as farmers plan the annual feed and milk production schedule and increase total production. The quality of silage is dominated by choice of plant and age at harvest, and overall efficiency of use in related to complementary nature of the silage with grazed forage, and suitable silage storage and feed out facilities.
Chapter 9. Cow nutrition

The efficiency of converting feed into milk has a major bearing on farm profitability, and cow nutrition is the science of optimising this efficiency.

**Feed conversion efficiency**

Feed conversion efficiency (FCE) is the ratio of milk output (M, L) to total feed intake (DMI, kg). FCE and total milk output are the key measures of productivity on a farm. The ratio is increased if either milk output is increased or less feed is needed per litre of milk. In practice these are closely related and on average the FCE increases with level of milk production per cow (Table 9.1). It is also an indicator of potential profit from a farm, provided increased feed inputs can be supplied at a cost below the marginal return from milk sales.

**Table 9.1.** A The association of level of milk production with feed conversion efficiency (FCE) in dairy cows (reference).

<table>
<thead>
<tr>
<th>Milk yield (L/cow/day)</th>
<th>FCE (L/kg DMI)</th>
<th>Maintenance needs (% DMI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.0</td>
<td>44</td>
</tr>
<tr>
<td>20</td>
<td>1.1</td>
<td>38</td>
</tr>
<tr>
<td>25</td>
<td>1.3</td>
<td>32</td>
</tr>
<tr>
<td>30</td>
<td>1.4</td>
<td>26</td>
</tr>
</tbody>
</table>

Cow nutrition aims to optimise the FCE by combining feeds produced in the feeding system in such a way that DMI is maximised and the balance of nutrients in the feed is suited to the cow’s needs for production and physiological changes.

**Cow nutrition**

The nutrients needed by cows are broadly classified as energy, protein, fibre, minerals and water. The quantity of each is determined by the level of milk production and other physiological functions such as maintenance, weight gain and pregnancy. The effects of good or poor nutrition on FCE are dominated by the level of milk production, but there are also significant indirect effects through changes in these physiological functions. For example if pregnancy rates are lifted by improved nutrition a greater proportion of the herd may be milking at any time, so increasing the proportion of feed going to productive animals and increasing FCE.

Much of cattle nutrition is about maximising rumen function, as many feeds are converted to useable nutrients in the rumen (Figure 9.1). The anaerobic fermentation greatly modifies the nature of feeds. Almost all the energy and a large part of the protein absorbed from forages are the products of rumen fermentation, namely volatile fatty acids and microbial cells. Similarly a large part of the nutrients in grains and other supplements are absorbed in these forms. The influence of nutrition on rumen function, including rate of fermentation and rate of turnover in the rumen, is critical to milk production.
Figure 9.1. Diagram of the rumen and associated gut sections of a dairy cow, showing some of the major sites of volatile fatty acids (VFA’s) and other nutrient absorption.

Modifications to feeds in the rumen mean the digestion in the cow is described in a multi-stage process. Gross energy (GE) intake is mostly fermented in the rumen to volatile fatty acids and microbial cells, which are absorbed through the rumen and intestines respectively, and methane which is eructated. The energy absorbed is referred to as metabolisable energy (ME; Figure 9.2a), which is then used to maintain the animal and produce milk and meat (net energy, NE). The greatest variation between feeds is in the breakdown of GE to ME, related to the amount of non-fermentable fibre in the feed.

Similarly protein in feed is modified in the rumen and absorbed largely from digestion of microbial cells in the intestine (Figure 9.2b). As rumen microbes can use either protein or non-protein nitrogen, such as urea, in fermentation, the protein intake of cows is measured as crude protein (CP), calculated as nitrogen in feed multiplied by 6.25. Optimum efficiency of this conversion from CP intake to protein in production is in the order of 30%.
(a) Energy

Nutritional needs
The nutritional needs of cows can be conveniently described on the basis of current production. The needs for maintenance, milk production, weight gain, pregnancy and activity can be summed for each of the major nutrients, energy and protein. The total will alter during the year with the average stage of the lactation cycle of the herd, but is more stable over a full year (Figure 9.3). A mix of feedstuffs can then be prepared to supply these amounts and any minerals or other additives required. The process is more precise for cows fed a TMR than for grazing cows, as assessing the intake of pasture has to be approximate.
Figure 9.3. The annual cycle in milk production, live weight and dry matter intake of the dairy cow (Dairy Predict).

Current production is invariably well below the genetic potential of the cows, and it is usual to offer 5% additional food to encourage a gradual increase in intake and to allow for day to day variations in appetite. Again this is simpler calculate and monitor with TMR and PMR than with grazing.

Under grazing the relationships among grazed forage intake, complementary feed intake at the bails or the PMR, and additional intake to encourage an increase in total intake are complex. Short term changes in providing additional complementary feed or pasture area are a reduction in efficiency of pasture removal, but feeding systems have shown a strong capacity to compensate for short term changes in the longer term.

Calculations of FCE on grazing and PMR farms show a very similar relationship between milk production and FCE to that in TMR situations, suggesting measures to increase total feed intake are equally important in the grazing situation as in hand feeding systems (Figure 9.4).
Over many years a great deal of effort was put into measuring marginal responses to an additional input of feed, often grain based concentrate. However experience with both TMR or PMR feeding systems and with long term grain feeding experiments has shown that despite a wide variation in short term responses, the longer term measures of efficiency are very similar. Thus long term feeding of grain returns 1 to 1.5 L milk/kg grain, depending on level of milk production, values in the same range as FCE for TMR herds. The emphasis is therefore on the longer term, usually annual, input and output relationships rather than the week to week variations in apparent efficiency.

Though wastage is to be avoided, there is confidence that any additional feed intake by cows will be reflected in annual milk output.

In northern Australia virtually all herds have the genetic capacity to produce more milk, and where herds have been fed at higher levels milk production responds. Consequently the optimum level of nutrition is an economic function rather than biological. To encourage high intakes of feed the ration must improve in nutritional value and usually forages of higher nutritional value are more expensive to grow and harvest. Whether the additional expense is warranted depends on the individual farm circumstances. Given the consistency of FCE in the longer term, this measure can be used to estimate the marginal cost of additional feed. If the FCE is 1.2 and the objective is to maintain feed cost at 60% of milk return, then the marginal cost of feed will be 72% (1.2 x 60) of milk price.

**Nutrition and milk composition**

Milk protein and fat content are altered by nutrition. Adequate levels of milk protein depend on a high dry matter intake and relatively high starch content in the diet (>20% DM), both of which increase the volatile fatty acids absorbed from the rumen. It can be depressed if these are not present, or by a high fat content in the diet. Milk fat is enhanced by adequate levels of fermentable fibre in the diet and adequate body condition (Figure 9.5).
**Figure 9.5.** The effect of body condition score at calving and level of feed intake on milk fat concentration during lactation (Holmes et al. 1987 – p157).

**Heat stress**
Heat stress has a direct effect on the cow by reducing dry matter intake, though this can be alleviated to some extent by increasing the energy density of the diet and increasing potassium content of the diet. However the focus is more on management changes, such as shade provision, which prevent heat stress in the cow. Offering pasture straight after the morning milking and then move the herd to shade as the temperature increases.

**Animal health**
When feeding cows diligence in assessing feeds for potentially negative effects on cow health is important. Metabolic diseases which are common in grazing systems such as bloat and nitrate poisoning should be considered in feed planning. Other likely problems are linked to the high input of purchased feed, such as acidosis and laminitis, and feed contamination from mould or the remains of wildlife. In grazing systems there are some plants species which taint milk, such as forage rapes, but this can be avoided by limiting intake to less than one third of daily requirements, and finish grazing rapes at least 4 hours before milking.

**Overview**
There are many aspects to the nutrition of dairy cows in addition to the basic knowledge of nutrient needs. The desire to continually increase production means the diet needs to be modified to encourage higher dry matter intake, and this needs to be integrated with decisions as to the capacity of the farm to grow feed and the supply of purchased feed and economics. There are nutritional effects on milk composition and responses to heat stress, and anti-nutritional factors in some feeds, and contaminants. The regular reformulation of diets to include grazed and conserved forages with various purchased feeds requires a balanced understanding of pasture management, knowledge of forage quality, ration formulation and nutrition.
Section 2
Technical strategies to manage a subtropical feedbase
Chapter 10. Forage Species Agronomy

Tropical grasses

In the tropical and subtropical zones tropical grasses can be a highly productive, permanent, pest and disease free pasture base, providing medium quality forage for 6 to 12 months of the year.

Varieties

Many varieties have been released and planted on dairy farms. With time a modest number of these are commonly grown on farm, often self selected from mixtures planted. Commonly used grasses can be reasonably described by the regions as below;

- Tropical upland – kikuyu, setaria, panicums (guinea and green panic), brachiaria, star grass, paspalum.
- Subtropical upland – kikuyu.
- Subtropical coastal – kikuyu, paspalum, setaria, Rhodes grass, green and Gatton panic.
- Subtropical hinterland – Rhodes grass, green and Gatton panic, paspalum. Kikuyu on deep, volcanic soils.

Most imported tropical grasses are from Africa. Main factors affecting grass choice are soil type and quality, temperature range (latitude), rainfall and soil fertility. Kikuyu requires deep fertile soils and a relatively cooler climate. Panicums prefer a light soil texture and paspalum a heavy clay base. Rhodes grass is suited to many soil types and performs best in drier areas (<1000 mm). Setaria is suited to high rainfall zones (>1000 mm).

All tropical grasses require a nitrogen source to remain vigorous, usually nitrogen fertiliser but in some cases a legume when the grass does not shade it out. Within species there are many variations among cultivars, often based on height or flowering habit.

Shorter cultivars of setarias and panicums are easier to manage for high leaf and low fibre than the original tall cultivars. Delayed flowering until the summer or autumn provides a longer growing season for Rhodes grass.

Establishment

Establishment is related to soil moisture conditions in the 6 weeks after planting, and success is often highest in early spring or autumn under dryland conditions. Summer heat waves will kill seedlings. Autumn plantings are often with a mix of grass seed and a cover crop of oats to suppress weeds and provide early forage.

There are substantial variations in the pure live seed (PLS) content of tropical grass seed and this needs to be accounted for in planting. Recommended seeding rates vary from 1 kg/ha for PLS of 30% to 5 kg/ha for PLS of 10% and usually average about 3 kg/ha. Seed pelleting with lime has become more common to increase germination and ease spread of seed when broadcast at planting, but markedly reduces the number of seeds per unit weight, often by about half.
Planting success requires a fully cultivated, fine seedbed. Seed is often surface spread, very lightly harrowed (e.g. light chain) and rolled with a heavy roller. Rolling is critical to success by pushing the seed into contact with soil. Graze lightly after establishment and allow to seed during the first year.

**Water use**
Tropical grasses respond to irrigation by increasing growth rate throughout the growing season. Total production is very high at up to 20 t DM/ha/year and efficiency medium at 16 kg DM/mm total water.

**Soil fertility**
At planting N is beneficial in boosting early growth on seedlings at approximately 50 N/ha. All grasses require nitrogen source for sward strength and production, at 50-100 kg N/ha/year for sward cover and vigour, and to 300 kg N/ha/year for maximum production (Cowan *et al.* 1995). Nitrogen applied in 3 applications each year, more frequent has not increased production. If urea is used it is preferable to spread into dry grass stubble of 20 cm or more in the week before rainfall. In coastal environments 100 kg N/ha/year maintained sward strength whilst optimum milk production occurred when 200 to 300 kg N/ha/year was applied (Teitzel *et al.* 1991).

Tropical's respond to P and K if soil availability levels are limited. Always test your soil to determine the nutrient status and identify potential limitations or excess that will restrict establishment and growth. Continued use of P and K dependent on soil tests:
- Soil P less than 25 ppm, apply 20 kg P/ha/year
- Soil K less than 0.8 mequiv%, apply 50 kg K/ha/year.

Lime may be needed after some years on certain soil types such as red kraznozems, if soil pH falls below 5.5. Add gypsum when Ca:Mg ratio is less than 1.

**Diseases and pests**
Very rarely a problem. Armyworm attack can be serious during autumn and winter in wetter years, particularly in well fertilised pastures. There are a range of insecticides that can be sprayed, as the armyworm feeds at night, spraying in the later afternoon may be more beneficial.

**Growth and grazing**
Leaf yield is the primary determinant of animal production, stem yield has little effect except at very high levels where it impedes animal access to leaf. Leaf yield is determined by growth rate, N fertiliser and stocking rate. Optimum average stocking rate measured as 4 to 6 cows/ha irrigated and 1.5 to 3 cows/ha dryland (Davison *et al.* 1985), and in practice changes from well above these values in mid summer to approximately half these values in late autumn and early spring.

Leaf quality varies with growth rate and age of regrowth, but is generally medium quality forage. CP varies from 10 to 20 % DM and NDF from 55 to 70% DM (Forage Plus project). Milk response ranges from 6 to 18 L/kg N.

With grass mixture animals will selectively graze the more palatable species. With adequate leaf yield grasses are very robust under a wide range of grazing systems, from small paddock to open grazing, and from short to long rotations. In far north Queensland, the farms practice a simple grazing rotation with the aim of easy management and allowing cows to select the maximum amount of leaf. The farms tend to have around 20 permanent paddocks of tropical grass, cows are offered a new paddock each day - and in some cases after each milking. The rotation is not fixed; cows enter the paddock that is assessed visually to be most ready for grazing. With this system, cows are always offered the best opportunity to select leaf. The number of paddocks grazed
during the high-growth summer season is reduced to increase grazing pressure, and to maintain leafy pastures ahead of the herd.

Milk production from tropical grasses is 10 to 14 L/cow/day after concentrates and supplements accounted for. Tropical grasses are generally marginal or deficient in P and Na for cows, containing in the order of 0.25 and 0.1 % DM respectively. Some species, such as Rhodes grass, can be adequate in salt if grown in saline soils. Calcium is also needed as in most grasses it is locked up with oxalate particularly setaria (Table 10.1), and in kikuyu is naturally low (Fulkerson 2012). High nitrogen application reduces plant P concentration. CP values range from 10 to 20 %DM and are related to N application.

Table 10.1. Differences in soluble oxalate levels and nutrient concentration of kikuyu, setaria and Rhodes grass grown in northern New South Wales.

<table>
<thead>
<tr>
<th>Minerals/Oxalate (% DM)</th>
<th>Kikuyu</th>
<th>Setaria</th>
<th>Rhodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>0.25</td>
<td>0.27</td>
<td>0.43</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.93</td>
<td>3.20</td>
<td>1.47</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.03</td>
<td>0.74</td>
<td>0.55</td>
</tr>
<tr>
<td>Soluble oxalates</td>
<td>1.25</td>
<td>5.39</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Weeds
A well fertilised and stocked tropical grass has few weed problems. An optimum stocking rate leaves a 20 cm stubble at the end of winter. Weed control by slashing or spraying may be needed during establishment.

Animal health
Health problems are rare with tropical grasses. Nitrate poisoning is possible at very high rates of nitrogen application. Oxalate poisoning sometimes occurs with a flush of setaria growth, as oxalate precipitates the calcium from the cows blood.

A condition described a kikuyu bloat has caused cow deaths on some farms and is largely prevented with salt supplementation. Kikuyu is very low in sodium (salt).

Silage and hay
Tropical grasses are readily made into an acetic acid type silage. Often a sugar supplement, such as molasses, is added at 30 kg/t at ensiling. Wilting to 35-40% DM essential to concentrate sugars. Silages are palatable. However low quality often means animal production response is small, and the economics are often negative.

Highest quality is made before stem elongation and emergence of seed heads, at about 4 weeks regrowth. ME value falls from 9 MJ/kg DM at early vegetative to 6 MJ at flowering.
**Agronomic characteristics of individual forage species**

An agronomic description and recommended management practices for each forage species commonly grown in the sub-tropics for dairy production follows.

The types of forages grown are large and varied. To enable the quick assessment and comparison among species in terms of dry matter production, quality and degree of difficulty to manage, the key agronomic characteristics for each species have been scored out of a possible 5 stars. Species with the most stars are regarded as potentially being able to produce high amounts of quality feed, although the level of difficulty to achieve this is high.

The key mineral content and nutrient quality parameters for each species were sourced from FeedPlus. The average, minimum and maximum values should be considered in terms of the potential variability in quality within a species caused by differences in stage of growth, the environment, soil type, soil nutrient and water status at time of sampling. It is recommended that this data be used to make general comparison within and between different forage species. For some species there were insufficient sample numbers stored in the FeedPlus database hence no data was included.

The very high variability in quality parameters within a forage species warrants analysing each feed when formulating the diet.

**Forage species**

<table>
<thead>
<tr>
<th>Tropical grasses</th>
<th>Kikuyu grass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Native grasses</td>
</tr>
<tr>
<td><strong>Tropical crops</strong></td>
<td>Maize</td>
</tr>
<tr>
<td></td>
<td>Sorghum</td>
</tr>
<tr>
<td></td>
<td>Millet</td>
</tr>
<tr>
<td><strong>Warm season legumes</strong></td>
<td>Lablab, cowpeas and soybeans</td>
</tr>
<tr>
<td></td>
<td>Summer pasture legumes</td>
</tr>
<tr>
<td></td>
<td>Lucerne</td>
</tr>
<tr>
<td><strong>Temperate pastures</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Types of annual irrigated pastures</strong></td>
<td>High density ryegrass</td>
</tr>
<tr>
<td></td>
<td>Ryegrass and clover/herb mixtures</td>
</tr>
<tr>
<td></td>
<td>Clover dominant pastures</td>
</tr>
<tr>
<td></td>
<td>Annual, irrigated high density ryegrass pastures</td>
</tr>
<tr>
<td></td>
<td>Ryegrass and clover/herb mixtures</td>
</tr>
<tr>
<td></td>
<td>Clover dominant pastures</td>
</tr>
<tr>
<td></td>
<td>Prairie grass</td>
</tr>
<tr>
<td></td>
<td>Medics</td>
</tr>
<tr>
<td></td>
<td>Perennial irrigated pastures</td>
</tr>
<tr>
<td><strong>Temperate crops</strong></td>
<td>Oats</td>
</tr>
<tr>
<td></td>
<td>Barley</td>
</tr>
</tbody>
</table>
Kikuyu grass (*Pennisetum clandestinum*)

<table>
<thead>
<tr>
<th>Management skills</th>
<th>★★★☆☆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★☆☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★☆☆</td>
</tr>
</tbody>
</table>

Where ★★★★★ is the highest rating.

**Origin**
Central Africa Adapted to east and south-west coasts of Australia.

**Establishment**
Seed, stolons or sods. Stolons more reliable but time-consuming. Sow in March or October when soil temperature >15°C. Whittet seeding cultivars are preferable to Noonan, plant at 2 - 5 kg seed/ha. Drill at a depth of 10 mm or broadcast then roll. Establish with a temperate species for autumn sowing to allow winter production e.g. 20 kg/ha ryegrass (short-rotation) or oats.

**Nutrient requirements**
Grazing at 10 - 18 day intervals apply N every second grazing, when every 19- 30 days apply after each grazing.

**Table 10.2.** Typical mineral content of kikuyu- based pasture and requirements to produce 10 t DM/ha utilised.

<table>
<thead>
<tr>
<th>Nutrient requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>3.4</td>
<td>0.4</td>
<td>3.2</td>
</tr>
<tr>
<td>kg applied (kg/ha)</td>
<td>340</td>
<td>41</td>
<td>320</td>
</tr>
</tbody>
</table>

**Growth rates**
Daily growth rates can average 80 kg DM/ha during the October to March Expected yield: Low: - 5 - 7 t DM/ha; medium: - 8 - 12 t DM/ha; high: >13 t DM/ha.

**Nutrient quality**

**Table 10.2.** Range in quality of kikuyu-based pasture (source FeedPlus database).

<table>
<thead>
<tr>
<th>Quality (%)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>22.7</td>
<td>16.1</td>
<td>32.1</td>
</tr>
<tr>
<td>Starch</td>
<td>2.2</td>
<td>1.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Sugar</td>
<td>8.9</td>
<td>3.5</td>
<td>10.9</td>
</tr>
<tr>
<td>NDF</td>
<td>50.5</td>
<td>35.7</td>
<td>57.6</td>
</tr>
<tr>
<td>Fat</td>
<td>3.5</td>
<td>2.5</td>
<td>5.6</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10.2</td>
<td>9.2</td>
<td>12.0</td>
</tr>
<tr>
<td>DM (%)</td>
<td>25.5</td>
<td>17.2</td>
<td>35.5</td>
</tr>
</tbody>
</table>

**Milk production**
Without supplements Holstein Friesian cows in mid-lactation (no reliance on body reserves, all milk from feed) grazing well managed kikuyu pastures will produce 12 - 14 L of milk/cow/day.

**Grazing management**
Grazed at 4.5 leaf stage to maximise forage quality (maximum leaf) and intake and maximise Ca, and Mg and minimise K levels. Recommended to mulch stem periodically or graze intensively with dry-stock to decrease build-up of low digestible stolons.

**Supplements**
Kikuyu is low in Ca, P Na and energy, therefore supplement with grain, molasses and minerals.

**Metabolic diseases**
Excess K and nitrate. Kikuyu poisoning highest in rapidly growing, young leaf (>25% CP) when nitrate and K are very high and very much in excess of cow requirements.
**Plant diseases and pests**

Kikuyu yellows is a fungal disease specific to kikuyu. These plants are also susceptible to black spot, armyworm, African black beetle. Fungus in roots, circular pattern and leaves.

**Silage**

Remove excess pasture to aid pasture management. Cut at 5.5 leaf stage, wilt to 30% DM.

**Over sowing in autumn**

Annual ryegrass is most commonly oversown into kikuyu, to a lesser extent white clover and brassica (forage rape or leafy turnip). Graze hard, mulch and over sow with a minimum of 30 kg ryegrass seed/ha. Plant when minimum air temperature <15°C, generally this occurs in late March NNSW through to late April in Queensland. Low rates of herbicide (0.7 L Roundup®/ha or 1.5 L/ha Sprayseed®) can be applied in autumn to inhibit the growth of kikuyu and increase establishment of ryegrass seedlings. However, continual use can lead to long-term deterioration of the kikuyu and lead to the introduction of volunteer species such as crows foot.

Following the establishment of ryegrass seedlings, frequent light grazing is recommended to prevent the kikuyu shading the seedlings.

**Fact sheet**

Native grasses

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★☆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★☆☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★☆☆</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★☆☆</td>
</tr>
</tbody>
</table>

On extensive properties native grasses provide reasonably nutritious forage for 3 to 4 months of the year. They are often valuable ground cover on hill sides and shelter belts of the farm and maintain biodiversity in landscapes.

Species
There are many native grasses, mostly C₄, but including some C₃ species. The most common and productive are spear grass (*Heteropogon contortus*), Queensland blue grass (*Dicanthium sericeum*), pitted blue grass (*Bothriochloa decipiens*) and Kangaroo grass (*Themeda triandra*).

On dairy farms native grasses occupy poorer quality land types such as stony slopes and ridges or larger, undeveloped areas of the farm. They are often used as wet weather shelter for cows or extensive grazing for young stock. In recent years the preservation of these relatively small areas has become important to landholders and communities.

Establishment
Native grasses occupy undeveloped areas or have reclaimed improved pasture areas as fertility declines. In some environments natives can be successfully over sowed with legumes such as medics and clover.

The tall, tufted native grasses can be easily overgrazed that preferentially suits volunteer grasses that are short and stoliferous as couch (*Cynodon spp.*).

Water use
Very well adapted to low and erratic rainfall, able to reach physiological maturity rapidly and set seed and die off above ground.

Soil fertility
Queensland blue grass considered higher quality than most and it prefers higher quality clay and clay-loam soils. Other grasses more tolerant of soil type, but do not grow on very poor shallow soils.

Growth and grazing
A short growing season, often from spring storms to December. Nutritional value equivalent to improved grasses in the 3 months after storms, then falls markedly to sub-maintenance levels (2 - 6%CP).

References and further information
New South Wales Department of Primary Industries.
Tropical Grassland Society.
Tropical crops
Maize (Zea mays)

| Management level | ★★★★★
| Yield            | ★★★★★
| Quality          | ★★★
| Water use efficiency | ★★★★★
| Reliability      | ★★★
| Versatility      | ★★★

Varieties
Select on grain (starch) to forage ratio and length of growing season which ranges from 90 - 150 days. High yield is essential to achieve a profit.

Establishment
When irrigated 60 000 - 75 000 plants/ha, when grown without irrigation in 600 - 800 mm/annum rainfall aim for 25 000 - 45 000 plants/ha. Precision plant into 65 - 100 cm row spacing. Confirm row spacing with harvest contractor. Plant into seedbed with full soil profile moisture. Minimum tillage or full seed bed preparation can be successful when soil conditions are agreeable to planting. Minimum soil temperature of 12 - 14°C at 9 am for 3 consecutive days at 10 cm. Pre and post-emergent herbicide is critical for weed control.

Irrigation
Ranges from 5 to 8 ML/ha per crop. Up to 70% of water is used in 3 weeks before and after tasselling.

Nutrient requirements and herbicide recommendations
Potassium requirements are often under estimated for a maize crop (Table 10.3). Soil test for level of Zn, often applied at planting as cautionary measure to minimise a reduction in rate of germination and seedling establishment. N and K split applications at 130 kg N before canopy closure or later in the growing season as fertigation. Figure 10.1 depicts level of water, N, P and K use in relations to crop growth. Pre-emergent herbicide is highly recommended to minimise weeds and competition for radiation, water and nutrients.

Table 10.3. Typical mineral content of a maize silage crop and requirements to produce 25 t DM/ha (~75 t wet/ha).

<table>
<thead>
<tr>
<th>Nutrient Requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>1.3</td>
<td>0.23</td>
<td>0.73</td>
</tr>
<tr>
<td>kg applied (/ha)</td>
<td>325</td>
<td>58</td>
<td>183</td>
</tr>
</tbody>
</table>

Minimum tillage to plant maize.
Figure 10.1. Rate of water, nitrogen, phosphorus and potassium use and recommended herbicide application for maize (Serafin et al. 2011 - Summer Crop Production Guide 2011).

**Silage**

Expected yields of 15 - 25 t DM/ha (45 - 75 t wet/ha). Yields less than 20 t DM/ha are likely to incur an economic loss. Harvest when milk line halfway down kernel and crop 30 to 35% DM (Kaiser et al. 2003).

**Nutrient quality**

Table 10.4. Range in quality for maize harvested as silage.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>9</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Starch</td>
<td>30</td>
<td>2.4</td>
<td>39</td>
</tr>
<tr>
<td>Sugar</td>
<td>4</td>
<td>1.2</td>
<td>8.9</td>
</tr>
<tr>
<td>NDF</td>
<td>46</td>
<td>37</td>
<td>55</td>
</tr>
<tr>
<td>Fat</td>
<td>3</td>
<td>1.8</td>
<td>3.8</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10.4</td>
<td>9.2</td>
<td>11.3</td>
</tr>
<tr>
<td>DM</td>
<td>33</td>
<td>21</td>
<td>53</td>
</tr>
</tbody>
</table>
Economics, risks and potential issues

Including establishment, fertiliser and irrigation costs - $2500 – 3000/ha; plus an additional $25 t wet for ensiling which includes: chopping; rolling; and covering.

Considered a high risk crop in terms of high level of inputs and high potential for decreased dry matter production (Figure 10.2), agronomic management needs to be precise. Additional costs associated with feeding out need to be considered.

Figure 10.2. Potential productivity losses caused by mismanagement.

References and further information


Sorghum (*Sorghum vulgare*)

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★☆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★☆</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★★☆</td>
</tr>
</tbody>
</table>

**Varieties**

Variety selection is dependent on end use:
- Silage vs grazing
- Quality vs quantity

There are a complex mix of open pollinated and hybrid varieties based on three parent types.

1. Sudan grass (sudan x sudan) - prolific tillering, rapid regrowth, fine stems, open pollinated, early flowering e.g. Superdan.
2. Sorghum (female) x sudan grass (male) hybrids - high DM production, rapid regrowth, drought tolerant, often late flowering e.g. Jumbo, Betta Graze.
3. Sweet sorghum hybrids – thick stems, high sugar, slower regrowth, maintain palatability and useful standover forage e.g. SugarGraze, Mega Sweet.
4. Sorghums which are bred to express the brown mid-rib gene. This reduces lignin content and so increases ME, without change in CP. Mid rib on leaf and stem may be brown, but not always. May be lower DM yield and more prone to lodging than other forage types e.g. Pacific BMR.
5. Grain x Grain - Red sorghum grown for grain has become more widely used as a silage crop because it is a short plant and is less susceptible to lodging during storm events. White sorghum grain (Liberty) may be better suited to rumen and monogastric digestion because the outer seed does not contain tannin.

**Establishment**

Soil temp is critical; at 10 cm depth (maximum daily temperature) + (2 x minimum daily)/3; plant when 18°C and rising (Table 10.5). Plant at 2 - 5 cm depth into moisture at 15 - 50 cm row spacing. Spacing can be greater than this when moisture is limiting.

Seeding rate when raingrown 1 - 5 kg/ha and under irrigation 10 - 15 kg/ha (seed size varies from 30 000 to 70 000 seeds/kg). Sorghum requires a well prepared seedbed, even and fine. Soil-seed contact is very important for germination (press wheels at 4 - 6 kg/cm). Zero till less effective, but possible on an even paddock without weeds or compaction. Pre and post-emergent herbicide is critical and treat seed with an insecticide. Sorghums are suited to heavy soils and have medium salt tolerance. Sweet, late flowering types mix well with lablab, providing autumn grazing.
Table 10.5. The effect of temperature on germination and emergence of sorghum.

<table>
<thead>
<tr>
<th>Soil temperature at planting (°C)</th>
<th>Effect on seed</th>
<th>Effect on emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Slow germination, pests and disease</td>
<td>Poor &lt;50% E.g. Fusarium, pithium</td>
</tr>
<tr>
<td>15</td>
<td>Satisfactory</td>
<td>Slow, &gt;50%, disease</td>
</tr>
<tr>
<td>16</td>
<td>Good</td>
<td>Adequate</td>
</tr>
<tr>
<td>18</td>
<td>Good</td>
<td>Good, quick</td>
</tr>
<tr>
<td>20</td>
<td>Ideal</td>
<td>Ideal</td>
</tr>
</tbody>
</table>

Water use

Dormancy during drought, with rapid recovery after rain. Tolerant of high ambient temperatures.

Water requirements (ML/ha) for sorghum have been calculated based on the sum of evapotranspiration rates less rainfall from November to March 1970 to 2007 (ICalc).

<table>
<thead>
<tr>
<th>Location</th>
<th>ML/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allora</td>
<td>2.2</td>
</tr>
<tr>
<td>Beaudesert</td>
<td>1.9</td>
</tr>
<tr>
<td>Gatton</td>
<td>2.3</td>
</tr>
<tr>
<td>Monto</td>
<td>2.5</td>
</tr>
<tr>
<td>Oakey</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Nutrient requirements

When grazed, typically 50 kg N/ha at planting and 50 kg N after first grazing.

Diseases

Relatively free of diseases. Wireworms and cutworms may be a problem at germination, this can be prevented by purchasing seed coated with an insecticide. Sorghum ergot sometimes develops in flowering heads, and can be toxic.

Growth and grazing

Graze to keep stem elongation and flowering to a minimum, this is often difficult to achieve because growth rates are very high following prolonged rainfall or irrigation. Ideal height at grazing is 1 m, with 0.25 m residual. Expected yield for raingrown sorghum is 10 - 12 t DM/ha from 2 to 3 grazings. Well irrigated and fertilised sorghum can yield 15 - 20 t DM/ha in 4 grazings.

Nutrient quality

Medium nutritional value and declines rapidly at heights above 1 m. Leaf content 60% DM at 1 m, 38% at 2 m. At 1 m in height expected quality will be:

- 8 - 9.5 MJME/kg DM
- 9 - 18% CP

Sweet sorghum – sugar content of stems 10% at 1 m, 20% at 2 m, maintains ME content about 9 MJ/kg DM.

The quality parameters of sorghum harvested as silage or grazed is highly variable (Table 10.6).
Table 10.6. Range in quality for sorghum harvested as silage or grazed.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silage</td>
<td>Graze</td>
<td>Silage</td>
<td>Graze</td>
<td>Silage</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>10.7</td>
<td>16.4</td>
<td>4.8</td>
<td>8.3</td>
<td>19.7</td>
</tr>
<tr>
<td>Starch</td>
<td>7.3</td>
<td>3.3</td>
<td>0.2</td>
<td>0.1</td>
<td>32.3</td>
</tr>
<tr>
<td>Sugar</td>
<td>9</td>
<td>13.3</td>
<td>0.3</td>
<td>0.9</td>
<td>19.6</td>
</tr>
<tr>
<td>NDF</td>
<td>57.7</td>
<td>55.4</td>
<td>38.9</td>
<td>34.3</td>
<td>70</td>
</tr>
<tr>
<td>Fat</td>
<td>2.8</td>
<td>3</td>
<td>1.7</td>
<td>1.9</td>
<td>4.7</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>9</td>
<td>9.7</td>
<td>7.2</td>
<td>7.9</td>
<td>11.4</td>
</tr>
<tr>
<td>DM</td>
<td>49.1</td>
<td>23.2</td>
<td>25.6</td>
<td>12</td>
<td>76.6</td>
</tr>
</tbody>
</table>

Animal health

Prussic acid (HCN) higher in sweet sorghum varieties and when plants are vegetative, stressed or heavily supplied with nitrogen. Ensilage destroys prussic acid, as does hay making to a lesser extent. Feeding sulphur and salt to cattle reduces the effects. If toxicity occurs drench with hypo (sodium thiosulphate).

Nitrite poisoning can occur if plant nitrate levels high (>2000 ppm) due to high soil N or halt to growth e.g. cold, cloudy weather. Ensilage and hay making do not destroy nitrate.

Silage

Are specialist silage varieties with very high yield and high sugar content. Greenchop usually sudan grasses or sorghum-sudan grass hybrids. Fine stem Sudan grass types if wrapped, any variety is suitable if chopped. Direct chop silage: 32 - 35% DM, cut and wilt; higher quality, lower yield. Rapid growing hybrids also useful as green manure crops. Sweet sorghums (Chopper, Mega sweet) 70 to 80 days to cutting at 2 - 2.5m height. Lower yielding grain sorghums are becoming more widely used to minimise crop lodging prior to harvest.

References and further information

Millet

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★</td>
</tr>
</tbody>
</table>

Varieties
There are three distinct types, not crossed, and open pollinated millets:
1. Temperate millets (*Echinochloa* spp.) include Japanese, Shirohie, Siberian.
2. Forage pennisetums (*Pennisetum glaucum*, pearl millet) can be open pollinated (Tamworth, Katherine) or hybrids (Nutrifeed).
3. Setaria (*Setaria italica*) are tall types (Panorama).

Establishment
All small seeded, require even, fine seedbed. Zero till possible if not compacted and clear of trash. Suited to light to heavy soils, but not crusting. Avoid the cultivar Nutrifeed on heavy soils. Temperate millets Japanese and Shirohie establish early (10 cm soil temperature above 14°C) and grow quickly (graze 60 to 70 days). Pennisetum and Siberian require soil temperature above 19°C. Pennisetum has a longer vegetative growth phase. Plant at 8 - 10 kg seed/ha dryland and 12 - 15 kg seed/ha irrigated, 3 cm deep and 18 cm row spacing. Press wheels beneficial, 4 - 8 kg/cm.

Well suited to double cropping or change over crops. Temperate millets tolerant of water logging and moderate salinity. They perform better at lower latitudes in southern NSW. Pennisetum very susceptible to frost, but drought hardy once established.

Soil fertility
Prefer high fertility soils, apply 5 - 10 kg P/ha if needed when P < 25 mg/kg, Colwell test). Recommended to apply 30 - 50 kg N at planting, similar rate after grazing for regrowth.

Diseases
Millet is generally resistant to most diseases. Late plantings of temperate millets may fail due to the stem boring shoot fly or maize sterile stunt virus.

Growth and grazing
Graze at 20 - 30 cm tall (temperates) and 40-60 cm (pennisetum). Expect dry matter yield in the order of 50 - 70% that of forage sorghums, but generally higher in quality. Temperate millets expected yield is 3 - 6 t DM/ha dryland, pennisetums 6 - 12 t DM/ha dryland or 12 - 15 t DM/ha when supplemented with irrigation. At optimum grazing height expect 15 - 17% CP and 9.5 MJ ME/kg DM.

Temperate millets often have just one main grazing whilst pennisetums will regrow multiple times if not grazed below 20 cm stubble.

Nutrient Quality

Table 10.7. Range in quality for millet.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>6.8</td>
</tr>
<tr>
<td>Starch</td>
<td>4.3</td>
</tr>
<tr>
<td>Sugar</td>
<td>-</td>
</tr>
<tr>
<td>NDF</td>
<td>65.6</td>
</tr>
<tr>
<td>Fat</td>
<td>1.5</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>7.8</td>
</tr>
<tr>
<td>DM (%)</td>
<td>91.2</td>
</tr>
</tbody>
</table>

Animal health
Unlike sorghum, millet plants do not accumulate prussic acid. Nitrate poisoning is possible in lush, heavily fertilised crops. Nutrifeed is sometimes unpalatable, maybe linked to dry conditions and high soil fertility.

Silage
Suit as opportunity silage crops, cut at milky dough stage. Sometimes used as specialist hay crops, under irrigation, and cut just before early head emergence.
References and further information


Warm season legumes
Lablab, cowpeas and soybeans

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★★★</td>
</tr>
</tbody>
</table>

Species
Lablab and cowpea are a valuable forage source in autumn on dairy farms as they hold their nutritional value while building up yield over summer. Soybeans are useful for autumn grazing or silage.

Varieties
Lablab; Highworth and Rongai. Cowpeas; Red Caloona, Banjo, Caloona, Poona and N/Meringa. Soybeans; Later flowering types of preferred for forage (Warrigal, Jabiru, Oakey).

Establishment
Full seed bed preparation is recommended to achieve highest germination rate. Plant lablab at 15 - 40 kg/ha, cowpea at 20 - 40 kg/ha, and soybeans at 40 - 60 kg/ha. Minimum soil temperature of 18°C at planting, generally plant between October and end of December. Late planting in January results in smaller plants and in the case of soybeans, early pod development. Generally plant at 70 to 100 cm row spacing for raingrown and 20 - 30 cm row spacing under irrigation at 30 - 50 mm depth into moist soil and press soil. Seed needs to be inoculated with rhizobia at planting, inoculate soybean with group H.

All species are suited to a wide range of soils and can be direct drilled into crop stubble. Lablab can be sown into dry soil if rain is expected, but not cowpea or soybeans. Soybeans seedlings tend to be more susceptible to damage from waterlogging and soil crusting during germination and seedling establishment. Although once seedlings are established, the plants are tolerant of dry or wet conditions.

Water use
Usually dryland crop in regions >600 mm rainfall targeted for autumn grazing, especially lablab. Relatively low water efficiency due to long growing season. Soybeans can be irrigated for silage crop, producing up to 10 t DM/ha.

Soil fertility and nutrient requirements
These legume crops can fix up to 100 kg N/ha/crop, related to dry matter yield, which is available to following crops or pastures. Soil fungi (michorizae, VAM (vesicular-arbuscular mycorrhizas)) are important to P and Zn uptake by roots, and after long fallows these fungi may be depleted and crops require additional P.

Table 10.8. Typical mineral content of warm-season legumes and requirements to produce 5 t DM/ha.

<table>
<thead>
<tr>
<th>Nutrient requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>4</td>
<td>0.4</td>
<td>1.7</td>
</tr>
<tr>
<td>kg applied (ha)</td>
<td>200</td>
<td>20</td>
<td>82.5</td>
</tr>
</tbody>
</table>

Crops may require P, K and S depending on soil test, particularly on coastal soils. Deficiencies of Zn more likely to occur on inland heavy clay soils. General recommendation is 125 kg/ha of each of superphosphate and muriate of potash. P <20 mg/kg, K < 0.3 mequiv%. Zn as foliar spray at 1 - 2 kg ZnSO₄/ha. Molybdenum may be required on light, acidic soils, as along the coast.

Diseases and pests
Only a few cases of bloat have been reported. Lablab and cowpea are susceptible to root rot in wet soil, soybeans are more tolerant. Cowpea; susceptible to phytophthora.
Growth and grazing

Dry matter intake of legumes is generally higher supporting an additional 2 - 4 L milk/cow/day more than tropical grasses and summer forage crops. Lablab and cowpea will regrow after one or two grazings, if cows only remove leaf and do not damage stems severely.

Grazing rule - when leaf cover forms a complete canopy, remove this with a short grazing period. Cowpeas are fastest to grazing, in 10 weeks, with lablab 3 - 4 weeks later. Yields typically 3 - 5 t DM/ha over 1 to 3 grazings. Soybeans graze once approximately 14 weeks after sowing or cut for silage at mid pod fill stage.

Table 10.9. Quality of lablab and soybean.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Lablab</th>
<th>Soybean (Grassy Silage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>17 - 26</td>
<td>16.5</td>
</tr>
<tr>
<td>Starch</td>
<td>7.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Sugar</td>
<td>11</td>
<td>9.7</td>
</tr>
<tr>
<td>NDF</td>
<td>30 - 43</td>
<td>56.1</td>
</tr>
<tr>
<td>Fat</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>11.2</td>
<td>7.5</td>
</tr>
<tr>
<td>DM (%)</td>
<td>18 - 30</td>
<td>74.6</td>
</tr>
</tbody>
</table>

Weeds

Weeds, especially grasses, can be a problem at establishment. This can be prevented by applying a pre emergent herbicide before planting. Whilst soybeans haven not been registered as pre emergent herbicide tolerant, on-farm demonstrations have shown that germination was not impeded when sprayed at label rates. Legumes are very sensitive to damage from 2, 4 D type herbicides.

Silage and hay

Need to be wilted to concentrate water soluble carbohydrate and to achieve desired DM percentage without decreasing quality. Recommended to use a silage inoculant to ensure fermentation. Chopping preferred to baling, to ensure compaction. No regrowth after cutting. Harvesting lablab has reportedly been difficult due to vine entanglement, although not always the case. Soybeans preferred for silage because they have an erect growth habit. Mowing at early pod fill may require wilting depending on DM content which can lead to contamination by soil and increased spoilage in the pit.

Lablab and cowpea have successfully been grown as a mixture with forage sorghum or maize. The legumes twine around the sorghum and maize plants and when harvested, increase the N content of the silage crop.
Summer pasture legumes
A summer growing pasture legume has the potential to combine with a grass in a sustainable and productive pasture, but the achievement of this goal has proved elusive.

<table>
<thead>
<tr>
<th>Management Level</th>
<th>★★★★☆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Versatility</td>
<td>★☆</td>
</tr>
</tbody>
</table>

**Species**
Various species have been introduced or bred.

The twining tropical legumes (TTL); siratro, glycine, desmodium
- The twining tropical legumes differ in their needs for soil type and rainfall, but all grow well with companion grasses in their respective niche if fertilised adequately. Stocking rate must be kept low to maintain productivity as heavy grazing removes growing points and severely weakens the legume component.

Shrubby legumes (SL); Wynn Cassia, joint vetches
- Shrubby legumes are more drought tolerant than twining legumes and less sensitive to high stocking rates, but have lower productivity and variable production from year to year.

Ground running or rhizomatous (GRL); Arachis, Shaw creeping vigna, lotononis
- The ground running or rhizomatous legumes are suited to high stocking rates, but require high rainfall and have modest levels of production.

Tree legumes (TL); Leucaena
- Tree legumes have high productivity once established, but land has low output during the long establishment phase and there are practical difficulties in managing the forage system.

Overall, each group has strengths and weaknesses, but no group has yet proved to be suited to widespread adoption by dairy farmers in the subtropics.

**Establishment**
Two methods of establishment.
- Usually a fully cultivated seedbed is prepared, seed is broadcast, harrowed lightly and rolled. Heavy rolling is essential, except on soils which crust badly. Almost always planted with a companion grass.
- In an established grass pasture strips are sprayed with glyphosate and seed direct drilled into these strips. This is the usual method for leucaena and can be used for other legumes, though establishment is much slower.

There is no ideal planting time as success depends on follow up weather conditions. Spring plantings have a high risk as probability of follow up rainfall is usually low. Despite high rainfall during summer hot conditions can dry and kill seeds within a few days. A compromise is late February and March plantings, when soil moisture is adequate, temperatures are falling and ground is warm enough for germination.

Obtain seed with certified viability and purity, free of weed seed. Seed must be inoculated. Pelleting of seed has advantages in establishment, add an inoculant and top dress with nutrients if necessary. Graze lightly in the first year to enable establishment of the legume. Leucaena may require 2 years for establishment.

**Seeding rates and companion grasses**
Twining: 2 - 3 kg legume seed and 1 - 3 kg grass seed/ha. Wide selection of grasses, based on rainfall and soil type.
**Shrubby**: 1 - 3 kg of legume and grass seed such as green or Gatton panic, Rhodes grass, and digitaria.

**Ground running**: 1 - 3 kg/ha Shaw creeping vigna. Arachis varieties can be planted using pieces of rhizomes and stems, by spreading, discing into a prepared seedbed and rolling. Arachis is typically planted from December to the end of February at 10-20 kg/ha approximately 20 - 30 mm depth into moist soil. Ideally plant with a modified Coventry plate direct drill or air seeder. Low impact machinery to avoid mashing the seed. Inoculation is required. Seed is expensive due to limited availability and is slow to establish taking 2 - 3 years to fully establish. Short, running grasses preferred, e.g. kikuyu, signal grass (*Brachiaria decumbens*), digitaria grass at 1 - 3 kg/ha.

**Trees**: 3 kg/ha leucaena. Wide selection, based on local experience. Use existing grass if strip sowing.

**Water use**
These pastures are almost always dryland and species are sensitive to rainfall zone. With high quality soils legumes can grow in lower rainfall zones. Arachis has persisted as the summer component of an annual, irrigated ryegrass pasture. Once established it is oversown each autumn with ryegrass.

**Twining**: Desmodium and glycine suited to higher rainfall, 1200 – 2000 mm, siratro 800 – 1200 mm/year.

**Shrubby**: 800 - 1200 mm/year.

**Ground running**: 1200 - 3000 mm/year.

**Trees**: 600 - 3000 mm/year.

**Soil fertility**
All the summer legumes prefer high quality soil, though the tolerance of medium quality soil varies.

**Twining**: Glycine requires deep, volcanic soils, while siratro is more tolerant of forest and shallow soils. Desmodium grows in both these soil types, but requires high rainfall.

**Shrubby**: Tolerant of forest and shallow soils.

**Ground running**: Tolerant of soil type provided rainfall is high. Arachis prefers light soils, even sandy.

**Trees**: Requires deep, friable clay soils. Grows on poorer soils but much less productive.

All legumes require high P and K availability at establishment, and recommended to apply 250 kg superphosphate and 125 kg KCl/ha at planting on all soil types. Molybdenum is added to the seed pellet in high rainfall areas.

Maintenance applications of superphosphate are based on soil tests taken every 3 years, with continuing applications where P is less than 30 ppm (Colwell). Molybdenum super can be used each 3 to 5 years in areas of molybdenum deficiency (usually high rainfall zones). Maintenance applications of K are usually not needed. Lime is generally not required.

**Growth and grazing**
Usually legumes are slow to respond in spring, and may be less palatable at this time (siratro, arachis), and make their main contribution to grazing in late summer and autumn. They are ideal standover pasture for late autumn and winter.

The average stocking rate is critical for legume-grass pastures.

**Twining**: A low average stocking rate is essential (1 cow/ha Atherton Tableland, 0.5 cows/ha Brisbane Valley). Efficiency of grass harvest is much less than for pure grass pastures, but diet quality is higher and
forage is available in late autumn and winter.

**Shrubby:** More robust with periodic heavy stocking, average approximately 0.8 cows/ha in the Brisbane Valley. Seed set is important before winter grazing.

**Ground running:** Need to be heavily stocked (2 cows/ha in the Brisbane Valley) to remove shading and encourage spread, especially the arachis varieties. Milking cows may require additional forage areas of other pasture types, such as pure grass, to obtain sufficient bulk.

**Trees:** Normally “crash” grazed after extended spelling periods to remove most leaf and small branches. Leucaena dies from continuous grazing. If machinery is available, often plants are “slashed” at approximately 1.5 m height after grazing.

All tropical legumes are frost sensitive. If likely to be frosted forage needs to be grazed before winter.

Pasture yield and milk yield are directly related to legume yield, as the legume is nutritious forage and provides nitrogen for the grass. Legume and grass mixed pastures supported 2 L milk/cow/day more than grass nitrogen pastures.

**Weeds**
During establishment the preferred method of weed control is slashing or light grazing. Once established a vigorous pasture should be almost free of annual and biennial weeds. Shrubby weeds such as groundsel and lantana are often physically removed or treated by spot spraying.

**Animal health**
There are few animal health problems with tropical legume and grass mixed pastures. Mimosine in leucaena can cause hair loss and poor digestion in cattle. To prevent this cattle are drenched, either naturally from other animals in the herd or by drenching, with bacteria from the rumens of adapted cattle. These cattle have rumen bacteria that can break down mimosine.

**Silage and hay**
There is difficulty in cutting and drying these pastures for hay or silage and it is not usually done. Also they are often grown in paddocks not suited to mechanical harvesting. In some situations arachis is grown as a specialist hay crop.

**References and further information**
Lucerne (*Medicago sativa*)

<table>
<thead>
<tr>
<th>Management level</th>
<th>Yield</th>
<th>Quality</th>
<th>Water use efficiency</th>
<th>Reliability</th>
<th>Versatility</th>
</tr>
</thead>
<tbody>
<tr>
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<td><img src="Image" alt="Rating" /></td>
<td><img src="Image" alt="Rating" /></td>
<td><img src="Image" alt="Rating" /></td>
<td><img src="Image" alt="Rating" /></td>
<td><img src="Image" alt="Rating" /></td>
</tr>
</tbody>
</table>

**Overview**

Highly productive, deep rooted legume which provides high quality forage (king of fodders). Excellent for grazing and conservation as silage and hay. Useful to restore organic matter and N in old cropping soils. Lucerne tolerates moisture stress, the crown remains dormant and produces a new shoot following rainfall or irrigation event.

**Varieties**

Many varieties available, grouped on bases of winter growth and disease resistance. Winter active and semidormant types preferred in Queensland.

- **Semidormant:** Grows significantly slower in winter than summer. Growth can stop for short periods. Autumn and spring growth is quicker than winter dormant varieties. Are generally more leafy and have broader crowns than winter-active varieties. (e.g. cv. SARDI 5).

- **Winter-active:** Maintains growth during winter, growth rates after harvest are quicker than dormant varieties. They have fewer tillers, narrower crowns and larger leaves. (e.g. cv. SARDI 7).

- **Highly-winter active:** Fastest recovery after harvest, the most winter growth. Lowest persistency due to depleted energy reserves. (e.g. cv. SARDI 10).

**Establishment**

Alluvial and sandy clay loams most suited, deep scrub soils. Must be well drained. A fine, firm seedbed essential, weed free and moist. Weeds controlled during previous crops and fallow. Winter preferred planting time, or spring if summer weeds are not a problem. Can be sown during summer in pasture mixes.

Planting rate 8 kg/ha dryland, 15 irrigated and 2 - 4 kg/ha in pasture mixes. Always use Group AL lucerne seed inoculants. Surface sown, lightly covered (12 - 25 mm) and rolled. Often roll before and after spreading seed. Can be drilled to a maximum depth of 50 mm. Can also undersow with winter cereal if reduce cereal rate.

Primary weeds are annual grasses including barnyard, feather top Rhodes and urochloa, and perennials such as Rhodes, couch, paspalum, green panic, Johnson and nut grass. Monitor germination of weeds, use herbicides when necessary and grass plants are young.

**Water use**

Ideally seedlings should remain unstressed until first cutting, apply frequent light applications <25mm. Once established lucerne has a high water requirement equivalent to 0.75 - 1.0 ML/ha/cut, up to 12 ML/year depending on environment (at 8 ML rainfall, irrigation is required to supply the remaining 4 ML). Lucerne is very susceptible to waterlogging because it is very susceptible to root rot.

Water requirements (ML/ha) for lucerne have been calculated based on the sum of evapotranspiration rates less rainfall for 12 months averaged from 1970 to 2007 (iCalc).
<table>
<thead>
<tr>
<th>Location</th>
<th>ML/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaudesert</td>
<td>6.3</td>
</tr>
<tr>
<td>Gatton</td>
<td>7.3</td>
</tr>
<tr>
<td>Gympie</td>
<td>5.0</td>
</tr>
<tr>
<td>Monto</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**Soil fertility**

Requires neutral pH. Apply lime if pH below 6. P soils may be adequate but an application at planting may boost seedlings. High K removal means will be needed. K deficient plants less tolerant of fungal diseases. N not usual, 50 kg after germination may boost winter active varieties.

**Table 10.10.** Typical mineral content of lucerne and requirements to produce 10 t DM/ha utilisation.

<table>
<thead>
<tr>
<th>Nutrient Requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>4.8</td>
<td>0.34</td>
<td>2.01</td>
<td>1.31</td>
</tr>
<tr>
<td>kg applied (ha)</td>
<td>150</td>
<td>30</td>
<td>200</td>
<td>170</td>
</tr>
</tbody>
</table>

Half the amount of N required is applied as fertiliser the remainder assumed to come from nitrification.

**Diseases and pests**

Lucerne is susceptible to a wide range of diseases and pests:
- Plant yellows and wilts, with brown areas in taproot.
- Phytophthora root rot.
- Spotted alphalpha aphid very severe in recent years, graze if more than 20 aphids/stem. Chemical control may be required if making hay.
- Blue green aphid and pea aphid can be a problem sometimes.
- Crown rot (anthracnose) common during wet periods, blue-black discoloration in crown and tap root. Select resistant varieties and grow lucerne in a rotation with grasses.
- Leaf spot more evident in winter active varieties, graze when obvious.
- Heliocoverpa (heliothis) usually only a problem with seed crops.
- Leaf roller reduces vigour during summer in more mature stands, graze to remove.
- White fringed weevil. The white maggots feed on the tap and secondary roots. Control by rotating lucerne with grasses.
- Jassids — bright green (vegetable) or yellowish green (lucerne) produce a stipple pattern on the leaves and a yellowing of leaves respectively. Graze to remove.

Cutworm larvae can thin and cut off seedlings. Large, soft brown larvae in surface soil, easily controlled with insecticides applied late evening. A wide range of chemicals available for pest control.

**Weeds**

Except in pasture mixes important to keep other species to a minimum. A wide range of chemicals available to use for weed control, for pre emergent, grass and broad leaf weeds. Generally a strong stand of lucerne will dominate weeds and prevent invasion.
Growth and grazing

High crown and is sensitive to grazing, and requires rotational grazing with 6 - 8 week spelling. Aim for a residual height of 15 cm to avoid overgrazing. Expected yields 5 - 10 t DM/ha under raingrown and 16 - 20 t DM/ha/year with irrigation. About 70% growth occurs in spring and summer. Winter dormant types have lower crowns and are more persistent under grazing. Typical life of stand is 3-5 years, longer if grass invasion accepted.

Table 10.11. Range in quality for lucerne when grazed, and harvested for silage and hay.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Pasture</th>
<th>Silage</th>
<th>Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>26.4</td>
<td>23.5</td>
<td>21.4</td>
</tr>
<tr>
<td>Starch</td>
<td>4.5</td>
<td>2.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Sugar</td>
<td>11.4</td>
<td>9.2</td>
<td>8.7</td>
</tr>
<tr>
<td>NDF</td>
<td>31.7</td>
<td>39.8</td>
<td>40.9</td>
</tr>
<tr>
<td>Fat</td>
<td>3.4</td>
<td>2.7</td>
<td>2.4</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10.8</td>
<td>10.1</td>
<td>9.6</td>
</tr>
<tr>
<td>DM (%)</td>
<td>25.1</td>
<td>66.3</td>
<td>88.6</td>
</tr>
</tbody>
</table>

Animal health

Bloat from grazing is the major health problem with feeding lucerne and it needs to be routinely managed. Control is through avoiding having cows hungry, keeping lucerne to <20 - 40% of the diet, include oils in the ration (whole cotton seed) and if necessary by dosing with bloat oils (20 - 40 ml/cow), spraying oil on lucerne (60 - 100 ml/cow), or supplying a feed additive such as rumensin (in feed or as a capsule). Grazing when more mature and having grass mixed in with the lucerne also reduce bloat risk.

Silage and hay

Can be cut 6 - 8 times a year under irrigation, producing 15 - 20 t DM/ha. Dryland 2 - 5 t DM/ha/year. Cut at early flowering or when new growth buds form from the crown at 3-5 cm. Continual earlier cutting will weaken the stand.

Advantages of silage – less weather dependent because less time in the paddock, and less leaf loss in the field from further drying and tedding.

Alternate winter forages

Can be oversown with ryegrass in autumn, especially in declining swards.

References and further information


**Temperate pastures**

In the subtropical zones temperate pastures have the advantages of growing during the cooler months of the year and high nutritional value. On the other hand plants rarely persist during the hot, wet summers and require adequate irrigation for winter growth.

Table 10.12. Common temperate pastures for northern Australia.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Annual</th>
<th>Perennial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td>By far the largest category, perhaps 90% of all temperate pastures. Pastures reseeded in autumn each year and irrigated through to late spring. Primarily short-rotation ryegrass (<em>Lolium spp.</em>) based pastures with various other species and varieties added to the seed mix.</td>
<td>In cooler zones it is possible for ryegrass pastures to persist for up to 3 years. Fescues can be grown as perennials, but the acreages are very small and animal acceptance and intake can be low. Small areas of white clover (<em>Trifolium repens</em>) growing in paspalum or kikuyu pastures are also irrigated. Tall fescue (<em>Festuca arundinacea</em>) is a temperate grass that can persist during summer. Prairie grass (<em>Bromus wildemowie</em>) is an alternative annual grass species, and with suitable management will self seed each year and therefore persist.</td>
</tr>
<tr>
<td>Dryland</td>
<td>Relatively small areas receiving high winter rainfall can be over sown with ryegrass into tropical pastures each autumn. In some localities medics are used as forage legumes.</td>
<td>Localised areas favourable for naturalised white clover.</td>
</tr>
</tbody>
</table>
Types of annual irrigated pastures
The largest group, annual irrigated pastures are further divided into categories based on the ryegrass, clover or herb content of the sward.

High density ryegrass
Many ryegrass varieties are available, approximately 60 are sold in eastern Australia, differing modestly in seasonal growth pattern, rust resistance and level of endopyhte. The key characteristics are,

- Fast establishment and early growth.
- Prolonged growth into late spring.
- Rust resistance in spring.

New varieties are released each year that reportedly have higher feed value and greater agronomic characteristics. Referred to as annual and Italian or Westerdal (Lolium multiflorum) and short rotation ryegrasses (although strictly speaking annual ryegrass is L. rigidum e.g. cv. Wimmera). Annuals are bred for a Mediterranean climate, but in the subtropics pastures are rarely 'locked-up' for seeding and tillers start to die once the weather heats up from October to November.

Annual ryegrasses can be further divided into diploid and tetraploid, where diploid have the normal 2 sets of genes but tetraploids have been bred to have 4 sets. Tetraploids have larger seed size and higher seedling vigour, larger cells and higher sugar content than diploids. Tetraploids are larger plants with larger leaves but less tillers than diploids. To achieve the same plants/m² as a diploid, tetraploids need to be sown at approximately one third higher rate.

Perennial ryegrasses are slower to establish from seed compared to short-rotation ryegrass. Perennial ryegrass grown in the subtropics generally experience 50% plant mortality during the first summer after planting, hence they are not widely used.

Ryegrass and clover/herb mixtures
Clover or herb varieties are included in the seed mixture to increase the nutritional value of the diet and prolong the forage production season into early or mid summer and clovers contribute N to the pasture. The carrying capacity is reduced compared with high density ryegrass and water requirements are higher. The proportion of clover in swards appears to be seasonally dependent and it is affected by the rate of growth of the grass.

White clover varieties include Haifa and Kopu. Also shaftal/persian (T. resupinatum cv. prolific, sardi), berseem (T. alexandrinum cv. multicut, alexandria) and subtErranean clovers (T. subterranean cv. clare) can be included in the mix.

Herbs include Chicory (Chicorium intybus cv. puna, forager), a warm season, deep rooted plant which may perenniate in cooler zones. Most useful in increasing forage production into early to mid summer, but prefers well drained soils. Plantain (Plantago lanceolata) is also used in winter pasture mixtures for similar effects.

Clover dominant pastures
Annual (shaftal/Persian, berseem, subtErranean) and perennial clover (white, red) and chicory/plantain dominate the pasture mix, with only small amounts of ryegrass for early weed suppression. Objective is to maximise nutritional quality of the diet, though carrying capacity is further reduced. The same clovers and herbs are used as in the mixtures, but at higher seeding rates, and ryegrass seeding rate is markedly reduced.
Annual, irrigated high density ryegrass pastures

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★★</th>
<th>Yield</th>
<th>★★★★★</th>
<th>Quality</th>
<th>★★★★★</th>
<th>Water use efficiency</th>
<th>★★★★★</th>
<th>Reliability</th>
<th>★★★</th>
<th>Versatility</th>
<th>★★★★★</th>
</tr>
</thead>
</table>

**Purpose**
Reliable, high carrying capacity and nutritious pasture for the period June to October in southern Queensland. Can carry up to 7 milking cows/ha during this period.

**Establishment**
Ryegrass can be sown from late March to early June. Fully prepared seedbed - seed spread on the surface at 40 kg/ha and rolled. Ideal for early planting. Heavier seeding rates 80 to 100 kg/ha will increase the amount of pasture on offer by 1 t DM/ha at first and maybe second grazing. Recommend using this technique sparingly on several paddocks to increase pasture on offer at the commencement of the ryegrass grazing rotation.

Table 10.13. Expected return from increased ryegrass seeding rate.

<table>
<thead>
<tr>
<th></th>
<th>40 kg/ha</th>
<th>50 kg/ha</th>
<th>88 kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed cost @ $5.10/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilised ryegrass (t DM/ha)</td>
<td>2.05</td>
<td>2.11</td>
<td>3.39</td>
</tr>
<tr>
<td>Milk return (50cpl @ 1:1)</td>
<td>$1,002</td>
<td>$1,055</td>
<td>$1,695</td>
</tr>
<tr>
<td>BENEFIT (40 vs 88 kg/ha)</td>
<td></td>
<td></td>
<td>$448/ha</td>
</tr>
</tbody>
</table>

When oversowing ryegrass into kikuyu, we recommend mechanical disturbance or chemicals to suppress the grass. Mechanical disturbance involves slashing and two passes with a disc cultivator. Or mulch 1 month prior to planting and mulch again at planting. Objective is to break up runners and expose soil. Sowed to late April or May plantings. Spread seed on surface, mulch, then irrigate. Increase seeding rate to 50 kg/ha to compensate for losses associated from competition with kikuyu. Alternatively, direct drill into very short stubble using a disc plant. Press wheels are an advantage. Herbicide is usually Glyphosate, and tropical grasses differ in sensitivity.

- Kikuyu very sensitive, 0.6 L/ha (at 36% concentration).
- Paspalum and Rhodes grasses intermediate, 1.5 - 2.5 L/ha. Desiccant can also be used e.g. Sprayseed® at 1.5 L/ha. With continued use of herbicides, summer pasture can become dominated by naturalised couch or crows foot.

Sowings in late March to early April are more productive in early winter but risk heat damage to seedlings, and tropical grasses may still be too competitive, unless grazed every 7-10 days to reduce shading of summer grasses. The yield from late plantings is lower in winter, and have a shorter growing season.
Water use
Amount of irrigation available is a primary consideration. Need approximately 4 ML/ha for the season and preferably be able to apply water every 3 days for 4 weeks following planting to ensure establishment, then often enough to avoid wilting (7 to 20 days, depending on location and soil type). Frequency and volume of application increases as temperatures rise in spring.

Table 10.14. Irrigation requirements for short-rotation ryegrass based on average evapotranspiration rates less rainfall from 1 April to 30 November (1970 to 2007).

<table>
<thead>
<tr>
<th>Location</th>
<th>ML/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaudesert</td>
<td>4.9</td>
</tr>
<tr>
<td>Gatton</td>
<td>5.4</td>
</tr>
<tr>
<td>Gympie</td>
<td>4.3</td>
</tr>
<tr>
<td>Malanda</td>
<td>4.7</td>
</tr>
<tr>
<td>Monto</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Nutrient requirements
Very tolerant of soil types ranging from sand to heavy clay. Fertiliser inputs for P, K and S should be based on soil tests but is not a good indication of N with application being essential for adequate growth of ryegrass.

Table 10.15. Typical mineral content of short-rotation ryegrass when vegetative and requirements to produce on 10 t DM/ha.

<table>
<thead>
<tr>
<th>Nutrient Requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>4.2</td>
<td>0.35</td>
<td>2.3</td>
</tr>
<tr>
<td>kg applied /ha</td>
<td>420</td>
<td>35</td>
<td>230</td>
</tr>
</tbody>
</table>

Apply N following each grazing equivalent to 100 kg Urea/ha/month, which equates to a total of 600 to 800 kg urea/ha/season.

Diseases and pests
Army worm invasion is probably the main pest in newly established ryegrass. More common if established in tropical grass where moths prefer to lay eggs. If infestation is high, treatment is via the application of an insecticide e.g. Lorsban® at recommended rates.

Growth and grazing
Grazing commences in 6 weeks for early planting in oversowed swards, in this case graze every 10 – 12 days. Generally later 8 - 10 weeks for late plantings and full seed bed cultivation when adequately anchored. Normal practice is to graze in a rotational system, using a front and back fence. Ideally grazing occurs when the plant has three fully expanded leaves/tiller (Figure 5.3) and ceases when stubble is 5 to 16 cm high. In practice the rotation varies from 25 days in winter to 12 – 14 days in spring. N fertiliser does not affect rate of leaf appearance, it increases the size of the leaf stimulates tillering and increases crude protein content.

Novel grazing management strategies have been applied to ryegrass to increase DM production and quality, but few have demonstrated any long-term benefits. For instance, only grazing the newly expanded leaf, in practice this is difficult to achieve as animals tend to graze to multiple leaves at once, and green leaves 2 and 3 that are not grazed will senesce and decay. On the other hand, delaying grazing to 6 leaves rather than 3 will increase the net production of green leaf because each new leaf produced is bigger than its predecessor.

Pasture yield from grazing 6 to 8 times is typically in the range 8 - 16 t DM/ha. Conserved (per cut) ranges from 3 - 8 t DM/ha. Often higher yields are the result of grazing earlier and later in the season.
Table 10.16. Range in quality for short-rotation ryegrass when grazed.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>28.6</td>
<td>15.3</td>
<td>33.6</td>
</tr>
<tr>
<td>Starch</td>
<td>3.2</td>
<td>0.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Sugar</td>
<td>15.1</td>
<td>10.8</td>
<td>18.4</td>
</tr>
<tr>
<td>NDF</td>
<td>40.0</td>
<td>29.4</td>
<td>53.8</td>
</tr>
<tr>
<td>Fat</td>
<td>5.8</td>
<td>3.7</td>
<td>7.0</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>11.4</td>
<td>9.8</td>
<td>12.9</td>
</tr>
<tr>
<td>DM</td>
<td>17.0</td>
<td>10.6</td>
<td>27.6</td>
</tr>
</tbody>
</table>

Weeds
A high seeding rate and rapid establishment aim to prevent weed invasion. Grazing often inhibits the regrowth of weeds, and broad leaf weeds can be sprayed if persistent.

Animal health
As with other green, lush forage cows can exhibit signs of nitrate poisoning or hypomagnesaemia. Loose faeces, nutritional scour, often occurs during winter when grass is very digestible, but rarely has any negative effects on production.

Cool weather, stressed plants and young growth have been associated with nitrate poisoning. Another important factor is excess nitrogen in the soil, particularly with fully prepared seedbeds, where nitrogen inputs from previous years are released by cultivation and additional nitrogen is applied in the current year. Reduce initial nitrogen inputs with a prepared seedbed if residual nitrogen from the previous crop is expected to be high.

References and further information
Callow et al. (2005).
Ryegrass and clover/herb mixtures

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★</td>
</tr>
</tbody>
</table>

**Purpose**
Higher nutritional value than high density ryegrass and less need for nitrogen fertiliser. Requires more management skill than pure ryegrass pasture. Highly nutritious forage from June to November and can carry up to 5 milking cows/ha during this period.

**Establishment**
Pasture can be sown from mid April to mid May. A fully prepared seedbed is necessary to establish these mixtures. Seed is spread on the surface at 5 - 10 kg ryegrass/ha, and 4 - 5 kg/ha of mixed clover and herb seeds. Legume seeds must be inoculated with the appropriate inoculants. Rolling is essential. If sowing onto acid soil pelleting seed with lime and molybdenum is advantageous.

Early sowings are more prone to summer grass and broadleaf weed invasion, and late heat waves can kill seedlings. Later plantings are slow to establish. Perennial ryegrass varieties are sometimes used to lessen competition with the clover, but these ryegrass plants fail to persist during summer.

**Water use**
Amount of irrigation available is a primary consideration. Need a minimum of 4 ML/ha and able to apply small amounts of 5 - 10 mm each 3 days during establishment. Irrigate each 3 to 4 days for 4 weeks to ensure establishment, then often enough to avoid wilting, every 7 to 20 days depending on location and soil type. Frequency increases substantially as temperatures rise in spring.

**Soil fertility**
Less tolerant of acidic and low fertility soils than high density ryegrass. Fertiliser inputs are based on soil tests although clovers tend to have a higher K requirement compared to ryegrass. Adequate fertiliser is essential to the pasture performance. Clovers require a soil pH above 6, and on acidic soils liming may be needed every 3 to 5 years to increase the pH.

Common practice is to apply 125 kg/ha muriate of potash, 250 kg/ha superphosphate and 125 kg/ha urea at planting, and 125 kg/ha urea after each grazing. With strong clover content nitrogen application may not be warranted after the first or second grazing without a decline in DM production. In total these mixed swards require 375 to 500 kg urea/ha/year.

**Diseases and pests**
There are few pests of importance, and grazing often is sufficient for control.

**Growth and grazing**
Grazing commences in 8 - 10 weeks or before ryegrass shades the clover. Normal practice is to graze in a rotational system, using a front and back fence. Grazing is managed to encourage clover growth early in the season, by removing ryegrass cover and leaving a high residual, about 15 cm. Later in the season the objective is to maximise yield of clover or herb, and grazing is delayed until forage yields are high and animals removed when the residual height is approximately 15 cm. In practice the rotation varies from 20 - 40 days.

Pasture yield is typically in the range 6 - 12 t DM/ha. Often higher yields are the result of earlier and later grazing in autumn and spring respectively. Forage quality is very high, with similar CP to ryegrass, but lower NDF (30-35% DM) content and a higher intake factor associated with legumes.
Weeds
Broad leaf weeds can be a problem as they compete with the clover and are difficult to spray as most effective chemicals also damage the clover and herbs. 2,4-DB can be used effectively once clover have 3 fully formed trifoliate leaves. A persistent weed problem may be best controlled by growing high density ryegrass.

Animal health
Bloat is the major concern. The prevalence of bloat can be reduced by avoiding grazing hungry cows. Bloat oils can be sprayed onto pasture at 60 - 100 ml/cow/day, cows can be drenched with 20 - 40 ml of bloat oil/cow/day or rumensin capsules could be inserted into the rumen and remain effective for 100 days. Alternatively and more commonly, rumensin can be mixed into the bail feed at 20 mg/cow/day.

Nitrate poisoning is less likely than with high density ryegrass. However cows can exhibit signs of hypomagnesaemia. Loose faeces, nutritional scours, often occurs during winter when grass is very digestible, but rarely has any negative effects on production.

A high ryegrass content of over 50% of the sward will lessen the risk of bloat, though not remove it.

Silage and hay
A ryegrass and clover mixture makes excellent silage, cut and wilt the pasture to 35% DM, baled and wrapped or pit.

Excess amounts of pasture available for ensilage are very rare, even more so than for high density ryegrass.

References and further information
**Clover dominant pastures**

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★☆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★☆☆☆☆</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★☆☆☆☆</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★☆☆</td>
</tr>
<tr>
<td>Versatility</td>
<td>★☆☆☆☆</td>
</tr>
</tbody>
</table>

**Purpose**
Maximum nutritional value during a relatively short period from June to October, and low need for nitrogen fertiliser. Requires more management skill than pure ryegrass pasture, especially during establishment. Can carry up to 5 milking cows/ha during this period.

**Establishment**
A prepared seedbed as for ryegrass and clover mixed pastures. Pasture can be sown from mid April to mid May. Inoculated seed can be broadcast on the surface or direct drilled at 5-10 kg/ha and rolled. Ryegrass seed at 2 to 4 kg can be added as a mixture to assist weed suppression early in establishment.

Early sowings are more prone to summer grass and broadleaf weed invasion, and late heat waves can kill seedlings. Later plantings are slow to establish.

**Water use**
Amount of irrigation available is a primary consideration. Need a minimum of 4 ML/ha and able to apply each 3 days during establishment. Irrigate each 3 to 4 days for 6 weeks to ensure establishment, then often enough to avoid wilting (7 to 20 days, depending on location and soil type). Frequency increases as temperatures rise in spring.

**Soil fertility**
Perform best on neutral soils with at least 50 cm topsoil. Adequate P, K and S are essential to the pasture performance. Common practice is to apply 125 kg/ha muriate of potash, 250 kg/ha superphosphate and 125 kg/ha urea at planting. Further nitrogen may not be needed.

**Diseases and pests**
There are few pests of importance, and grazing often is sufficient for control.

**Growth and grazing**
Grazing commences in 8 - 10 weeks. Normal practice is to graze in a rotational system, using a front and back fence. Grazing is managed to encourage clover growth. To promote growth of stolons it is important to graze sufficiently to allow sunlight to penetrate the sward, whilst avoiding overgrazing. Later in the season it is recommended that grazing is delayed until forage yields are high and animals are removed at a residual of about 15 cm. In practice the rotation varies from 20 - 40 days.

Pasture yield is typically in the range 4 - 10 t DM/ha. Variation in yield is largely associated with success of establishment. Forage quality is very high, with 30% CP, 25 - 30% NDF and a high intake factor associated with legumes. Milk yield is often about 1 - 2 L/cow/day higher than for ryegrass.
Table 10.17. Range in quality for white clover and Persian clover.

<table>
<thead>
<tr>
<th>Quality(% DM)</th>
<th>White Clover</th>
<th>Persian Clover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Minimum</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>28.0</td>
<td>26.5</td>
</tr>
<tr>
<td>Starch</td>
<td>4.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Sugar</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NDF</td>
<td>26.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Fat</td>
<td>4.6</td>
<td>3.9</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>11.4</td>
<td>11.2</td>
</tr>
<tr>
<td>DM</td>
<td>16.4</td>
<td>15.1</td>
</tr>
</tbody>
</table>

Weeds

Broad leaf weeds can be a problem as they compete with the clover and are difficult to spray as most effective chemicals also damage the clover and herbs. 2,4-DB can be used effectively when clover seedlings have a minimum of 3 trifoliate leaves. A persistent weed problem may be best controlled by growing high density ryegrass.

Animal health

Refer to previous section under ryegrass and clover/herb mixtures.

Silage and hay

These pastures may be difficult to wilt as they have a high water content, but if this can be achieved and minimal leaf is lost, they make excellent silage. A silage inoculant is added to make up for the low soluble carbohydrate content of legumes. Excess amounts of such pasture available for ensilage are very rare.

References and further information


Prairie grass

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★★★</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★</td>
</tr>
</tbody>
</table>

Purpose
Prairie grass is an alternative to ryegrass on fertile well drained soils as it does not tolerate pugging by stock. It can be annual in the subtropics, but about 2/3 of plants will persist into the second year and the sward can self seed from year to year if the sward is grazed fairly lax (leaving a few seedheads) from November onward at 3 week intervals. The grass performs better at the lower latitudes of the subtropics.

Establishment
Prairie grass establishes best into a prepared seedbed because it is slower to establish than ryegrass. Ideally it should be sown in late March as it is less tolerant to cold at establishment than ryegrass. It can be direct drilled into a ‘clean’ site during March and April at 40 - 60 kg/ha. Use harrows and roll. Prairie is not suited to over sowing.

Prairie grass should self seed each year germinating in February and March. If pasture becomes infested with summer grasses, spray the area with 2 - 3 L/ha of glyphosate in early/mid February. This will allow seed to rejuvenate the pasture. Whilst prairie grass plants will also be killed, the seed will be unaffected and germinate in autumn.

Water use
Need approximately 6 ML/ha of irrigation although this varies between season and region. Preferably apply water each 3 days during establishment.

Table 10.18. Irrigation requirements for prairie grass based on average evapotranspiration rates less rainfall for 12 months (1970 to 2007).

<table>
<thead>
<tr>
<th>Location</th>
<th>ML/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allora</td>
<td>6.0</td>
</tr>
<tr>
<td>Beaudesert</td>
<td>6.2</td>
</tr>
<tr>
<td>Gatton</td>
<td>7.0</td>
</tr>
<tr>
<td>Gympie</td>
<td>5.1</td>
</tr>
<tr>
<td>Monto</td>
<td>7.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient Requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>3.7</td>
<td>0.5</td>
<td>2.4</td>
</tr>
<tr>
<td>kg applied (tha)</td>
<td>370</td>
<td>48</td>
<td>240</td>
</tr>
</tbody>
</table>

Diseases and pests
There are few pests of importance, and grazing often is sufficient for control. Army worms may invade pasture.

Growth and grazing
In the first year grazing occurs in 8 - 10 weeks. In subsequent years light grazing continues during establishment. A rotational grazing system is essential, using a front and back fence. Normally pasture is grazed when 3 - 4 leaves have been produced per tiller, and to a residue of approximately 15 cm. Grazing is managed to allow seed set during November, allow 6 - 8 weeks interval commencing in October to form a senescent mat and to allow seed set and shed. In practice the grazing rotation varies from 20 - 40 days.

Pasture yield is typically in the range 8 - 14 t DM/ha. Often higher yields are the result of later grazing in spring and early summer.

Quality
Forage quality is high, with similar CP and NDF to ryegrass during the cooler months.
Table 10.20. Range in forage quality for prairie grass (source FeedPlus database and Fulkerson W.J. *per. comm.*)

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>23.5</td>
<td>18.2</td>
<td>28</td>
</tr>
<tr>
<td>Starch</td>
<td>5.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sugar</td>
<td>4</td>
<td>1-2</td>
<td>8</td>
</tr>
<tr>
<td>NDF</td>
<td>48</td>
<td>44</td>
<td>51.7</td>
</tr>
<tr>
<td>Fat</td>
<td>4</td>
<td>3.2</td>
<td>4.9</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>11.1</td>
<td>9.7</td>
<td>10.5</td>
</tr>
<tr>
<td>DM (%)</td>
<td>27.8</td>
<td>24.5</td>
<td>30.6</td>
</tr>
</tbody>
</table>

**Weeds**
Similar to ryegrass.

**Animal health**
Similar to ryegrass. Prairie grass may be low in magnesium content and if cows graze prairie continually, it is recommended they be supplemented with magnesium.

**Silage and hay**
As for ryegrass.

**References and further information**

Medics

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★★★</td>
</tr>
</tbody>
</table>

**Varieties**

Burr medic (*Medicago polymorpha*) is naturalised and Barrel (*M. trunculata* cv. caliph and sephi) and snail (*M. scutellata* cv. sava) medics are often planted. Medics distinguished from clovers by yellow flowers.

Annual legumes from Mediterranean areas, suited to wet winters and dry summers. Often used in ley pastures in cropping areas to rebuild soil nitrogen, e.g. Darling Downs. Snail medics preferred for ley pastures, barrel for permanent grass and legume mixed pasture.

**Establishment**

Sowing is in April, May and June. Sown into a prepared seedbed as a pure stand or as a mix with winter wheat or oats. Seed is surface spread, harrowed and rolled. If barrel medic is mixed with barley or oats it needs to be spread or planted separately at a shallow depth (< 20 mm). However snail medic can be planted up to 50 mm deep, with cereal seed. Seeding rate of 4 - 6 kg/ha for pure stands and 2 - 4 kg/ha in mixtures. Seed must be inoculated (Group AL) before sowing.

Good establishment will depend on rainfall during the autumn and winter. Medics are sometimes oversown into grass pasture. Heavy grazing before and after sowing reduces competition and tramples seed into the soil. Heavy grazing in early autumn will encourage seedling establishment, but should not be repeated each year as the grass component will weaken and decline. Very hard seeded, softening and germinating over a 5 year period. This helps survive drought.

**Water**

Most suited to regions receiving 400 - 800 mm rainfall, with >30% occurring during winter. Yield varies greatly between years, related to rainfall and its distribution through the year.

**Soil fertility**

Prefer neutral to alkaline (pH 6.5 - 8.0) clay or clay-loam soils of high fertility. Sulphur deficiency may be evident in permanent pastures, and cause pale green leaflets. Surface application of 20 - 60 kg S/ha will be adequate for dry matter production for 3 - 5 years.

**Diseases and pests**

Blue green and spotted alphalpa aphids are the primary pest. Tolerant varieties are available.

**Animal health**

Bloat is the main concern, though not as evident as with lucerne and clover. Occurs primarily in wet winters following dry summers, when medics are dominant. If possible delay grazing until medic matures.

**References and further information**

Queensland government Department of Agriculture, Fisheries and Forestry (2013).
Perennial irrigated pastures

<table>
<thead>
<tr>
<th>Management level</th>
<th>★★★★</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>★★★</td>
</tr>
<tr>
<td>Quality</td>
<td>★★★★</td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>★</td>
</tr>
<tr>
<td>Reliability</td>
<td>★★★★</td>
</tr>
<tr>
<td>Versatility</td>
<td>★</td>
</tr>
</tbody>
</table>

**Purpose**
In cooler latitudes perennial ryegrass and clover mixtures will persist for some years, so reducing pasture costs compared with annuals. Tall fescue (*Festuca arundinacea*) is a temperate grass that can persist in the subtropics of south east Queensland for at least three years, although cow acceptance and intake are greatly reduced during winter from persistent varieties. In Queensland, very few farmers have repeatedly planted fescue because of low animal acceptance, even though results from quality tests are similar to other temperate grasses.

Throughout the subtropics small favoured areas in mild climatic regions such as Gowrie Junction and Warwick on the Darling Downs, are colonised by perennial mixtures of white clover with perennial ryegrass. Mostly though, perennial ryegrass is not present in Queensland, nor persistent for more than 3-years outside of cool-temperate environment of Tasmania and New Zealand.

**Establishment**
Perennial ryegrass pastures are established as for annuals, but at approximately half the seeding rates and with just light grazing for the first 3 months. Fescue seedlings are weak, and the grass is slow to establish and susceptible to competition from other sward plants. Sow in autumn at 20 kg seed/ha, with low rates of companion legumes (1 - 2 kg/ha), using similar methods to ryegrass. Graze lightly in the first winter. Once established the grass is very deep rooted and persistent and will stand heavy stocking.

**Water use**
Depending on locality and winter rainfall, perennial ryegrass pastures will require more than 6 ML irrigation water each year because swards require water during the cool and warm growing seasons. It may need to be applied each 3 days during to maximise establishment seedlings.

**Soil fertility**
Perennial ryegrass pastures have similar N needs to annual pastures. Fescue is tolerant of a wide range of soils of different fertility, structure, pH and salinity. It is recommended that fertiliser inputs are based on soil tests. Adequate fertiliser is essential to the pasture performance. Fescue will require 125 kg urea/ha after each grazing, in total 400 - 800 kg urea/ha.

**Diseases and pests**
There are few pests of importance, and grazing often is sufficient for control. Army worms may invade pasture. Fescue may develop leaf and crown rust during summer.

**Growth and grazing**
Fescue is grazed as for ryegrass. Fescue will continue to provide grazing during summer and total yield is 8 to 14 t DM/ha. Forage quality is high, with similar CP and NDF to ryegrass during the cooler months. However, during spring and summer the quality of fescue becomes more like that of the tropical grasses, with NDF levels over 55% DM.

Pasture yield for perennial ryegrass pastures is typically in the range 6 to 12 t DM/ha, reflecting the slower growth during autumn and winter.

**Weeds**
Similar to ryegrass.

**Animal health**
Perennial ryegrass and fescue can contain endophytes which is a fungus that lives mostly at the base of the plant and moves upwards during seed development. Some of these endophytes are naturally occurring in
perennial ryegrass and fescue whilst others are selected and called novel endophytes. They may assist the plant in the prevention of disease and increase drought tolerance, but they may also have a negative impact on an animal production and health and can cause toxicity and “fescue foot” in cows. The incidence of problems Queensland is highly variable because endophytes are seasonal and perennial ryegrass and fescue must make up a large part of the diet.

**References and further information**

Harris and Lowien (2013).


Kemp *et al.* (2007).
Temperate crops

Oats (Avena sativa)

Management level  ★★★
Yield  ★★★
Quality  ★★★★
Water use efficiency  ★★★★
Reliability  ★★★
Versatility  ★★★★

Varieties
Many varieties and consistently changing to improve resistance to leaf rust. Primary source of green forage during winter and spring on dryland areas that receive <800 mm rainfall/year. Versatile plant, can be grazed, hayed or ensiled. Varieties classified on:
- Resistance to leaf rust
- Growth form (prostrate or erect)
- Early growth rate (medium or quick)
- Late growth rate (medium or late)

Establishment
Plant mid March to mid June in southern Queensland, a month later in central Queensland when soil temperature 15 - 25°C mid afternoon. Recommended planting depth is 5 - 7 cm deep, though it can be planted to 10 cm if moisture is present. Row spacing 15 - 23 cm, wider rows 76 cm sometimes used to minimise rust infestation. Seeding rate 40 - 60 kg/ha for raingrown and 80 kg/ha when irrigated or grown for hay.

Weeds can generally be managed by seedbed preparation and grazing. Keep in mind that oats is more sensitive to 2,4 D than other cereals.

Water use
Usually dependent on stored moisture for a substantial part of the growth, therefore plant into soils with a high plant available water content.

Diseases
Leaf rust (or crown rust) forms small, yellow-orange pustules on leaves is very prevalent. Stem rust, large, red pustules on stem and leaf,) can be severe. Red tipped oats can be a problem on the Darling Downs, reducing growth and making oats unpalatable and sometimes poisonous to stock.

Leaf rust favoured by cool, moist weather, stem rust by warm, moist weather. Minimise by:
- Avoid early sowings.
- Use adequate N, P.
- Graze off if rust becomes visible.
- Select resistant varieties.
- Control out of season wild oats, oats and broome grass.

Growth and grazing
After germination, rain is needed to establish secondary roots and for continued growth. Graze soon after secondary roots formed, usually 6 - 8 weeks after sowing, and avoid removing growing points, graze just above the first node (Figure 10.3). ‘Optimum defoliation height pre-grazing for prostrate varieties is 10 - 15 cm, and for erect varieties 20 - 25 cm. Residual height post-grazing is 5 - 10. Residual height <5 cm will severely reduce regrowth and plant persistence.

Expected yields are 1 - 2 t DM/ha at each grazing, and total yield 5 - 7 t for raingrown and 7 - 10 t DM/ha under irrigation.
Quality

Table 10.21. Range in quality of oats when grazed or harvested for silage.

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silage</td>
<td>Graze</td>
<td>Silage</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>17.5</td>
<td>21.1</td>
<td>12.3</td>
</tr>
<tr>
<td>Starch</td>
<td>3.6</td>
<td>5.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Sugar</td>
<td>9.5</td>
<td>18.1</td>
<td>4.0</td>
</tr>
<tr>
<td>NDF</td>
<td>48.9</td>
<td>42.4</td>
<td>45.1</td>
</tr>
<tr>
<td>Fat</td>
<td>4.7</td>
<td>4.4</td>
<td>3.6</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10.1</td>
<td>11.0</td>
<td>9.4</td>
</tr>
<tr>
<td>DM</td>
<td>39.0</td>
<td>21.3</td>
<td>30.3</td>
</tr>
</tbody>
</table>

Animal health

Hypomagnesemia, hypocalcaemia and nitrate poisoning can occur in older cows grazing lush oats. Prevention can be achieved by avoiding hunger and feeding Causmag at 50 gm/cow/day, and administering Calcigol (grass tetany and milk fever) or methelyne blue (nitrate).

Silage

Suited to silage or hay. Highest quality occurs when crops are cut early at flowering or early boot stage and wilted. Yields up to 10 t DM/ha can be achieved for crops grown on fertile soils and received good rainfall. Chop to 1 cm to aid compaction of hollow stems.

Figure 10.3. An oat plant with (a) an erect growth and (b) a prostrate growth habit showing the optimum grazing height as just above the first node.

References and further information

Hennessy and Clements (2009).
Winter (2013).
Barley (*Hordeum vulgare*)

<table>
<thead>
<tr>
<th>Management Level</th>
<th>Yield</th>
<th>Quality</th>
<th>Water use efficiency</th>
<th>Reliability</th>
<th>Versatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

**Varieties**
Primarily bred for grain, e.g. at Warwick–fitzroy, Gairdner, grimmett, mackay, grout, hindmarsh, shepherd, Dictator II. However, in the last 10 years there has been increased use of barley for silage and hay production. Primary selection is for disease tolerance, e.g. yellow dwarf virus, and leaf rust. More frost hardy than wheat.

**Establishment**
Plant late May to July at 50 - 80 kg seed /ha to achieve 120 plants/m². Aim for a seed depth of 5 - 7 cm into moisture with a row spacing of 17.5 to 36 cm. Increase seeding rate on heavy clay soils by 30%. Use pre-emergent herbicide to decrease competition from weeds.

Relatively rapid growth makes it suited to double cropping/early grazing.

**Water use**
High water efficiency relative to other cereals. Water extraction to more than 80cm.

<table>
<thead>
<tr>
<th>Nutrient requirement</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient (% DM)</td>
<td>1.8</td>
<td>0.26</td>
<td>1.6</td>
</tr>
<tr>
<td>kg applied (/ha)</td>
<td>180</td>
<td>26</td>
<td>160</td>
</tr>
</tbody>
</table>

**Diseases**
Leaf and root fungal diseases, yellow dwarf virus. Select tolerant varieties. Rotate with wheat or legumes. Avoid very early or late crops. Incidence of leaf diseases is reduced if crops are grazed.

**Growth and grazing**
Expected yield between 6 - 11 t DM/ha, up to 14 t DM/ha silage crop can be achieved when nutrients and water are not limiting. 1st grazing at 6 - 8 weeks, ensure plants are well anchored, should correspond to a crop height of 20 - 25 cm height. Recommended that subsequent grazings occur before stem elongation.

Primary growth period July to October inclusive. Growing point just above top node, tiller will not recover if removed.

**Quality**

<table>
<thead>
<tr>
<th>Quality (% DM)</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>11.5</td>
<td>6.5</td>
<td>16.8</td>
</tr>
<tr>
<td>Starch</td>
<td>15.8</td>
<td>0.2</td>
<td>30.6</td>
</tr>
<tr>
<td>Sugar</td>
<td>9</td>
<td>1.2</td>
<td>22.8</td>
</tr>
<tr>
<td>NDF</td>
<td>49.5</td>
<td>37.7</td>
<td>63.3</td>
</tr>
<tr>
<td>Fat</td>
<td>3.3</td>
<td>2.3</td>
<td>4.7</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10</td>
<td>8.1</td>
<td>13.3</td>
</tr>
<tr>
<td>DM</td>
<td>35.8</td>
<td>23.0</td>
<td>50.6</td>
</tr>
</tbody>
</table>
Animal health
Nutritional scours often occurs but with no reduction in animal production. Potential for hypomagnesemia, nitrite and hypocalcaemia. Avoid grazing varieties with large awns.

Silage
To maximise yield, harvest at mid dough stage although quality will be lower (7%CP, 9ME). If preference is for high quality silage, harvest at boot stage but expect yields to be 50% lower.

References and further information
Barley planting and disease guide 2013 Qld NNSW.
Hennessy and Clements (2009).

Alternate winter forages
Barley, triticale and wheat may also be used for winter forage although oats is usually more productive. Barley and triticale are useful for late planting in cool weather, to provide rapid growth in late winter for grazing. Barley and wheat produce higher grain yield in silage cut at milky dough stage, but overall yield lower (~60%).
Chapter 11. Irrigation

Water supply and quality
An adequate supply of high quality water is the first essential in farm irrigation.

Supply
Various schemes;
- Supplied from public water way. Usually rationed; ML/year, Hr/week. Quality generally high.
- Bores, often licenced at L/hr over sustained period (24hr). Quality ranges from high to low.
- Dams; capacity ML, quality generally high.

Salinity
Effects on soil salinity and sodicity. Water quality may vary somewhat depending on soil-water interaction. Salinity of bores increased during the 2001 to 2007 drought because of greater reliance on underground water for irrigation and reduced rate of recharge. Salinity can be managed by; frequent irrigation, leaching irrigation, mixing water sources, gypsum and selecting crops with a comparatively high tolerance.

The effect of salinity is not always evident, the effect can be decreased germination rate or yield. Severe cases may scorch leaves or margins of leaves due to Na and Cl ions accumulating in the leaves. Some plant species such as maize will experience leaf burn if water is sprayed onto the crop.

Rainfall
Added to irrigation to give total water used/ha. On many farms, total water ML (rainfall (mm) x farm area) from rainfall is greater than water supplied as irrigation. Effective rainfall and irrigation are measured after evaporation and drainage are accounted for.

Water testing
Primary tests are pH, EC, alkalinity, chloride, SI and SAR.
- **pH** – Balance between positive hydrogen ions (H\(^+\)) and negative hydroxyl ions (OH\(^-\)), referred to as acidity. pH 5.5 -8.0 suitable for plants.
- **EC** – Electrical conductivity, a measure of salt concentration in the water. <2 dS/m, salt sensitive plants (clovers, lucerne). >5 dS/m, unsuitable for any plants.
- **Alkalinity** – A measure of bicarbonate in water. <90 mg/L low risk. >300 mg/L high risk of scale and soil damage (sodicity).
- **Chloride** – Concentration of chloride ions (Cl\(^-\)). Limits, citrus/fruits 175 mg/L, most crops 700 mg/L.
- **SI** – Saturation index, a measure of potential for scaling. Low (<0.5), medium (0.5-1.5) and high (>1.5) risk.
- **SAR** – Sodium absorption ratio, measures the potential for sodium damage to soils and crops. Low (<3), medium (3-6) and high (>6%) risk.

<table>
<thead>
<tr>
<th>Salt level dS/m</th>
<th>Forage species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low &lt; 2</td>
<td>Clover, peas, beans, lucerne.</td>
</tr>
<tr>
<td>Medium 2 - 4</td>
<td>Corn, millet, sorghum..</td>
</tr>
<tr>
<td>High 4 - 6</td>
<td>Ryegrass, barley, wheat, tropical grasses.</td>
</tr>
</tbody>
</table>

Soils
Soil quality has a large bearing on the efficiency of irrigation. Soil is a complex natural material derived from eroded and decomposed parent rock and organic materials which provide nutrients, air, moisture and a site for plants to grow.
Soils are best understood when we talk about them in terms of the three major properties that contribute/influence the overall health and productivity of a soil: physical, chemical and biological.

Physical
These include soil texture, structure, porosity and water and air content as well as parent materials. Collectively they determine the availability of oxygen in soils, the mobility of water into and through the soil profile and ease of root penetration. They are not as easy to measure as the chemical properties of a soil.

Chemical
A soil’s chemical properties are most of those commonly found on a soil test. Chemical factors like pH, cation exchange capacity, calcium : magnesium ratio, salinity and sodicity issues can all have a major impact on nutrient availability for growing plants.

Biological
A productive soil will contain large populations of bacteria, fungi, algae and insects which feed from the soil’s organic matter that contains energy and nutrients, which in turn improve the physical and nutrient content of the soil. The availability of nutrients in the soil are dependent on decomposition of organic matter and mineralisation of nutrient elements.

Physical properties
Texture - The texture of a soil is determined by the proportion of how much sand, silt and clay is present and their ability to group together. Large particles that don’t group together (sand) have a low ability to hold water in the profile, whereas small particles that can group together (clay and humus) have much greater total pore space and bonding ability and so retain more soil water.

Structure - The structure of a soil is characterised by the size, shape and arrangement of soil particles and the aggregations of peds. Peds have the effect of increasing the total space between soil particles where water, air and growing roots can move freely. Improved soil structure increases water holding capacity. The opposite condition to aggregation is dispersion. When wet, soil peds will collapse and disperse to individual particles causing slowed water movement through the soil. Two primary indicators of poor structure are:

- Crusting or powdering of surface soil and poor water infiltration
- A hard pan 20 to 40 cm deep, preventing roots and water movement to deeper profiles.

Structure is improved with;

- Zero tillage or minimum soil disturbance. Maintain ground cover, using crop, pasture or stubble and minimise erosion.
Avoid working soil when wet or pugging with cattle.
Applying soil conditioners such as manure or gypsum.
Allowing heavy clay soils to dry and crack naturally.

Three ways of assessing structure:
- At planting soil should be springy, not hard, and have small, stable peds and no clods. There should be no crusting or visible sand grains on the surface. Prolific root growth after planting indicates good structure.
- When peds are dropped in water they should soften but not disperse. If water develops a cloudy look within 2 hours after placing in water it indicates sodicity (high salt content).
- A pointed steel probe inserted into the ground can detect dry or hard layers. Also spades of soil (30 cm) from under a long term fence line and the paddock can be compared for look and feel.

**Water Infiltration and drainage** - Soil texture and structure influence the amount of water plants can extract from the soil where smaller clay particles sit closely together and larger sand particles sit further apart creating greater pore spacing and passage for water infiltration and drainage. The smaller clay particle sizes also have higher surface areas than large particles which significantly increase the amount of water absorbed by a soil as it is held more tightly between particles sometimes limiting uptake and drainage.

**Chemical properties**

**pH** – Soil pH is a measure of the concentration of hydrogen ions in the soil solution. The more hydrogen ions the more acidic a soil will be, and the more hydroxyl ions the more alkaline a soil will be. pH is measured on a logarithmic scale of 1 to 14, where 1 is the most acidic, 14 is the most alkaline, and 7 is neutral. The availability of certain nutrients change as the soil pH changes, therefore trying to keep your soil at a neutral position is best (Figure 11.2). Acidity is a common problem in high rainfall areas of the tropics and subtropics. More serious if acidity is at depth as it is then difficult to treat. Problem tends to be worse with high inputs of some fertilisers, especially those containing ammonium (Gran-am, DAP). Acidity reduces nutrient uptake by plants and soil organisms, and leads to aluminium and manganese toxicity. The best solution is to apply dolomite or lime as indicated by soil tests, recommended to apply 3 - 5 t/ha every 3 to 5 years.
Figure 11.2 Change in nutrient availability with soil pH (Fertilising dairy pastures).

**Cation Exchange Capacity (CEC)** -
The CEC of a soil can be measured to give an understanding of a soil's nutrient holding capacity. The exchange pathway of nutrients in the soil from clay particles and organic matter, to the soil solution and then to the plant roots for uptake is called the "ion exchange". The CEC is a measure of the number of sites a clay particle has on its surface to which nutrients can attach and detach during the ion exchange process - hence being described as the soil's nutrient holding capacity. Sandy soils and soils with a low clay content and low organic matter, have a low CEC and cannot hold many nutrients and are less fertile. Typical soil CEC contents are: heavy cracking clays >20 meq/100 g, red brown earths 8 - 12 meq/100 g, and sandy soils <5 meq/100 g.

**Calcium: Magnesium Ratio (Ca:Mg)** -
The Ca:Mg is a measure of the percentages of the total CEC that calcium and magnesium ions occupy or the percentage of occupied sites on the clay particles surface. The Ca:Mg can have an impact on the uptake of nutrients and the overall stability and structure of a soil. Ratios <1 will inhibit nutrient availability, application of gypsum (2 - 3 t/ha) will increase the ratio.

**Salinity and Sodicity** - Salinity or saline soils have high concentrations of salts, mostly sodium and chloride, which can impair the uptake of water and is commonly measured by the electrical conductivity or electrical conductivity of a soil. Sodicity is related to dispersive soils, where an excess of sodium on clay particle surfaces (CEC) causes clay particles to repel each other and move into the soil solution and fill pore spaces, thereby reducing water and root infiltration and often forming hard setting layers of clay. High proportions
of magnesium relative to calcium (Ca:Mg) amplifies the dispersive effects. Primary remedy is to apply gypsum. Rate will vary depending on severity of problem, but is often 5 t/ha/year, with up to 25 t/ha in total before large improvements are seen.

**Biological properties**

Soil nutrient availability and uptake by plants predominantly depends on the decomposition of organic matter and mineralisation of nutrient elements. This will only happen if the biological component of the soil is active.

**Organic Matter** - Organic matter includes plant and animal material and humus. They store nitrogen and other key nutrients, and provide the main source of feed for the soil organism populations. These populations breakdown organic matter and release nutrients from their organic form into soluble forms ready for plant absorption. Organic matter is often measured by the organic carbon levels in the soil, where a factor of 1.7 is used to convert %C to % organic matter. Primary means of increasing are perennial forage production, green manure and application of manures and compost.

**Micro organism populations** - Soil organisms range in size from microscopic, bacteria, nematodes, fungi, to organisms that can be visibly identified such as earth worms and other macro-insects. Most soil organisms depend on organic matter as their protein and energy source which is why the majority of organisms are located in the top 15 - 20 cm of the soil profile. Repeated cultivation and cropping practices can have negative impacts on microorganism numbers, as well as soil moisture, temperature, aeration, nutrient supply and pH. However, some cultivation will boost organic decay.

**Soil water content**

Objective of irrigation management “is to supply a desired amount of water to the crop at a specific time” = Irrigation scheduling

Good irrigation management requires an understanding of:

- Measuring water use within the soil profile.
- The availability of water within the forage root zone.
- Rate of forage water use.
- When to apply.
- How much to apply.
- Rainfall pattern, rate of evaporation.
- Characteristics of the irrigation system.

**Measuring soil water**

Understanding soil water content helps to manage an efficient irrigation program. Not all water in the soil profile is available for uptake by plants. Plant available water is the difference between field capacity and wilting point:

**Field capacity** - As much water as the soil can hold under gravity.

**Wilting point** - Water content of soil when plants wilt.

Water content expressed as either % of soil or mm, both to a specified depth (often 75 cm). Water below wilting point is unavailable to plants. It is a relatively small amount of water on sandy loams or Krznozem, but a substantial amount on heavy clay soils.

**Plant available water** - Plants extract water between field capacity and wilting point.

Usually there are basic measures of soil water to obtain key reference points to determine when and how much to irrigate. After this there is a wide range of methods used to monitor soil moisture during an irrigation program.

The basic measure of soil water is obtained by taking a soil sample, weighing it, drying in an oven, then reweighing. Weight loss, expressed as a percentage of weight of dry soil, is the water content. This test can be done when soil is at field capacity, usually 1 to 2 days after filling the
profile with water, and at wilting point. Plant available water is then water at field capacity less water at wilting point.

These measures are for a certain depth of soil, related to the root depth of plants. For example ryegrass is usually drawing water from within the top of the soil profile down to 40 cm, whereas lucerne, tropical pastures, forage sorghum and maize may draw water from over 1 m depth.

It is useful to convert depth of water as rainfall (mm) into volume (ML) e.g. 100 mm applied over 1 ha requires 1 ML of water. Multiply 100 mm by 10 000 m² = 1 ML/ha. Remember it takes 1 L of water to apply a depth of 1 mm across 1 m².

Water holding capacity
The amount of water a soil can hold depends strongly on the texture and structure of the soil. Soil depth has a large bearing on the water holding capacity of a soil. If the soil profile is reasonably uniform then the water capacity is directly related to the depth.

Plant available water
Plant available water is always less than water holding capacity and varies markedly between soils (Table 11.2). The maximum plant available water in a sandy loam is 50% of total soil water compared with 40% for a clay loam soil.

Deeper rooting plants have more plant available water due to the greater volume of soil accessed. For example on a clay loam soil ryegrass may have 80 mm available water at field capacity, compared with 150 mm for a maize crop. Plant available water is constantly changing, reflecting a balance of water input through irrigation and rainfall, evapotranspiration through the plant and deep drainage. Plant growth is generally not impeded until plant available water is very low.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Plant available water (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>50</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>110</td>
</tr>
<tr>
<td>Loam</td>
<td>160</td>
</tr>
<tr>
<td>Silt loam</td>
<td>220</td>
</tr>
<tr>
<td>Clay loam</td>
<td>170</td>
</tr>
<tr>
<td>Clay</td>
<td>150</td>
</tr>
</tbody>
</table>

Tools to monitor soil water
Direct measurement of soil water content, by taking soil core samples at planting and drying them in an oven is seldom warranted in an irrigation system as the stored water is small relative to that applied in irrigation. It is more important to monitor soil moisture status and use this information to adjust irrigation schedules. The monitoring tools available include experience and visual observation, measures of evaporation in weather monitoring, and in ground devices such as neutron moisture meter, capacitance probes and gypsum blocks.

Experience and visual observation are the most commonly used technique. Experienced operators interpret many indicators of water status in a paddock, related to the soil, plant and weather, and use this information to adjust irrigation schedules.

Evaporation from an open water surface or pan is a common weather record. It is related to the water lost from the plants and bare surfaces in a paddock, so a cumulative total of water lost indicates when water in the soil profile is used. For example after irrigation the soil profile holds 150 mm of plant available water, then if evaporation is 5 mm/day (Table 11.3) the next irrigation will be at approximately 25 - 30 days.
Table 11.3. Average evaporation (mm/day) measured on dairy farms at different latitudes in subtropical Australia.

<table>
<thead>
<tr>
<th>Location</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Queensland</td>
<td>7.0</td>
<td>3.0</td>
</tr>
<tr>
<td>South East Queensland</td>
<td>7.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Northern New South Wales</td>
<td>5.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Evapotranspiration refers to the sum of water loss from the bare soil surface and through the plants. It is closely related to evaporation, but is considered a more accurate measurement of water loss from a paddock, and is calculated from weather data on rainfall, humidity, temperature and wind speed. It is then used in a similar way to evaporation measures.

Evapotranspiration is used to monitor soil moisture (Table 11.4). They are grouped as porous media (e.g. gypsum block), capacitance meters and neutron probe. The porous media are simple and relatively easy to use, and capacitance and neutron meters more sophisticated. They can each be read manually and some are automated to assist in decisions on when and how much water to apply.

Table 11.4. The three main types of in ground monitoring devices and the measures related to soil water content.

<table>
<thead>
<tr>
<th>Type</th>
<th>Measure</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous</td>
<td>Pressure or electrical resistance</td>
<td>Gypsum block</td>
</tr>
<tr>
<td>Capacitance</td>
<td>Electrical resistance</td>
<td>Enviroscan</td>
</tr>
<tr>
<td>Neutron probe</td>
<td>Resistance to neutron passage</td>
<td>Neutron moisture meter</td>
</tr>
</tbody>
</table>

Surface cover
Surface cover has two major effects on soil water balance.

- Firstly growing plants or mulch on the surface break down rain droplets as they fall and enhances water infiltration into the soil.
- Secondly surface cover reduces evapotranspiration. The water loss through growing plants over shaded soil is less than that from bare soil. Also a surface mulch will markedly reduce evaporation from the soil surface when no plants are covering the soil.

Heavy rain direct onto soil may cause soil particle breakdown, which in turn can impede water infiltration into the soil.
Water requirements

Evapotranspiration

Requirement is the water needed for evapotranspiration from planting to the end of the growing season. Evapotranspiration is typically 70 to 90% of evaporation as water loss from soil surface and through plants is less than from an open water surface in the sun (pan). As with evaporation daily averages will vary with seasons, from means of 1 - 4 mm/day during winter to 6 - 12 mm/day in summer.

Total evapotranspiration will be the mean daily rate multiplied by the number of days the forage is growing. Mean evapotranspiration increases with latitude, from approximately 4 mm/day in northern NSW to 6 mm/day in central Queensland. A difference of 2 mm/day increases water requirements by 400 mm for a 200 day growing season, or 4 ML extra water per hectare.

Effective rainfall

The amount of evapotranspiration that can be met by rainfall is termed effective rainfall. It is rainfall that infiltrates the soil rather than running off or evaporating before plants roots can access it.

During fallow periods 15 to 25% of rainfall is stored as soil moisture, the higher figures occurring with adequate surface cover. During the growing season the amount of rainfall that infiltrates the soil will vary with soil type, but an approximation is,

- Less than 5 mm/day is assumed lost to evaporation
- More than 50 mm/day runs off the surface.

In practice effective rainfall is typically 60 to 80% of total rainfall, depending on intensity of summer rainfall events, and may be up to 90% of winter rainfall.

Irrigation water required

Irrigation provides the difference between effective rainfall and evapotranspiration, plus any losses through drainage, excess evaporation from a wet soil surface and water left in the profile at the end of the growing season.

Irrigation management aims to minimise the inefficiencies of water use occurring through runoff, drainage and evaporation. Effectiveness varies between forages and seasons. Winter forages such as ryegrass generally receive more water than the deficit as evaporation is lower and plants are shallow rooted, meaning water is frequently applied to keep the top 40 cm above wilting point. Summer forages are deep rooting and evaporation is high, meaning water is more efficiently used (Table 11.5). Often with summer crops the profile is left dry at the end of the growing season, but this is not possible with shallow rooted forages.
Table 11.5. Evapotranspiration (ET), effective rainfall and irrigation applied to various forages grown in south east Queensland.

<table>
<thead>
<tr>
<th>Forage</th>
<th>ET</th>
<th>Effective rainfall</th>
<th>Irrigation applied (mm)</th>
<th>Irrigation applied (% deficit)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass</td>
<td>830</td>
<td>276</td>
<td>831</td>
<td>150</td>
</tr>
<tr>
<td>Forage oats</td>
<td>830</td>
<td>276</td>
<td>672</td>
<td>121</td>
</tr>
<tr>
<td>Lucerne</td>
<td>1626</td>
<td>573</td>
<td>1125</td>
<td>106</td>
</tr>
<tr>
<td>Maize</td>
<td>560</td>
<td>227</td>
<td>165</td>
<td>50</td>
</tr>
<tr>
<td>Forage sorghum</td>
<td>800</td>
<td>265</td>
<td>443</td>
<td>82</td>
</tr>
</tbody>
</table>

* Deficit refers to evapotranspiration less effective rainfall.

Water use efficiency
Increasing the output of forage and milk per ML of water will assist in making milk production profitable.

Definition
Water use efficiency (WUE) is measured as the amount of forage or milk produced per unit of water applied as irrigation and effective rainfall. It is usually expressed per mm or ML of water over the full growing season of the forage or annually.

An alternative definition of WUE is DM output per unit of evapotranspiration, which more directly compares the efficiency of plants. However in practice it is the water applied, rather than evapotranspiration, that is costed in budgets and they can be quite different (Table 11.6).

Table 11.6. A comparison of water use efficiency (kg DM/mm) for annual ryegrass, lucerne and maize expressed relative to water applied and evapotranspiration.

<table>
<thead>
<tr>
<th>Forage</th>
<th>WUE (water applied)</th>
<th>WUE (evapotranspiration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass</td>
<td>11.7</td>
<td>15.6</td>
</tr>
<tr>
<td>Lucerne</td>
<td>10.8</td>
<td>32.3</td>
</tr>
<tr>
<td>Maize</td>
<td>46.9</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Main factors in WUE
The major factors which influence WUE on subtropical dairy farms are:
- Plant species, especially C₄ species.
- Efficient irrigation systems.
- Boosting plant growth.
- Reducing water losses.

Applying water uniformly, when it is needed and in the right quantities makes for an efficient irrigation system, where a high proportion of the water applied is used for plant growth.

If plant growth is restricted by factors other than water input WUE will be reduced. Adequate plant population, weed control and soil nutrient supply are basic to achieving a high WUE. Soil conditions conducive to rapid root growth will also boost yield and WUE. Maintaining surface cover and avoiding long fallow periods will reduce water loss.

Tropical forage species have higher WUE than temperate species and using them in the forage system increases efficiency of forage production. Quality of forage is lower, but as part of an annual forage program they can increase milk output per unit of water.

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Defoliation practice
Grazing or cutting practices impact on WUE, through either increasing forage yield or reducing water needs. Management to optimise forage yield will increase leaf area, transpiration and usually increase WUE. Optimum grazing management practice has been defined for each forage species, designed to maximise the harvest of forage and enable rapid regrowth after grazing.

Repeated defoliation under grazing can affect plant regrowth capacity, root mass and time soil is exposed to sunlight. Increased evaporation from exposed soil may increase water demand.

Measured WUE
Maize has a relatively high WUE compared with other forages, as it has a relatively short growing season, is deep rooted and has a high yield of forage. Other tropical grasses have lower efficiency but are higher than the temperate species (Table 11.7). Maize maintains the advantage in terms of ME, due to the high grain content of maize silage. Other tropical grasses lose some of the advantage but still have a higher efficiency than temperate species.

Some measured WUE of other forages are prairie grass 8.3 kg DM/mm, white clover 7.3, lablab 9.6, and perennial ryegrass 11.

WUE of forage systems
When forages are combined into feeding systems WUE for milk is closely related to the amount of milk produced from home grown forage. WUE increased by 247 L milk/ML for each 1000 L additional milk produced per hectare from home grown forage. For example an irrigated temperate pasture system was more efficient than a dryland tropical grass system, producing 1267 and 1020 L milk/ML respectively. The greater production from the irrigated system meant that system was more efficient than the dryland system (Table 11.8).

Table 11.7. WUE measured for a range of forages in subtropical Australia.

<table>
<thead>
<tr>
<th>Cool season forages</th>
<th>WUE (kg DM/mm)</th>
<th>WUE (MJ ME/mm)</th>
<th>Warm season forages</th>
<th>WUE (kg DM/mm)</th>
<th>WUE (MJ ME/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass</td>
<td>11.7</td>
<td>114</td>
<td>Maize</td>
<td>47.0</td>
<td>516</td>
</tr>
<tr>
<td>Forage oats</td>
<td>9.2</td>
<td>95</td>
<td>Forage sorghum</td>
<td>16.4</td>
<td>154</td>
</tr>
<tr>
<td>Lucerne</td>
<td>10.7</td>
<td>97</td>
<td>Rhodes grass</td>
<td>15.2</td>
<td>132</td>
</tr>
</tbody>
</table>
Table 11.8. A comparison over three years in south east Queensland of the forage yield and WUE of feeding systems using dryland tropical grass and irrigated temperate grass.

<table>
<thead>
<tr>
<th>Forage system</th>
<th>Forage yield (t DM/ha/year)</th>
<th>WUE (kg DM/mm)</th>
<th>WUE (L milk/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical grass, dryland</td>
<td>6.7</td>
<td>16.7</td>
<td>1020</td>
</tr>
<tr>
<td>Irrigated, annual ryegrass in winter/spring, forage sorghum in summer</td>
<td>13.6</td>
<td>16.6</td>
<td>1267</td>
</tr>
</tbody>
</table>

Methods of application

General

The objective of an irrigation system is multifaceted and ideally it will:

- Deliver water to match plant evapotranspiration requirements.
- Supply adequate water for peak water requirements for all plant species grown at the site.
- Apply water uniformly across the irrigable surface.
- Minimise labour inputs with automation of startup and completion of irrigations cycles.
- Minimise energy use and decrease cost per ML of water pumped.
- Fertigate to increase nutrient use efficiency.

The correct irrigation system is very dependent on the purpose and site and potential increase in productivity, and gains in labour and water efficiency. It is designed specifically for the situation where irrigation is to be installed, and design should not be compromise the objective of the irrigation system. Even with forage production on dairy farms there is a wide range of options.

Some factors to consider when designing an irrigation system.

- Capacity to deliver required amount of water.
- The land profile.
- Labour needs.
- Level of technology or skill needed in operations and maintenance.
- Expected life of the system
- Commissioning of system to handover.

Types of irrigators

Irrigation methods are characterised by pressure required to force water to the field and rate of water flow (Table 11.9). Drip methods use both a low pressure and low water flow rate, and deliver water to a precise point with minimum loss. A low pressure is also used in centre pivots and lateral irrigators, though flow rate is high. Hand shift is intermediate, and the travelling gun irrigators use both high pressure and high flow (Table 56).

Electricity cost is closely related to pressure requirements, hence travelling gun irrigator has high pumping costs $100 to 120/ML (@ 100 psi at pump), compared to centre pivot with $35/ML (@ 40 psi at pump). Generally systems with a low capital cost tend to have high annual operating costs and vice versa.

Many factors affect the life of these units and it is likely water quality, maintenance levels and damage will determine this, rather than inherent life span. Unless there is sound evidence to the contrary it is prudent to assume that lifespan would be similar. Hand shift has the highest labour need, with most other systems being intermediate and centre pivots and drip systems the lowest. However drip systems require careful maintenance to flush the lines to minimise root invasion to assure long life.

Land profile is an issue for dairy farms, though centre pivot, hand shift and solid set have been successfully installed and used on undulating land.
### Table 11.9. Some advantages and disadvantages of different methods of applying irrigation water.

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip tape</td>
<td>Low pressure and water flow</td>
<td>More suited to permanent crop</td>
</tr>
<tr>
<td></td>
<td>Can irrigate frequently</td>
<td>Need overhead system at establishment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cannot be moved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Careful management needed</td>
</tr>
<tr>
<td>Lateral</td>
<td>Medium effect of wind</td>
<td>High pressure hose</td>
</tr>
<tr>
<td></td>
<td>An even DU</td>
<td>Maintain guidance furrows</td>
</tr>
<tr>
<td>Hand shift</td>
<td>An even DU</td>
<td>High labour needed</td>
</tr>
<tr>
<td></td>
<td>Suited to odd shaped paddocks</td>
<td>Not suited to tall crops</td>
</tr>
<tr>
<td>Travelling gun</td>
<td>Suited to tall crops</td>
<td>High pumping cost</td>
</tr>
<tr>
<td></td>
<td>Long, straight runs</td>
<td>Severely wind affected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large droplets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Application is generally high &gt;25 mm</td>
</tr>
<tr>
<td>Centre pivot</td>
<td>Low pumping costs</td>
<td>Require large contiguous area with only modest undulations.</td>
</tr>
<tr>
<td></td>
<td>An even DU</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can apply small volumes &lt;10 mm</td>
<td></td>
</tr>
<tr>
<td>Solid set</td>
<td>Suited to odd shaped paddocks</td>
<td>High capital cost</td>
</tr>
<tr>
<td></td>
<td>Low labour needed</td>
<td>Limits options for working paddock</td>
</tr>
</tbody>
</table>

**Maintenance**

It is important to periodically check current capacity against specified capacity. Checking capacity requires measures to be made of water flow at the pump and outlets, electricity usage and application uniformity. Nozzels require additional checks; ensure nozzle pressure is within the optimum operating range.

**Distribution Uniformity**

Distribution uniformity refers to the evenness of water application across the paddock. It is measured as a percentage, with 100% being totally even distribution. The acceptable minimum when tested with minimal wind depends on the type of irrigation system, even though in theory all systems can potentially achieve 100%. Minimum target for centre pivots and laterals is 90%, whilst for solid set, travelling booms and high pressure travelling guns the minimum standard is 80%.

Survey of subtropical dairy farms showed 40% of farms had DU below 70%. If some areas under irrigation receive only 80% of nominal water application, then the irrigation run time needs to be longer to ensure all areas receive at least the nominated amount. This results in overwatering on those areas where application rates are higher and inefficiency in use of water (Figure 11.3).

**Infiltration rate**

The rate of water application should not exceed the infiltration rate of that specific soil. Rate of application will set the period of time for each irrigation run. Infiltration rates of heavy black soils will vary according the soil water status with high rate of infiltration >10 mm/hr possible when the soil is dry and cracking, to a low rate of 1 - 5 mm/hr when the soil is wet.
Figure 11.3. The effect of distribution uniformity over a paddock on the amount of water needed to be applied to ensure all areas of the paddock receive at least the nominated 25 mm.

Low pressure applicators

General
Low pressure systems, especially the centre pivot, have become very popular because they require low labour, have relatively low electricity costs in their operation, provide flexibility in irrigation scheduling, and have a medium capital cost per hectare irrigated. ‘In most cases soon after a grower has installed a centre pivot, they begin planning for a second system.’

Application efficiency
Application efficiency is the percentage of water pumped which is used for evapotranspiration. It is relatively high with centre pivot applicators at 90 - 92%.

The primary means of water loss are wind drift of fine droplets and evaporation (Figure 11.4). These should total less than 10% of water pumped. With the centre pivot system losses through run off and deep percolation should be minimal because the volume and frequency of water applied can be controlled in small amounts. On larger centre pivots, rate of application on the outer spans can be high leading to run off because of the large area these spans have to travel. Losses through wind and evaporation can be managed through altering:

- Height of sprinklers to minimise the effect of wind.
- Increasing the droplet size from nozzles to avoid fine spray.
- Adjust nozzle size to increase or decrease application rate.
- Change emitter type to alter the wetted area and minimise the effect of wind.
Figure 11.4. A diagram showing the potential sources of water loss after pumping from a centre pivot.

**Distribution uniformity**

Centre pivots have the potential for very high distribution uniformity (DU) which is why 90% is considered the minimum standard. Distribution uniformity can be measured using catch cans (approximately 100 mm in diameter), preferably 200 under a pass.

The calculation is,

\[
\text{DU (\%) = 100 – [1 – (\text{sum of } Ss \times (D_s-D_a) / \text{sum of } D_sSs)}
\]

Where:

- \(D_s\) = depth of water in the individual catch can
- \(S_s\) = distance of the individual catch can from the centre of the pivot
- \(D_a\) = (sum of \(D_sS_s\))/(sum of \(S_s\))

Factors affecting DU are similar to those for application efficiency.

- Emitter spacing.
- Machine movement in relation to wind.
- Changes to flow rate with end gun operation.

**Pressure regulators**

As water is being applied along an extended boom and at potentially different elevations and flow rates, pressure regulators are often an advantage in maintaining DU. On undulating land, an unregulated system may result in some sprinklers operating at excess pressure and emitting very fine droplets. There should be less than 10% variation in pressure between sprinklers. Flow rates vary greatly as end guns come on and off during the rotation, hence it is recommended not to install these. Remember that in most instances water is the limiting factor not land area.

The effects of elevation on sprinkler pressure are shown in Figure 11.5. Those sprinklers at lower elevations have higher pressure and emit more water than those at lower elevations. Figure 11.6 is a useful guide to determine if pressure regulators are required. To some extent differences in elevation are compensated if
operating pressure is high, but there are limits to this compensation.

Unregulated system:
underwater at pivot,
overwater at outer end

Unregulated system:
overwater at pivot,
underwater at outer end

Unregulated system:
overwater at point B,
underwater at points A and C

Figure 11.5. The effects of undulating land on water pressure at individual sprinklers.

**Fertigation and Chemigation**

The uniformity and steady flow rate of the centre pivot offers the potential to apply fertiliser and chemicals through the water to increase nutrient use efficiency by the forage. Water quality is important as solids may precipitate out if water and additive are not compatible. The correct pump size is necessary to apply nutrients at the desired rate. Consideration must be given to the likely range in rate of nutrients per ha, concentration of nutrients in additive (%), and flow rate of irrigation system (L/hr).

Maintenance is important, especially flushing after the application to minimise corrosion. The chemical supplier should be asked if chemicals are suited to chemigation and if registered for use in this way.
Advantages of fertigation and chemigation:

- Nutrients can be supplied to the forage needs throughout the growing season i.e. maize.
- Improved uptake and nutrient use efficiency.
- Uniform application of nutrients.
- Reduced application costs.
- Minimal human contact with chemicals.

Disadvantages:

- High level of understanding required to achieve desired rate of nutrient application.
- Restricted range of suitable fertilisers.
- Additional pump and equipment is needed.
- Potential for accelerative corrosion of irrigator.

Scheduling

Scheduling with a centre pivot provides far greater flexibility compared to higher pressure systems. It is possible to water more frequently and lightly. The principle questions remain the same: when to irrigate and how much to apply.

Decisions are usually based on soil moisture monitoring, expected rainfall and soil type. As a general rule of thumb for forages grown on clays and loams, apply irrigation water when water is accessed from 40 cm. The volume of water applied should refill the soil profile. The soil water holding capacity and infiltration rate sets a limit to the amount of water that can be applied in one pass.

If the centre pivot cannot supply sufficient water during peak demand then "moisture banking" is possible, where extra water is applied early in the crop life to build up reserves of water deeper in the root zone, and this is used to complement irrigation during peak demand. Alternatively, an area under the centre pivot is dropped out of the irrigation rotation, thereby reducing the irrigable area to be watered. Remember a smaller area irrigated well will be more productive than a larger area which is under irrigated.

Wheel tracks

A specific issue with centre pivots is wheel tracks. The primary factors involved are,

- Soil type, heavy, poorly drained soils are most susceptible.
- The frequency of rotation.
The weight of the tower, associated with span length - do not exceed 50 m.

The wheel contact area with the soil.

Wheel tracks should not exceed 10 cm depth. Some management decisions can help prevent deep tracks.

- Avoid irrigation on wet soil.
- Minimize the number of rotations, especially during wet weather.
- Keep tyre pressure to recommended levels, and fit wider tyres.
- Raise the tracks with suitable material.
- Modify sprinklers near towers to avoid water falling in front of them - direction, height, use of boom backs.

**System capacity**

System capacity is the amount of water the system is able to deliver to the paddock, measured as mm/day. The key point in deciding on system capacity is peak demand for water, at the height of the crop growth. Calculated within the growing season for each crop by identifying the maximum cumulative evapotranspiration rate over 5 - 7 days. Other factors of importance are the rooting depth in the soil, which determines how much water can be stored, the infiltration rate for the soil, and pump capacity.

The systems capacity (Q) is defined as:

\[ Q \, (\text{L/second}) = 0.1157 \times A \times d \]

Where A is total ha to be irrigated, and d is required watering depth (mm/day).

**Towable centre pivot**

Many centre pivots are set in place, but some can be moved by towing behind a tractor. Key points to consider with towable centre pivots:

- Systems with a maximum of 2 - 3 spans are easier to move.
- A reliable means of lifting wheels for rotation, requires jacks or front end loader.

- Slow movement (<5 km/hr) along smooth lanes.
- Accuracy of anchoring each time important to avoid multiple ruts.
- If moving over slopes a second tractor may be needed to brace the end of the pivot.

**Corrosion**

As the centre pivot is designed to be used 20 hrs a day 7 days a week, potentially it is in almost constant use and there is a high potential for water to corrode parts. The pH of the water and salt content (Na, Cl, Mg, Ca, SO4) are potentially corrosive.

Galvanised pipe is unsuited to water with low pH or high chlorine and sulphate levels. Aluminium is unsuited to high pH water. PVC underparts can be used with all water types, as can stainless steel. Modifying materials for the water lines may add up to 15% to the cost of the unit, but will be economical in the longer term if water has the potential to cause corrosion. Avoiding long periods when static water sits in pipes will also prevent corrosion.

**Scheduling irrigation**

**Definition**

The practice of knowing how much water to apply and when to apply it. Inappropriate scheduling is the main source of inefficiency in irrigation and reduced productivity.

**Forage water use**

The main determinants of forage water use are:

- Climate. The evaporation varies markedly between seasons (Figure 11.7), but there is also substantial variation between adjacent days.
- Forage growth stage. Water use by a crop varies up to 8 fold between the establishment phase and at maximum growth. With grazed forages this pattern is repeated to some extent each time the forage is grazed and the leaf area is reduced.
- Surface wetness. A wet surface maximises the rate of evaporation.
Shallow rooted plants such as ryegrass draw much of their water for growth from the surface to 40 cm below ground level, but may use deeper water to “stay green”. Consequently such plants may reduce growth well before they show signs of moisture stress.

Figure 11.8 shows change in soil water pattern during growth and following irrigation. The aim is to refill the soil profile once soil water content falls to a depth for that soil, but avoid over watering. For established

forages growing in clay or loam soils with a uniform A-horizon, we recommend irrigating when the pattern of soil water extraction occurs at 40 cm.

Scheduling is most important in soils with low water holding capacity such as sand, and where most of the forages water input is from irrigation. When irrigation is interspersed with rainfall, errors in irrigation scheduling decrease although production and possible quality are compromised.

**Figure 11.7.** An example of seasonal variation in maximum and minimum temperature (lines), rainfall (solid column) and evapotranspiration (white column) in south east Queensland.
Figure 1.8. Diagram of daily change in soil water content in relation to field capacity, refill point and irrigation applications.

**Scheduling methods**

All scheduling methods are based on an assessment of forage need for water. One or more of the following are used in the assessment.
- The habits developed from experience.
- Assessment of water stress in the forage.
- Assessment of soil water content.
- Measures of evaporation.

Basing applications on experience takes into account many factors that cannot be measured or scheduled, but often leads to overwatering during seedling establishment and under watering during peak growth and evaporation. Water stress expressed by plants as leaves wilting normally occurs once plants are severely stressed, production is reduced well before wilting is evident.

The most accurate means to schedule is to monitor soil water content, and apply water once this falls to a certain level, this is termed the ‘refill point.’

Evaporation can be summed daily to provide a cumulative deficit (Table 11.10). Once the deficit reaches a certain point e.g. 25 mm for ryegrass, water is applied.

<table>
<thead>
<tr>
<th>Day</th>
<th>Evaporation (mm/day)</th>
<th>Rainfall (mm/day)</th>
<th>Cumulative water loss (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>0</td>
<td>25</td>
</tr>
</tbody>
</table>

**Table 11.10. Calculating net cumulative evaporation rate (mm).**

**Terms**

RAW – readily available water. The water between field capacity and the refill point.

AWC or PAWC – Plant available water content. Water available between field capacity and maximum rooting depth.

**Application**

Ryegrass is a shallow rooted plant and applying more than 25 mm at any time is likely to move water below the root zone. Light applications of 10 - 15 mm are required each 3 - 7 days during the
3 weeks of establishment, then 25 mm at 14 - 20 day intervals during winter and 10 - 12 day intervals during spring. Deeper rooted crops, and especially single cut crops such as maize, can utilise water at 50 to 100 mm depth. However, it is recommended to irrigate before the soil water content is depleted because many irrigation systems do not have the capacity to apply water surplus to the crops requirements.

Rule of thumb – 10 L of water applied over 1 m² will recharge soil water content to a rooting depth of 1 cm on good quality soils.

Up to 30% water savings have been shown when experience is combined with monitoring of evaporation and using this to help schedule applications.

With grazed forages the application of irrigation must also enable grazing at appropriate intervals, typically this restricts watering just prior to grazing.

Local knowledge on the farm is important for adjusting schedules, for example wet flats, drying winds and soil variations will modify the need for water application. The benefit of monitoring water deficit or soil water content will largely be through a more informed knowledge of how much water to apply when irrigation is scheduled, so saving cost and environmental effects of excessive watering.

Dairy forages
Scheduling needs to take into account the defoliation cycle of the forages and the practical aspects of cow access to forages for grazing at optimum times. Thus irrigation scheduling for dairy forages will always be a balance between optimum for the plant and for the grazing animal.

More often than not there is insufficient water to meet the evapotranspiration requirements of all forages across the farm. We recommend calculating the seasonal water requirements for each forage using ICalc. Growers need to prioritise water according the value of the crop which is dependent on yield, quality, amount of stored feed, input costs and time of year. High value forages are watered to maximise yield and quality, lower priority forages may be irrigated once or twice to support germination and seedling establishment. Allocation of irrigation water will vary from year to year and should be adjusted regularly. Table 11.11 provides a decision check-list for irrigating.

Many growers plant large areas of forage in excess of irrigation allocation or system capacity and gamble on rainfall to provide sufficient water. Often enough water can be applied during establishment, but moisture stress typically occurs when growth rates and evapotranspiration rates increase during August and September. At this point, the irrigable area should be reduced and irrigation focused on a smaller area to achieve high production from this area.
Table 11.11. An irrigation decision check list for a dairy farm.

<table>
<thead>
<tr>
<th>Forage requirements</th>
<th>Determine forage requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal water requirements</td>
<td>Calculate the likely water needs. Consider dry, average or wet year.</td>
</tr>
<tr>
<td>Prioritise forage species</td>
<td>Prioritise forages is terms of quality and yield. In dry years high yielding forages are</td>
</tr>
<tr>
<td></td>
<td>a high priority. Following wet years and with a large amount of conserved feed at hand,</td>
</tr>
<tr>
<td></td>
<td>select forage high in quality.</td>
</tr>
<tr>
<td>Monitor water status of soil, bores and</td>
<td>Soil water content is most effective and robust.</td>
</tr>
<tr>
<td>of storage</td>
<td></td>
</tr>
<tr>
<td>Assess forage needs for farm for a</td>
<td>Calculate the seasonal forage requirements of the milkers and dry stock.</td>
</tr>
<tr>
<td>minimum of 6 months</td>
<td></td>
</tr>
<tr>
<td>Consider cow access or harvest</td>
<td>Forage growth stage and soil firmness.</td>
</tr>
</tbody>
</table>

### Pumps and pipes

**Efficiency**

The efficiency of an irrigation system generally refers the electricity and labour used to pressurise and distribute water. Some measures of efficiency are running costs ($/ML), friction losses and leaks in mains, application amount and rate (mm/hr) and distribution uniformity (5).

**Evaluating efficiency**

Key measures for evaluating efficiency are:
- Operating pressure.
- Pump efficiency.
- Pumping costs.
- Application amount.
- Distribution uniformity (DU).

Because irrigation is used regularly, a decline in efficiency can develop without the grower being aware. Hence an annual evaluation of the irrigation system is recommended.

**Pump efficiency**

Pump efficiency is the power output of the pump compared to the power delivered to the pump, the target is 70%. On average 87% of electricity costs are from running the pump. Causes of poor pump efficiency are; incorrect pump selection especially undersized, incorrect size of suction line and mainline, and routine wear and tear and from poor water quality.

To calculate pump efficiency:
- Record the pumping rate (L/s) using a flow meter.
- Record kilowatts of electrical energy from meter (kW/hr). The KW usage can be read from the meter taking a start and finish time and expressing the value as KW/hr.
- Record the operational pressure reading from the pump pressure gauge (psi).
- Measure the suction lift in metres (vertical distance between the pumping water level and the pump).

Pump efficiency \((Pe) = (0.98 \times Q \times H)/(KW \times Me \times Df)\)

Where:
- \(Pe\) = pump efficiency as a %
- \(Q\) = pump discharge in litres/second
- \(H\) = total pump head in metres
- \(kW\) = electrical kilowatts
- \(Me\) = motor efficiency as a decimal: 7.5 – 18.5 kW = 0.8;
- 822 – 55kW = 0.90;
- 75kW and over = 0.92
- \(Df\) = Drive factor:
- Direct coupled = 1.0;
- Gear drive = 0.95;
- Vee belt = 0.93;
- Flat belt = 0.88

**Note:** Compare pump efficiency to the pump performance curve to determine efficiency loss from wear and tear. Accurate measurements are required for assessment of efficiency.
Table 11.12. An example of calculating pump efficiency.

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pump rate: litres per sec Q</td>
<td>30</td>
</tr>
<tr>
<td>2. Electrical energy kW</td>
<td>55</td>
</tr>
<tr>
<td>3. Pressure gauge: kPa x 0.102 or psi x 6.895 x 0.102 m</td>
<td>104.6</td>
</tr>
<tr>
<td>4. Suction lift (m)</td>
<td>4</td>
</tr>
<tr>
<td>5. Motor efficiency (Me)</td>
<td>0.92</td>
</tr>
<tr>
<td>6. Drive type (Df)</td>
<td>0.93</td>
</tr>
<tr>
<td>7. Pump efficiency (Pe)</td>
<td>= 66%</td>
</tr>
</tbody>
</table>

References and further information
Callow (2011).
Glendinning (199).
ICalc
Warren and Miller (2012).
Chapter 12. Cow nutrition

A knowledge of cow nutrition assists in allocating forages, concentrates and byproducts in the most productive and efficient manner. The rumen is very important to the nutrition of cows and understanding rumen needs for nutrients is a first step in dairy cow nutrition.

Rumen function
The dairy cow rumen is capable of converting large amounts of forage into nutrients for milk production.

Rumen
The rumen refers to the first 2 chambers of the cows gut (reticulo-rumen), where feeds are digested by microbial fermentation (Figure 12.1). The rumen is an anaerobic, meaning fermentation goes on without oxygen. The rumen is a large organ, capable of containing up to 100 kg of feed and water mix (approximately 1:9). The rumen responds to improved feeding, increasing in size and thickening of walls, and these changes precede responses in animal weight or milk production. Gases including carbon dioxide (CO₂) and methane (CH₄) are a byproduct of fermentation, an animal will expel between 600 to 1200 L/d depending on diet and dry matter intake.

Rumen microbes
The primary microbes are bacteria, fungi and protozoa. There are two main groups of rumen microbes: the slow-working fibre-digesters located on the fibre mat at the top of the rumen, and the fast-working microbes that float in the rumen fluid and primarily digest more simple carbohydrates such as sugar and starch. Bacteria are the most numerous, but there are hundreds of species of each. The species mix will change with a change in diet, taking from 1 to 3 weeks for adaptation. The microbes break down feed to grow and produce volatile fatty acids (VFA) as a by product, which are absorbed through the rumen wall and used by the cow as energy for maintenance and milk production. VFA supply up to 80% of the energy used by the cow. The rumen microbes move through to the abomasum and intestine for digestion and absorption. These microbial cells are the main protein source for milk production, providing 70 - 90% of a cow's protein requirements.

Since the majority of protein and energy for milk production comes from the rumen the primary purpose on feeding dairy cows is to maximize rumen function.

Effects of feeding
Because each group of microbes has very specific functions - like digesting fibre, starch, sugar or protein - the numbers of each are directly related to diet. A minimum amount of longer (>2 cm) fibre particles is needed to form the rumen mat which is required for optimal microbe production. The type of feed, especially its fibre content influences the type of microbe in the rumen, the speed of digestion, and the total intake of dry matter and nutrients. Concentrates and lush forage containing lower amounts of fibre build up the quick-working ‘floating’ microbe population, and feed is moved quickly through the rumen and digestive tract.
The cow wants more food, and intake is potentially increased.

Mature forages contain higher fibre and lower soluble nutrients, which build up the slow-working, fibre-digesting microbes and cause feed to move more slowly through the system. The cow feels less hungry, and intake is reduced.

Microbe populations take time to recover and build up after sudden feed changes. Forage digesting microbes may take 4 - 6 weeks to build up numbers, starch (grain) digesting microbes 4 - 5 days, and lactic acid-producing bacteria (from slug feeding) take 2 - 4 hours. If the diet keeps changing every few days the required microbes will not be present in sufficient numbers for optimum digestion. The diet should therefore be as consistent as possible.

**Nutrients required**

Because a large proportion of the animals nutrient supply comes from the rumen, the nutrients required by the rumen are very similar to those required by the cow.

**Water**

Cows require up to 100 L of drinking water/cow/day, to maintain the rumen liquid environment, which contains up to 80 L water, support microbe metabolism and dilute acids in the rumen. Cows should have access to water in paddocks, feedout areas and at the dairy. Cows are particularly thirsty after milking, so provide water at both dairy exit and entry points. Water intake is affected by water cleanliness and salt/mineral content.

**Energy**

Most energy for microbes to grow and multiply is sourced from:
- Starches e.g. cereal grains.
- Sugars e.g. lush forages, molasses and citrus pulp.
- Digestible fibre e.g. forages, cottonseed hulls, palm kernel extract and brewer's grain.

**Protein**

Microbes use both true protein e.g. protein meal and protein in pastures and non-protein nitrogen e.g. urea for growth and reproduction.

**Minerals**

Depending on the forage sources, calcium, phosphorus, sulphur and magnesium are often required as supplements for microbes to grow and multiply.

**Effective fibre**

The rumen requires longer feed particles (2 - 5 cm long) to stimulate cud chewing and rumination and to stimulate sufficient saliva secretion. Effective fibre is that fibre which promotes rumination and microbial digestion, rather than being inert in the rumen. Usually sufficient is provided with 28 - 34% neutral detergent fibre (NDF) in the dry matter. Higher levels tend to increase the amount of inert fibre, and slow intake of digestible forage.

**Rumen health**

**pH**

pH measures the acidity or alkalinity of the rumen fluid. A pH 6.2 - 7.0 (neutral to slightly acid) is ideal for all rumen microbes. A pH below 6.2 slows fibre-digesting bacteria, and a pH below 5.4 will cause fibre-digesting bacteria to die, lactic acid bacteria increase, and acidosis results.

**Rumination**

During rumination, or cud chewing, salivary glands secrete up to 100 L/day saliva into the rumen. The bicarbonate in saliva buffers the acidity from VFA production and maintains rumen pH. The most common factor affecting rumen health is a change in the forage to grain ratio. This may be sudden, for example cows refuse to eat a new forage yet continue to eat their grain, or more gradual as happens with seasonal changes in pasture and forage condition. A safe working range of forage to concentrate ratio is 40:60 to 60:40 DM. This range
enables high production by the cow and maintains a healthy rumen.

**Activity**
A healthy rumen has 1 - 3 contractions each minute.

**Indicators of rumen health**

**Milk production and composition**
Milk production and composition are readily available and useful indicators of rumen health. Daily milk production will show up any variation.

Any large variation in milk composition indicates an inconsistent diet. Sudden changes in daily milk production are usually the result of rumen problems, through a sudden reduction in feed intake. This may be caused by cows refusing to eat different forage types or a metabolic disorder in the rumen.

A decline in milk fat below 3.3% often indicates a lack of effective fibre, and a decline in milk protein by 0.25% units over 1 - 2 days may indicate a reduced intake or lack of digestible energy in the diet.

Farms that regularly check and formulate diets generally have less variation in diet quality and milk composition.

**Number of cows ruminating**
At least 50% of the herd chewing their cud when resting indicates good rumen health.

**Manure composition**
Check manure regularly for consistency and undigested feed.

- Normal manure is a well formed pat with dimple in top (Figure 12.2). If manure is thick and dry it indicates too much fibre. Very liquid manure often indicates not enough fibre.
- Bubbly manure indicates hindgut fermentation of starch and is an indication of acidosis. Mucous in manure indicates sloughing of lining of the intestines and is also an indication of acidosis.
- Grain in manure indicates it is passing too quickly through the rumen, possibly due to a lack of NDF in the diet or grain not processed sufficiently for optimal digestion. Red sorghum grain is protected by an outer tannin coating which inhibits digestion.

![Figure 12.2. Examine formation of manure to assess fibre content, acidosis, and look for undigested grain.](image)

**Body condition**
General body condition, including coat condition, is an indicator of overall herd health, including rumen function.
Cow nutrient requirements
A herd with a high capacity for milk production will have a high intake and be efficient in converting feed into milk.

Capacity
The cow has a capacity for dry matter intake and milk production which is set by her genetic make up and rearing and feeding practices. Genetic make up sets the potential for growth, live weight and milk production and composition. Rearing and feeding practices will determine how close to this potential the animal achieves.

Rearing
Rearing practices have their major effect through live weight and age at first calving. Live weight is important as the heifer’s ability to eat is related to her live weight. Often dry matter intake is 3 - 3.3% live weight during lactation. The target is to achieve 80% of mature weight at first calving.

A delay in first calving usually causes an economic loss as the animal takes longer to begin producing an income.

Genetics
Genetic merit refers to a number of criteria for the cow, including milk production and composition, fertility, fitness in the system of production and milking ease.

- Fitness refers to aspects like walking ability, resistance to footrot and foraging drive.

Genetic merit is extremely important as it sets the potential of the cow.

The genetics need to be selected for the system of production. For example the Holstein Friesian has been bred for a high volume of relatively low fat milk under very intensive feeding systems, whereas the Jersey and its cross breeds are more suited to extensive grazing systems where the focus is on production of milk solids.

Dry matter intake
Dry matter intake (DMI) is the fundamental feature of milk production. All important aspects such as live weight, body condition, milk production and fertility are dependent on dry matter intake.

Cows have a minimum requirement for protein and energy to maintain normal body functions known as their ‘maintenance’ requirement which is a DMI of approximately 1.5% live weight. Increasing DMI beyond this provides more nutrients to rumen microbes, which in turn provides more nutrients to the cow for milk production and composition, growth, reproduction and body condition.

Dry matter intake (DMI) is the fundamental feature of milk production. All important aspects such as live weight, body condition, milk production and fertility are dependent on dry matter intake.

Every day, an efficient milking cow needs a dry matter intake equivalent to 3 - 4% of her body weight. A high-producing (>30 L/day) 600 kg cow could eat 600 kg x 4% = 24 kg DM/day.

The efficiency of milk production is also strongly influenced by DMI. The feed conversion efficiencies (FCE) in Holstein Friesian cows increases from 1 to 1.5 L milk/kg DM as DMI increases (Figure 12.3), and in very high producing herds may reach 1.8 L/kg DM.
Figure 12.3. The effect of increasing dry matter intake on the efficiency of milk production in dairy cows.

**Estimating DMI**

Estimating DMI of cows can be calculated several ways. The first is to measure how much they are eating by weighing feeds and measuring dry matter content of feeds. The second is to estimate using live weight and milk production.

1). Weigh daily allocations of grain, protein meals, conserved forages and hay. Intake of pasture and forage crops are more difficult to estimate. However, visual estimation, cutting quadrats and using rising plate meters are ways of estimating pasture/forage intake levels. Estimates of forage yield are made before and after grazing. None of these measures under grazing are accurate, but they can give a guide to assist in management decisions when one forage is being grazed. The task becomes particularly difficult when two or more forages are being grazed.

Always compare feed intake on the basis of dry matter content. There are two common ways to determine the dry matter content of feeds.

- Weigh, dry and reweigh samples of each feed in an oven or microwave.
- Obtain an approximate dry content from feed tables.

The DMI is then calculated as:

\[ \text{DM intake (kg)} = \text{kg of fresh feed (as fed)} \times \text{DM\%} \]

E.g. 40 kg fresh feed x 50% DM = 20 kg DM.

2). A proven and tested method of forage intake is from milk production, live weight and the amount of concentrate fed daily. Then by using FCE equations forage intake can be calculated (Table 12.1).
Table 12.1. An example of estimating the amount of milk that is being produced from forage using local knowledge on feeds.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Amount (kg DM/day)</th>
<th>Milk factor* (L/kg DM)</th>
<th>Milk (L/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain meal</td>
<td>6</td>
<td>1.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Hay</td>
<td>2</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Total milk yield</td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Milk from forage</td>
<td></td>
<td></td>
<td>19 – 8.6= 10.4</td>
</tr>
</tbody>
</table>

3). Milk from forage can be used as an index of the contribution forage is making to milk production.

- Potential of temperate forages 16 L/day.
- Potential of tropical forages 12 L/day.

Predicted FCE’s for different feed types for cows producing medium and high milk yields are shown in Table 12.2.

Table 12.2. Examples of milk factors for converting feed intake to milk yield.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Average milk yield (L/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain mixes</td>
<td>10 - 20</td>
</tr>
<tr>
<td></td>
<td>20 - 30</td>
</tr>
<tr>
<td>Molasses</td>
<td>0.8</td>
</tr>
<tr>
<td>Maize silage</td>
<td>0.9</td>
</tr>
<tr>
<td>Hay (high quality)</td>
<td>1.0</td>
</tr>
<tr>
<td>Hay (low quality)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Factors affecting dry matter intake

Feed availability

The amount of feed on offer must be sufficient to satisfy appetite and meet production targets. It is recommended to provide sufficient area which enables all cows access to feed, particularly at troughs or on a feedpad (0.5 m/cow). It is normal to feed to 5% refusals for cows at a feed pad or trough, to allow for day to day variations in intake. Refusals are collected and fed to growing or dry stock.

Under grazing it is necessary to balance intake per cow and pasture harvested per hectare. With temperate pastures such as ryegrass a forage yield on offer of 1.5 - 2.0 t DM/ha and grazed to a 5 cm stubble allows efficient pasture harvest and higher feed intake. Total intake per cow will increase with the area of ryegrass offered, and is close to maximum at 50 to 75 cows/ha/day at 1.5 - 2.0 t DM/ha on offer.

Intake of tropical grasses and forage crops is maximised when cows have access to high leaf yields. Yields of 1 t leaf DM/ha (2 - 3 t total DM/ha) are associated with maximum intake. Intake falls markedly when >75% of leaf is removed. Recommended post-grazing residual for kikuyu is 7 cm, this way intake is not limited and senescence of leaf biomass is minimal. Summary of indicators to assess if level of intake is appropriate is provided in Table 12.3.
Table 12.3. Indicators of adequate and inadequate dry matter intake by dairy cows.

<table>
<thead>
<tr>
<th>Adequate</th>
<th>Inadequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield and composition on target</td>
<td>Low milk yield and a decline or inconsistency with composition from day to day</td>
</tr>
<tr>
<td>Lush pasture allocation not fully eaten</td>
<td>Cows seem hungry, bellowing, waiting for feed</td>
</tr>
<tr>
<td>Silage, grain or mixed feed remaining in troughs</td>
<td>Cows rushing to fresh forage, to feed troughs, and into the dairy for grain</td>
</tr>
<tr>
<td>Cows not standing ‘waiting to be fed’</td>
<td>Cows eating all feed allocated in paddocks and troughs</td>
</tr>
<tr>
<td>Body condition score on target</td>
<td>Low body condition score</td>
</tr>
</tbody>
</table>

Feed quality
The diet needs to be well balanced for energy, protein and fibre to maximize intake. Mould, spoilage and moisture content reduces feed quality and palatability.

High NDF in individual feeds and the total diet will restrict the cow’s ability to consume a high intake. Neutral detergent fibre in forages and the total diet determines dry matter intake. Diets need to be balanced to contain sufficient and effective NDF for healthy rumen function while not providing too much fibre, as this slows down digestion and limits intake.

As a general rule of thumb, the maximum intake of NDF in the total ration is 1.2% of body weight (1.3% for a high-producing cow). More than this slows digestion and restricts intake (Table 12.4). The maximum NDF intake from forage only is 1% of the cow’s body weight. Example: A 600 kg cow can consume 600 * 1.2/100 = 7.2 kg NDF daily. Of this 600 * 1/100 = 6 kg NDF can come from forage.

Optimum intake is achieved when NDF content is 28% to 34% of total diet as DM.

Table 12.4. Effect of neutral detergent fibre (NDF) content of the forage on total intake of a dairy cow weighing 600 kg.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Temperate forage (ryegrass)</th>
<th>Tropical forage (sorghum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF (%DM)</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Maximum NDF intake from forage (kg/day)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Maximum forage intake (kg DM/cow/day)</td>
<td>13.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Maximum concentrate intake (kg DM/cow/day)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Maximum total intake (kg DM/cow/day)</td>
<td>21.3</td>
<td>16.6</td>
</tr>
</tbody>
</table>
Other factors

Feed preparation
Attention to aspects such as area of pasture allocated each day, location of water in relation to the paddock and water quality, chop length of silage, processing of grain, thorough mixing and cow preferences will ensure optimum intake.

Cow size
Bigger cows have a higher capacity to eat than small cows (intake increases by about 3.5 kg for each 100 kg live weight), but also have a higher maintenance requirement (about 1.2 kg for each 100 kg live weight). Consequently if intake is restricted big cows may suffer more than small cows.

Rumen health
A well developed rumen, with a microbial population adjusted to the diet, will accommodate a high intake for feed.

Stage of lactation
The intake of a cow increases during the first 2 to 3 months of lactation and then gradually declines as the cow enters late lactation. Maximum intake is approximately 1 month after maximum milk yield.

Heat stress
Cows intake reduces when they are experiencing heat stress, almost no effective grazing occurs at temperatures >30°C. Grazing intensity will increase at night but can compensate for reduced day time intake only up to daily maximum of 27°C. Beyond this total daily intake will be reduced.

Body Condition Score
Body fat is mobilised and used as an energy source for milk yield and composition when feed intake is insufficient to meet energy demands, particularly in early lactation. Cows calving in ideal body condition have sufficient energy reserves to reach potential peak yield. Also their body condition is unlikely to fall to a level that affects fertility. However, overfat cows at calving can suffer from ketosis and calving difficulty. Ketosis is another way of saying fat is used for energy and ketones are produced as part of the metabolic process.

Body condition targets for different stages of lactation have been set for Australian dairy herds. Regular use of body condition scoring (BCS), which visually assesses body fat cover around the tail, pin and hip area, can provide a picture of the body condition profile of the herd.

The most common BCS system in Australia is based on a 1 - 8 scale, where a score of 1 is emaciated and a score of 8 is obese.

Five key body areas are assessed (Figure 12.4):
- Area between the tail and the pin bones.
- Deepness inside the pins: hollow, slightly hollow, full.
- Backbone: ridgey, bumpy, flat.
- Hip: protruding, sharp, rounded.
- Depression between the hip and pin bones: over the rump - deep, flat.
Recommendations when condition scoring:

- Stand 5 - 10 m away from the rear of the cow.
- Record individual cow id and condition score.
- Use a consistent method; preferably have more than one person condition scoring for a more impartial result.
- Monitor seasonally calved herds for body condition 8 - 10 weeks before drying off, just before calving, and two weeks before mating.
- Monitor year-round calving herds monthly, and record days-in-milk (DIM) or stage of lactation. An ideal time to record would be at herd recording time, including cows due to calve (zero DIM).

Ideally calve cows at a score of 5 - 5.5 (Table 12.5) and in the first two months of lactation, lose no more than 0.75 of a condition score. At peak lactation body condition should not drop below 4 - 4.5. The target is then to recover this condition and dry cows off at the condition required at calving (5 - 5.5). Body condition is maintained during the dry period.

**Analysing body condition scores**

The most effective means of analysing BCS for a herd is to graph the BCS against days in milk (DIM). There are programs to assist with this ([www.dairyinfo.biz](http://www.dairyinfo.biz)). Ideally, 80% of the herd are within 5% of the ideal target for each stage of lactation. Figures 12.5 provides examples of herd profiles and general interpretation.
Table 12.5. Preferred BCS at different stages of lactation

<table>
<thead>
<tr>
<th>Stage of lactation</th>
<th>BCS &lt;4.5</th>
<th>BCS 5.0–5.5</th>
<th>BCS &gt;6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediately after calving</td>
<td>Too thin; risk of metabolic diseases such as ketosis and milk fever plus retained membranes.</td>
<td>Ideal condition; should produce to potential if other management OK.</td>
<td>Too fat; risk of ketosis and other metabolic diseases such as fatty liver syndrome.</td>
</tr>
<tr>
<td>100 DIM</td>
<td>Cows may lose up to 0.75 of a condition score after calving, but score should remain above 4.</td>
<td>Too fat for this stage of lactation and peak milk yield; ration may be too high energy/too low protein.</td>
<td>Too fat; ration may be too high energy and/or low in protein.</td>
</tr>
<tr>
<td>200 DIM</td>
<td>Too thin; cow not performing to potential.</td>
<td>Score 5–5.25 ideal; but score 5.5 may be too fat at this stage of lactation.</td>
<td>Too fat; ration may be too high energy and/or low in protein.</td>
</tr>
<tr>
<td>300 DIM – dry off</td>
<td>Too thin for next lactation; ideally only increase condition by 0.25–0.5 during the dry period.</td>
<td>Ideal condition; maintain this through dry period.</td>
<td>Too fat, but best to maintain condition until calving; will be risk of ketosis at calving.</td>
</tr>
</tbody>
</table>

Figure 2.5. Two examples of herd profiles of body condition score. In Herd A cows dry off at the target body condition, but lose BCS during the dry period as demonstrated in early lactation. In Herd B cows are at target BCS, but do not lose condition during early lactation.
Chapter 13. The feeds for cows

A knowledge of the major nutrients in feed and methods of balancing the diet will facilitate a high intake, milk efficiency and milk components.

Nutrients

The nutrient groups in feed are energy, protein, minerals, vitamins and water. For ruminants it is rare to consider vitamins as the microbes in the rumen normally produce sufficient. Nutrient requirements refers to the sum of a particular nutrient need for the various body processes,

- Maintenance of the body.
- Milk production.
- Live weight gain.
- Foetal growth.
- Activity.

Usually energy requirements are worked out in detail and other nutrients expressed relative to energy. Energy is the major nutrient and used for all processes in the body. It is provided from a variety of sources, including the breakdown of protein.

Protein is needed for the synthesis of body and milk protein and is provided from feed protein and microbial protein in the rumen.

Minerals are needed for body growth and milk production and for many chemical processes in the body. They must be provided in the feed.

Water is essential as a carrier and medium for all body processes.

Energy needs of a typical cow are showing the major demands are for milk production and maintenance (Table 31.1).

Table 13.1. Energy requirements of a lactating cow.

<table>
<thead>
<tr>
<th>Body function</th>
<th>Energy (MJ ME/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance (600 kg)</td>
<td>70</td>
</tr>
<tr>
<td>(0.55 MJME/kg LW^{0.75})</td>
<td></td>
</tr>
<tr>
<td>Milk production (24 L @ 5.1 MJME)</td>
<td>122</td>
</tr>
<tr>
<td>Live weight gain (0.2 kg)</td>
<td>8</td>
</tr>
<tr>
<td>(kg@ 40MJME/kg)</td>
<td></td>
</tr>
<tr>
<td>Foetal growth (mid term)</td>
<td>8</td>
</tr>
<tr>
<td>Activity</td>
<td>14</td>
</tr>
<tr>
<td>(20% maintenance)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>222</td>
</tr>
</tbody>
</table>

Energy

Energy is measured as megajoules (MJ) of metabolisable energy (ME). The main feed energy sources are carbohydrates (starch, sugar, digestible fibre) and fat. Protein in feeds can also be used as an energy source, especially if protein content of the diet is higher than required. Much of the feed energy (60 - 90%) is fermented by rumen microbes and

converted to volatile fatty acids (VFA: acetic, propionic, butyric), which are absorbed through the rumen wall and used by the cow as energy. Volatile fatty acids are the major energy source for the cow.

Starch

Starch is a complex carbohydrate that is readily fermented in the rumen, producing a high yield of propionic acid which boosts milk yield and milk.
protein content. Sources include cereal grains, cereal silage (including corn, barley, sorghum and wheat silage), vegetable waste (including potatoes, peas and beans), bread and bakery waste. Pulses (chickpeas, mung beans, fava beans) contain low starch levels but high levels of other complex carbohydrates which are fermented in a similar way to starch. Similarly ryegrass pastures contain low levels of starch during the vegetative and reproductive growth stages but high levels of sugars when grazed at the 3 leaf stage.

The time taken for rumen digestion varies from 2 hours for potatoes to 10 hours for sorghum grain (Table 13.2). Processing of feed changes the speed and extent of digestion of starch by rumen microbes. The more highly processed the grain, the greater the surface area to volume and the faster and more thoroughly starch is broken down by rumen microbes.

**Table 13.2.** Starch content and fermentation time in the rumen for some common feeds.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Starch content (% DM)</th>
<th>Time in rumen (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>64 - 67</td>
<td>2.5</td>
</tr>
<tr>
<td>Barley</td>
<td>52 - 56</td>
<td>3.3</td>
</tr>
<tr>
<td>Corn grain</td>
<td>64 - 70</td>
<td>5</td>
</tr>
<tr>
<td>Sorghum</td>
<td>62 - 66</td>
<td>10</td>
</tr>
<tr>
<td>Potatoes</td>
<td>65 - 75</td>
<td>2</td>
</tr>
<tr>
<td>Bakery waste</td>
<td>40 - 60</td>
<td>4</td>
</tr>
</tbody>
</table>

Sugar
Sugars are simple carbohydrates compared with starch, and also are used as energy by rumen microbes. They are very rapidly fermented in the rumen, within 15 - 45 minutes of intake.

Ryegrass has a higher sugar content than tropical grasses (Table 13.3). The levels of sugar in grasses increase throughout the day with photosynthesis and peak late in the afternoon. Other sources include fruit, fruit byproducts such a pineapple pulp and molasses.

Too much sugar (or highly refined starch) in the diet can cause rumen pH to drop rapidly (acidosis), lowering the number of fibre digesting rumen microbes and increasing those producing lactic acid. Ketosis and laminitis can follow. A sugar content in the total diet of 5 - 10% is considered appropriate.

**Table 13.3.** Sugar content of a range of feedstuffs fed in northern Australia.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Sugar (% DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryegrass</td>
<td>4 - 14</td>
</tr>
<tr>
<td>Tropical grass</td>
<td>3 - 10</td>
</tr>
<tr>
<td>Molasses</td>
<td>75 - 80</td>
</tr>
<tr>
<td>Citrus pulp</td>
<td>20 - 25</td>
</tr>
<tr>
<td>Ripe bananas</td>
<td>20 - 25</td>
</tr>
<tr>
<td>Fruit waste</td>
<td>10 - 25</td>
</tr>
<tr>
<td>Sugar cane stalk</td>
<td>25 - 35</td>
</tr>
</tbody>
</table>

Fibre
Fibre is a general term for the structural material of plants, mostly cell walls. In lush, young plants the cell walls are thin and mostly digested, whereas in older plants the walls thicken and are only partly digested. Neutral detergent fibre is an analysis of the amount of fibre in the cell walls. It includes both fibre that the microbes in the rumen can ferment and fibre they cannot (ADF, acid detergent fibre). Forages low in NDF (< 40%
DM) are often very low in ADF, and cell walls are easily fermented, whereas forages high in NDF (> 60% DM) usually have a high ADF fraction.

Neutral detergent fibre is likely to be lower and more digestible when pastures are young and lush (Table 13.4) and higher and less digestible when pastures are mature and setting seed. Neutral detergent fibre is a useful guide to dry matter intake, as it is a measure of the total fibre the cow will be eating and so the likely amount of time the forage will take to ferment in the rumen. Cows can process about 1.2% live weight as NDF daily.

ADF tends to be more closely related to the average digestibility of the forage, as it is the indigestible fraction.

**Table 13.4.** The NDF content of some forages and grain used in subtropical dairy feeding systems.

<table>
<thead>
<tr>
<th>Feed</th>
<th>NDF (% DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>35</td>
</tr>
<tr>
<td>Clover</td>
<td>25</td>
</tr>
<tr>
<td>Rhodes grass</td>
<td>50</td>
</tr>
<tr>
<td>Kikuyu</td>
<td>45</td>
</tr>
<tr>
<td>Lablab</td>
<td>-</td>
</tr>
<tr>
<td>Grassy lucerne hay</td>
<td>-</td>
</tr>
<tr>
<td>Maize silage</td>
<td>-</td>
</tr>
<tr>
<td>Barley straw</td>
<td>-</td>
</tr>
<tr>
<td>Barley grain</td>
<td>-</td>
</tr>
</tbody>
</table>

The effects of NDF content on intake are two fold.

- A low NDF content indicates a rapidly fermented cell wall and a high digestibility and ME content of the forage
- The high fermentation rate means forage remains in the rumen for a short time, and the animal has capacity to eat more forage.

The combined effect is to increase dry matter intake to a greater extent than ME content (Figure 13.1).
Figure 13.1. The effects of increasing NDF content of the diet from 40 to 60 % DM on the relative changes in ME content (MJ ME/kg DM) and forage intake (kg DM/cow/day).

Protein
Dairy cows digest protein from two major sources, rumen microbe cells and true protein in the feed.

Crude protein (CP, % DM) in feedstuffs includes both true proteins that contain amino acids (such as protein meals) and non-protein nitrogen (such as urea). It is calculated from the nitrogen content (N, % DM) of the feeds.

\[
CP (\%) = N \times 6.25
\]

Rumen microbes use the non protein nitrogen and much of the true protein in feeds (rumen degradable protein RDP) in fermentation and turn it into true protein in their cells. They also use much of the true protein in feeds. The microbes are subsequently digested and absorbed in the small intestine as the main protein source for milk production, providing 70 - 90% of protein requirements.

The remaining 10 - 30% of protein is from digestion in the small intestine of true protein which was not fermented in the rumen, referred to as rumen undegraded protein (RUP). The total protein absorbed through the intestine from both microbial protein and RUP (referred to as metabolisable protein MP) is available to the cow for maintenance and production (Figure 13.2).

Crude protein (% DM) is the appropriate measure of protein content of feeds for ruminants. Urea is almost immediately available for rumen microbes and most true protein is fermented within 2 to 6 hours.
**Crude Protein**
Comprised of:
- True protein (amino acids)
- Non-protein nitrogen (urea fertilizer)

**Rumen**
Microbes use:
- True Protein
- Non-protein nitrogen

**Microbe population**

**Microbes digested**
- Volatile fatty acids
  Acetic, butyric, lactic

**Small Intestine**

**Microbes absorbed**
Provide 70 - 90% of protein

**Rumen Undigested Protein**
True protein of feed accounts for remaining 10 - 30% protein

**Metabolisable Protein**
- Milk production
- Growth
- Maintenance

*Figure 13.2.* Protein digestion in the rumen and small intestine.

**Water**
Milking cows need approximately 60 - 120 L of drinking water/cow/day to maintain healthy rumen function, body maintenance and milk production. The requirement is highest in hot weather and immediately after milking. Experience has shown a benefit to having water available to cows throughout the day, both in the paddock, laneways or feeding area and at the dairy.
Minerals
The need for minerals is proportional to the size of the cow and production, as they are essential to chemical processes and are laid down in growing tissue. The minerals most likely to be deficient in subtropical Australia are phosphorus, calcium and sodium. Other less common deficiencies include magnesium and copper. In modern feeding systems a substantial amount of feed is purchased and many of the minor minerals such as copper are included.

Managing diets
The management of diets is based on the knowledge of cow nutrient requirements and the nutrient content of feeds. The details for both of these are obtained from tables, in print or computer programs, once the basic information on cow production and diet ingredients are known (Table 13.5).

Table 13.5. The process of matching cow nutrient requirements with nutrients in feeds.

<table>
<thead>
<tr>
<th>Cow requirements</th>
<th>Nutrient requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production</td>
<td>Energy (starch, sugar, fibre)</td>
</tr>
<tr>
<td>Milk fat content</td>
<td>Protein</td>
</tr>
<tr>
<td>Live weight</td>
<td>Minerals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feeds</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forages</td>
<td>Energy (starch, sugar, fibre)</td>
</tr>
<tr>
<td>Grains</td>
<td>Protein</td>
</tr>
<tr>
<td>Byproducts</td>
<td>Minerals</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
</tr>
</tbody>
</table>

Target values for nutrients in the diet

Dry matter (DM) intake
Daily intake of 3% of live weight at 16 L milk/cow/day, 4% for 30 L/day.

Neutral detergent fibre (NDF) intake
Maximum daily intake of 1.2% of live weight in total diet and 1% from forage.

NDF content of the total diet
- 28 - 32% NDF in diet DM for cows producing >9000 L.
- 30 - 34% NDF for late lactation/medium production.
- 34 - 40% NDF for cows producing <6000 L on tropical pastures.

Effective NDF (eNDF)
Minimum of 20% of total NDF as effective NDF with particle length greater than 2 cm.

Non fibrous carbohydrate (NFC)
- 35 - 40% of diet DM at high production (> 8000 L/cow).
- 32 - 37% at lower production (< 7000 L/cow).

Starch
- 22 - 25% of diet DM (approximately 40% grain in the diet).

Sugar
- 3 - 6% of diet DM. Up to 10% sugar tolerated on mature tropical grass/molasses diets.

Crude protein (CP)
Minimum 16% of diet DM at peak/high production.
Minimum 13% at late lactation/low production.

Rumen degradable protein (RDP)
66 - 72% of the CP content of the diet at peak lactation/high production.
70 - 76% of the CP content of the diet at late lactation/low production.

Rumen undegradable protein (RUP)
The lysine and methionine contents are important to high producing cows (>9000 L/cow). They need to be in a 3:1 ratio in RUP.

Fat
Maximum of 5 - 6% of diet as DM.

References and further information
Nutrition Plus technical note series.
Chapter 14. Feeding management

There are many issues to be dealt with week to week in a feeding system, and attention to these ensures the overall feeding strategy is successful. Some of the more important issues are:
- Allocating pasture.
- Feeding dry and transition cows.
- Heat stress.
- Slug feeding.
- Procurement and management of feeds.

A feeding system involves the long term, often annual, planning and the weekly or monthly adjustments needed to ensure the system works efficiently.

**Allocating pasture**

The objective is to balance pasture and animal needs, and ideally both cow intake and pasture growth are maximised. Normally there are periods of the year when one or both are compromised.

Estimating the area of pasture to allocate to cows requires knowledge of pasture yield. This is usually a skill developed from experience and visual assessment. Rising plate meters and rapid pasture meters drawn behind a quad-bike can also be used.

Pasture yield per hectare is divided by the desired pasture intake per cow to calculate the daily stocking rate.

Adjustments to the area are then made on the basis of residual yield following grazing, increasing the area if residuals are too low or decreasing the area if excessive pasture remains.

With tropical grasses and forage crops a modification to this system of allocation is needed to accommodate the high stem content. An estimate of the leaf yield per hectare is more useful than total yield to calculate daily stocking rate. Typical leaf contents at the optimum stage for grazing are 35 to 45 % DM.

For temperate pasture species, completing a feed wedge each week by measuring the pasture on offer in each paddock is a useful exercise to assess the availability of pasture ahead of the cows. If the wedge is increasing pasture growth rates are increasing, if the curve is decreasing then pasture growth rates are declining and the grazing rotation should be slowed down accordingly (Figure 14.1). A linear wedge indicates pasture growth rate are constant.

Ideal grazing management enables the sward to fully express its genetic potential to produce quality feed. This in turn will maximise dry matter intake by stock. The frequency and height of defoliation and whether to graze or conserve depends on the pasture species, time of year and growth rate.
Feeding dry and transition cows

The nutritional needs of these two phases are quite different.

- The dry period is from drying off until 2 - 3 weeks before calving, usually a period of 3 to 6 weeks.
- The transition period is from approximately 3 weeks before calving to 2 weeks after.

Dry cows

Reduce feed intake by 50 - 70% for 2 - 3 days when milking stops and the cow is removed from the herd. The aim is to maintain body condition through the dry period, ideally at a score of 5 - 5.5. Over fat cows can have health problems, including displaced abomasums, udder oedema and ketosis at calving. However, if animals are over fat at time of drying off they should not lose weight during the dry period as this can lead to fatty liver and ketosis. Diet should be predominantly forages with low or nil concentrate input (Table 14.1).

Table 14.1. Ideal dietary composition of the dry cow.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Level in the diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food intake</td>
<td>1.5 - 2.0% live weight</td>
</tr>
<tr>
<td>Neutral Detergent Fibre</td>
<td>40% DM</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>12% DM (15% DM for heifers)</td>
</tr>
<tr>
<td>Minerals</td>
<td>Calcium 0.44%, phosphorus 0.22%, magnesium 0.11%, sodium 0.1% DM, selenium 0.3 ppm</td>
</tr>
<tr>
<td>Vitamins</td>
<td>Vitamin E (1200 IU) and niacin (6 g) can be beneficial</td>
</tr>
</tbody>
</table>

Transition cows

In the last few weeks of pregnancy the priorities are to increase dry matter intake in readiness for lactation and adapt rumen microbes to the feeds in the milkers' diet. Introduce grain-based concentrates slowly (by 1 kg every two days) to reduce the risk of acidosis.

Recommended strategies to minimise metabolic disorders include:

- Avoid feeding high levels of calcium and buffers (containing sodium and potassium) and
reintroduce them immediately after calving.

- Dry matter intake is markedly reduced 1 - 3 days both before and after calving. Increased sugar, grain or high quality grass hay may help minimise this reduction.

- If milk fever and retained placentas are a herd problem feed anionic salts as part of the ration. Anionic salts provide anions (chloride and sulphate) to counteract the cations (potassium and sodium) in the diet. They lower body pH stimulate calcium release from the bones and calcium absorption from the gut, and help prevent milk fever and retained placenta at calving.

- Anionic slats are unpalatable and may further depress DM and energy intake. To determine whether they are working test the urine with pH test strips. A urine pH of <6.5 in Holstein Friesians and <6 in Jersey cows is ideal.

- Minimise feeds that have a high sodium (e.g. buffers, sodium bicarbonate), potassium (molasses, sorghum, ryegrass) or calcium (lucerne) content.

- In the first weeks of lactation cows go into negative energy balance and produce milk from body reserves. Aim to limit loss to 0.75 of a condition score over the first 6 weeks. Increase the amount of concentrate gradually (1 kg every two days) up to its highest level and include buffers such as sodium bicarbonate to help prevent acidosis. Be alert for signs of metabolic diseases such as milk fever, acidosis, and ketosis. Late detection can result in long-term production effects and even death.

**Feeding strategies**

Some strategies that can be used to reduce the effects of heat stress on cow production are:

- In hot weather transport feed to cows rather than walk the cows to feed.

- Allow greater access to pastures for grazing at night. Cows will spend 70% of their daily grazing at night time in hot weather.

- High-fibre forages will generate more heat through digestion, compared with concentrate diets. Increase the energy content of the diet with good quality forages and concentrates to reduce the metabolic heat load.

- Increase the concentration of minerals and vitamins in the diet to compensate for the reduction in feed intake, particularly sodium, potassium, magnesium and niacin. Supplementing cows with 1.5 - 1.6% DM of potassium and 0.5 - 0.6% DM of sodium may improve milk yield in heat-stressed cows. Include magnesium at 0.35 - 0.4% DM to help to avoid metabolic problems (grass tetany) when feeding higher amounts of potassium.

- Including niacin (6 g/cow/day) may also be beneficial. It has been reported to reduce skin temperature and increase milk yield.

- Improvement in milk yield has also been reported from feeding 150 - 200 g/cow/day of sodium bicarbonate during hot weather to help buffer the rumen.

**Dry matter intake**

At daily maximum temperatures above 27°C cows reduce time spent grazing and voluntarily intake declines by 9 - 13% at 30 - 32°C. When animals suffer from heat stress panting is increased which reduces cud chewing and slows the breakdown of feed. Cows stand in the shade to keep cool, so restricting grazing time. There is also a slowing of rumen contractions, which in turn slows digestion.
Management strategies
Provide cool, clean water and ample trough space in close proximity to cows at all times. In hot weather lactating cows have the capacity to drink >100 L a day. Cows may drink 50% of their daily water intake as they exit the dairy. A 200-cow herd may therefore require a supply of up to 5000 L of cool, clean water during the 1 - 2 hours that cows exit the dairy.

Allow access to shade throughout the day. Shade can reduce the cows’ heat load from the environment by up to 50%. Cooling cows at the dairy with shade, sprinklers and/or fans before and after milking will improve their comfort and enhance their capacity to eat.

Let cows wander home and stand under sprinklers before the afternoon milking. Lowering body temperature will encourage higher feed intake. Queensland trials have shown that 30 minutes of wetting cows with sprinklers can produce an extra 1 L milk/cow, and 60 minutes an extra 1.5 L in hot weather. Sprinklers should deliver large drops to thoroughly wet the cows’ skin.

Slug feeding
Usually refers to the feeding of more than 4 kg grain based concentrate during each milking.

Management
The aim is to keep the diet as consistent as possible for maximum microbial production.

➢ Move cows quickly out to pasture or forage after feeding grain/molasses in the milking bales.
➢ If feeding over 6 kg concentrate daily feed some or all grain and molasses in a total or partial mixed ration with conserved forages if a mixer wagon is available.
➢ Increase energy concentrates in the late dry period to acclimatise rumen microbes to the lactating ration. Make a gradual transition from dry-cow to lactating-cow diets.
➢ Change grain types gradually. The digestion rate and release of energy in the rumen varies widely between grains.
➢ Avoid over processing grains. The more processed the grain, the faster it is broken down in the rumen.
➢ Provide a buffer (sodium bicarbonate) with grain fed in the dairy (100 - 150 g/cow/day, and up to 300 g/day in hot weather).

Digestion of a large quantity of starch or sugar by rumen microbes in a short time will cause a drop in rumen pH, from the ideal of 6.2 - 7.0 to below 5.5 (ruminal acidosis). Milk production and milk fat content may fall. Cud chewing and saliva production may be reduced. If <50% of the herd is ruminating while resting, rumen health may be suffering.

Manure may be loose and inconsistent. Bubbly manure indicates hindgut fermentation of starch and potential acidosis. Mucous in manure indicates sloughing of the lining of the intestines also an indication of acidosis.

Preparing feeds
Grain processing
Processing grain increases starch availability to the rumen: steam-flaked > hammer-milled > rolled > whole grain.

Wheat, triticale or barley fed during milking should be coarse cracked rather than fine ground. However as part of a mixed ration finer grinding is beneficial.

Sorghum and corn require a higher degree of processing (hammer-milling, rolling or steam flaking) to make starch available to the rumen microbes.
Pelleting with heat and pressure increases grain digestibility.

**Silage**
Well-made conserved forages contribute energy, fibre and protein. Cereal crop silages are an alternate source of starch to improve milk yield and milk protein.

Ensure silage chop length is 2 - 5 cm to maximise effective fibre. Ensilage forage for at least 17 days before feeding out. Minimise disturbance of the silage face to minimise air penetration and to avoid fungal contamination. The silage face should be even and perpendicular to the floor, removing at least 20 cm daily. Clean away any loose feed every day. Including as little as 5% spoiled feed in a ration can depress intake and reduce diet quality.

Minimise wastage in the feedout process with suitable equipment and troughs and allow 0.7 m of trough space per cow. Test silage for nutrient and DM content and re-balance the diet regularly.

Recheck the ration formulation month to month, as forage quality is constantly changing. Make any changes gradually, as rumen microbes can take up to 4-6 weeks to adjust to a large diet change. Conduct a feed analysis on any byproducts that are regularly used in the diet.

**Byproducts**
The availability of byproducts can be variable and this can lead to significant changes in the diet. Digestive and metabolic problems can be avoided by limiting byproducts to the recommended maximum feeding rates: molasses 3 kg (wet weight)/cow/day; brewer’s grains 15 kg/cow/day (wet weight); whole cottonseed 3 kg/cow/day (wet weight). Generally other by products can be safely fed at approximately 2 kg DM/cow/day, including feeds such as pineapple pulp, palm kernel extract, copra meal, vegetable waste, whey, and bakery waste.

**Milk composition**
The diet of the cow has a significant effect on milk composition and altering the diet is often the most effective way of remedying low milk fat or protein values.

**General**
Milk fat and protein are affected by different diet components. Protein is affected by total feed intake and the energy density in the diet, whereas fat is affected by the diet fibre content and forage to grain ratio. Both milk fat and protein are improved for cows in higher body condition. A substantial amount of milk fat is formed by mobilizing body fat.

**Milk protein**
In the subtropical dairy regions milk protein tends to decline during the summer, reflecting the lower forage quality at this time and the effects of heat stress on the foraging effort of the cow.

If feed refusals and pasture residual are low, it is an indication the herd is hungry and in this situation milk protein is likely to fall. Insufficient energy intake is the most common dietary factor causing low milk protein % and yield. Energy is required to produce rumen microbial protein, which in turn becomes an important source of protein for milk protein production. Most energy for the rumen microbes is sourced from starch, sugar and fibre in the cow’s diet.

Increasing ME intake increases milk protein percentage by an average of 0.003 - 0.005/MJ ME.

**Starch**
The starch content of the diet has an effect on milk protein % as starch is a readily available energy source for rumen microbes. The target is 22 - 25% starch in the diet. Higher levels of starch should be avoided as there is a risk of rumen acidosis. Primary starch sources include cereal grains,
cereal silage (including corn, barley, sorghum and wheat silage), some vegetable waste such as potatoes, and bread and bakery waste.

Processing grain changes the speed and extent of starch digestion by rumen microbes. The more highly processed the grain, the faster starch is broken down. Steam flaking and hammer milling increase rumen degradability of starch, more than dry rolling and cracking of grain, but may also increase the risk of acidosis.

**Sugars**
Sugar is less effective than starch in changing milk protein concentration, but in modest amounts is beneficial as a rapidly available energy source. The optimum level is 5 - 8% DM.

Because sugar is digested very rapidly in the rumen levels in the diet above 10% DM can cause rumen acidosis. Temperate and lush tropical grasses are high in sugar content. Sugar reserves in grass increase throughout the day and peak in late afternoon. Other sources include molasses, citrus pulp and other fruit byproducts.

**Diet protein**
A level of 14 - 16% CP is sufficient for rumen microbes, and extra protein above this does not influence milk protein. Diet protein will be used efficiently if there are adequate sources of rumen available energy, such as starch and sugar.

In very high producing cows (> 33 L/cow/day) the quality of the diet protein can have an influence on milk production and protein content. The amino acids methionine and lysine are needed in greater quantities than is provided from microbial protein. Methionine and lysine are provided in the diet by including high quality protein meals such as canola and soybean meals.

**Diet fat**
Diet fat above 6% DM tends to depress milk protein percentage.

Above 6% fat in the diet starts to decrease the rate of rumen microbial breakdown of starch and fibre thereby reducing the supply of energy.

**Milk fat**
Milk fat is formed from volatile fatty acids absorbed from the rumen and body fat mobilized from tissues. For optimum milk fat content there needs to be a consistent rumen fermentation of forage and adequate body reserves.

Volatile fatty acids are formed from fibre fermentation in the rumen, which is optimum with a consistent and high intake of forage and a rumen pH above 6. The major interruptions to forage fermentation are inconsistent diet, where forage intake varies markedly day to day, or rumen acidosis due to excess intake of starch or sugar.

**Forage to concentrate ratio**
A low milk-fat test indicates inadequate forage and usually excessive concentrate for that level of forage in the diet. It may also indicate a mild form of acidosis. A drop in both milk production and milk fat % indicates acidosis. A rumen pH below 5.4 inhibits fibre-digesting bacteria and increases lactic acid producing bacteria resulting in acidosis. This can be caused by abrupt changes in the diet, insufficient effective fibre, and/or excess rumen-available carbohydrates (usually grain).

The optimum forage to concentrate ratio can be maintained by:
- Keeping the forage content of the diet between 50 - 70% DM.
- When grain intake is >6 kg/day, feed it more than twice/day.
- Move cows onto fresh or conserved forage immediately after feeding grain in the dairy.

**Fibre**
An indication of adequate fibre is about 30% NDF in the diet. To be effective in rumen fermentation the fibre needs to be more than 3 cm in length (3 - 5 for chopped roughages).
The proportion of the herd ruminating during rest is an indication of adequacy of fibre in the diet. If the proportion is:
- < 30% fibre is too low.
- ~ 50% fibre is adequate.
- >70% fibre is excessive.

Consistency
If fibre digesting microbes are lost due to acidosis or other factors it may take 4 - 6 weeks for their numbers to rebuild. Consequently a consistent rumen environment is important to maintaining milk fat levels. Consistency is achieved by:
- Maintaining the forage to concentrate ratio in the diet.
- Including buffers in the grain mix if acidosis is suspected. Buffers include sodium bicarbonate and are included at 1 - 1.5% DM of the diet.
- Maintaining modest levels of fat in the diet (5 - 6% DM). Higher levels will interfere with fibre fermentation.

Animal health
Potential feed-related health problems in dairy cows include metabolic diseases (acidosis, ketosis, milk fever); disorders related to forage and grazing management (grass tetany, bloat, nitrate, prussic acid, plant poisoning); and ill-health/death from feed contamination (botulism, aflatoxins and ergot).

Metabolic diseases
Metabolic diseases tend to occur more frequently in high producing cows and in early lactation. They are often associated with high quality feeds, needed for high milk production, and cows with strong appetites, as for high producers in early lactation.

Acidosis
Acidosis occurs when rumen pH declines, primarily due to the over feeding of highly fermentable carbohydrates such as grain and molasses. Once rumen pH declines to below 5.4 fibre-digesting bacteria die out and lactic acid producing bacteria increase, resulting in a rapid further decline in rumen pH and hence the clinical signs of acidosis.

Symptoms of acidosis include cows not eating, less than 50% of herd chewing the cud when resting, a drop in milk production and milk fat % (below 3.3% milk fat), sore hooves/laminitis, diarrhoea, foamy faeces and undigested grain in faeces.

Acidosis is usually triggered by abrupt changes in the diet, either a sudden increase in intake of highly fermentable carbohydrate (grain) or a sudden decrease in forage intake causing the forage to grain ratio to fall markedly. It can also occur where forage intake suddenly has a very low content of effective fibre, may be caused by feeding conserved forage that has been finely chopping.

Prevent acidosis by:
- Balancing the diet for starch and effective fibre.
- Avoiding sudden feed changes and slug feeding of grain and/or molasses.
- Providing roughage with or immediately after feeding grain/molasses.
- Providing buffers such as sodium bicarbonate or ionophores such as Rumensin®.

Laminitis
Laminitis is a symptom of acidosis but can also be associated with mastitis, hard surfaces, lack of/or excessive exercise on rough surfaces or wet weather. Symptoms include the cow bunching its feet together, arching its back and reluctance to move. Cows can become profoundly ill, lose their appetite and produce much less milk. Hooves may loosen, distort and slough off.

Prevention is by feeding for stable rumen conditions to avoid acidosis, and providing foot baths containing 2 - 5% copper sulphate during wet conditions. Essential minerals zinc (40 - 60 ppm) and selenium (0.3 ppm) help
prevent laminitis. Biotin, a part of vitamin C, has been shown to help prevent laminitis when fed at 10 - 20 mg daily.

**Ketosis**

Ketosis occurs from the excessive use of body fat for energy. It often occurs in early lactation in high producing cows when food intake is restricted and animals mobilise large amounts of body fat as an energy source. This leads to a build up of ketone bodies, a product of fat mobilisation and which are toxic in large quantities. The primary symptoms are sweet smelling breath (acetone), loss of appetite and mucous covered faeces (gut wall lining sloughed off). Other symptoms include excessive loss of weight and condition, dullness, depression and a staring expression, reduced milk production, constipation, lack of coordination or partial paralysis, highly excitable, licking, teeth grinding, shallow breathing.

High body condition score at calving (>6) or overfeeding in the dry period, followed by a short period of starvation during calving and very early lactation will predispose the cow to ketosis. Other factors which suddenly restrict food intake, such as acute mastitis, retained placenta and milk fever, may also trigger ketosis.

Prevention is primarily through:
- Ensuring a balanced ration, particularly energy intake.
- Maximise dry matter intake before, at and after calving.
- Adapt dry cows to the milking-cow diet by lead feeding.
- Avoid overfat cows at calving (BCS>6).
- Lowering potassium and calcium levels in the dry cow and springer diet may help avoid ketosis, and niacin at 6 g/day may be effective.
- Monensin (Rumensin) in the month before calving has been shown to reduce the incidence of acidosis.

**Milk fever (hypocalcaemia)**

Milk fever usually occurs within 72 hours of calving and is caused by a low blood calcium level. Increased risk occurs with cold, wet conditions and poor nutrition prior to calving. Older cows and the high milk fat breeds such as Jersey are more prone to milk fever. Symptoms include unsteady gait, cow lying down with head displaced to one side or into the flank, depression, dull eyes, staring, pupils dilated, dry muzzle, cold ears, groaning, slight muscle spasms, inability to rise, coma and if left untreated, death.

Treat promptly with slow intravenous or subcutaneous calcium borogluconate injection. Prevention is by stimulating the cow’s calcium mobilisation before calving. This is achieved by feeding a transition cow diet in the three weeks before calving. Transition cow diets include anionic salts (chloride, sulphur, phosphorus) and avoid feeds high in calcium, potassium and sodium (cations). Increase dietary calcium immediately after calving. Avoid fat cows at calving and administer vitamin D injections 2 - 8 days before calving for cows with a history of milk fever.

**Grazing management**

Often grazing management diseases are associated with the highest quality and abundant forages. A mental check list for bloat, nitrate and grass tetany should be a routine procedure before each new forage grazing season starts.

**Grass tetany (hypomagnesaemia)**

Grass tetany occurs when cows graze lush pastures with low available magnesium levels, and is more prevalent when there is an increased demand for magnesium during early lactation and late pregnancy. Grass tetany generally occurs on grass-dominant pastures that have been fertilised with potash (potassium) and nitrogen, as high contents of these elements restrict the absorption of
magnesium. Short periods of fasting (e.g. due to wet weather), a deficiency of sodium or early grazings of a lush, new pasture may also be predisposing factors.

Symptoms include restlessness, stagers, over-alertness, muscular twitching, excitability and in some cases aggression. Animals fall down and go into convulsions, and may die rapidly. Prevention is best achieved by feeding 30 - 40 g magnesium/cow daily as a mineral supplement when cows are considered at risk. Balance the diet for sodium and avoid high potassium feeds in the ration.

**Nitrate poisoning**

When soil nitrate levels are high but growth of pasture or forage crop is slowed by cool weather or herbicide application, then nitrate can accumulate in the plant. Levels of more than 1.5% potassium nitrate on a dry matter (DM) basis are potentially dangerous to hungry stock. High levels can persist in hay or silage.

In the rumen nitrate is reduced to nitrite, which is absorbed rapidly and binds oxygen in the bloodstream. Often animals die suddenly without noticeable warning. If detected early symptoms are increased breathing rate and depth, muscular twitching, staggering, collapse, convulsions and coma. Poisoned animals found alive can be saved by treating with intravenous methylene blue (best administered by a veterinarian).

Prevention is primarily through vigilance in assessing forages and with holding stock or increasing supplement levels during periods of suspected danger.

**Prussic acid (cyanide) poisoning**

Cyanide (prussic acid) accumulates in the forage of both grain and forage varieties of sorghum. Accumulation is greater under stress through hot, dry conditions or frost. The likelihood of occurrence is higher with young plants or stressed regrowth, and toxic levels can persist in hay. However ensiling significantly reduces the risk.

At first sign of symptoms, remove all stock from the forage and do not reintroduce until the crop has grown through this phase. Sodium thiosulphate in high doses is effective up to 30 minutes after ingestion of a toxic dose of cyanide. Drench affected animals immediately (60 g in 600 ml water), repeat hourly until animal recovers; also drench unaffected animals in the group; most effective treatment is an intravenous injection of sodium thiosulphate by a vet.

Prevention is by delaying grazing until sorghum plants are >45 cm (grain varieties) and >75 cm (forage varieties) in height. Plants forming flowers or grain are least risky. Observe stock for the first hour of grazing and at regular intervals. A supplement providing sulphur, such as a lick block containing 10% sulphur, helps prevent poisoning.

**Bloat**

Bloat is caused by the rapid digestion of lush rapidly-growing legumes (clovers, lucerne) and other high-protein forages including kikuyu that produce a stable foam in the rumen, preventing gas from being belched. It sometimes occurs in feedlot cattle on finely-processed feed. Symptoms include dead cattle within an hour of access to bloat-susceptible forages, upper left flank is distended and uncomfortable, cattle kick at their sides, breathing difficulties are obvious and there is salivation and tongue extension. Rumen movement is constricted and animals lie down and die quickly.

Drench animals orally with surfactants such as oil (bloat oil or vegetable oil). Prevention can be achieved with various methods, often used in combination:

- Make sure animals are not hungry when introduced to pasture
containing a high proportion of legume.

- Treat animals or spray the forage with anti-bloat oils.
- Place slow-release anti-bloat capsules in the cows rumen.
- Feed monensin (rumensin) in the grain mix before grazing.
- Treat drinking water with bloat oil (only effective where alternate water sources are not available).
- Limit the intake of high-risk forage and feed with other low risk forage.
- Feed low-protein hay prior to grazing high-risk forages to slow the rate of intake.

**Contamination**

Contamination can be difficult to detect in routine operations of a farm, and often the problem is only obvious after animals become sick or die. However vigilance in feed preparation, storage, purchase and vaccination is the main means of prevention.

**Botulism**

Very small amounts of botulinum toxin in stored feed, usually resulting from rotting carcasses of rodents, birds or reptiles, in severe instances it can kill animals. The incidence and risk are increased in dairy herds using large amounts of stored feeds. Symptoms are weakness, paralysis (which begins at the hind legs and moves forward along the body), paralysed tongue and excessive drooling. Death is sudden and other symptoms may not be noticed.

In Queensland, examples of serious cow losses have been with dead snakes in grain silos, chicken litter spread on paddocks and rodents or birds ensiled with forage. Little can be done to treat affected cattle. In mild cases removal of the toxin source may allow animals to recover.

Prevention is best achieved with a vaccination program for clostridial diseases. Full protection may not occur until four to six weeks after the first vaccination.

**Ergot poisoning**

Sorghum grain contaminated with ergot can be toxic to dairy cattle. There is a regulated limit of 0.3% ergot in grain intended for stock feed. Ergot infestation can affect milk production.

Symptoms of animals overheating are the main signs of poisoning, as ergot poisoning reduces the cow's ability to shed heat, and is therefore less tolerated during summer. Cows begin dribbling, standing in the shade and seeking water. Best treatment is to quietly move affected stock to alternate feeds in a shaded, cool area.

Prevention is by purchasing and feeding grain with an ergot content less than 0.3%. Grain can be visually inspected for ergot content by spreading a small sample on a white sheet of paper. Ergot fruiting bodies (sclerotes) appear as small, dark and elongated grains. Use caution if a forage sorghum crop displays honeydew infection of seed heads. It is safer to graze or cut forage sorghum for silage before flowering, particularly in late summer/early autumn.

**Moulds and mycotoxin poisoning**

Moulds grow on all feeds and normally do not produce mycotoxins. However under certain conditions, usually abnormal temperature or moisture regimes, these toxins are produced. Silage is the most common source of mycotoxin contamination. Other sources include grains (corn, wheat, barley, sorghum), whole cottonseed and by-product feeds.

Symptoms include reduced feed intake, a rough hair coat, slightly arched back, digestive upsets (such as diarrhoea and/or rumen stasis), mucous in the manure, tissue oedema (swelling of the brisket and hock areas), and a high rate of abortion or foetal resorption.

If mycotoxin poisoning is suspected, then a toxin binder such as bentonite should be added to the diet. Keep in
mind that this may also bind other vitamins and minerals. Prevention is achieved by not feeding suspect feeds. If mycotoxin is suspected there is a laboratory test which can be used for confirmation. The most practical test is smell for mould and if the feed smells mouldy, do not feed it. Silage is at risk if the removal face is untidy or too small a depth is removed daily.

**Aflatoxin**

Aflatoxin is the mycotoxin most highly recognised. Aflatoxin-contaminated grain and nuts can poison livestock and can also persist as residues in milk and meat. Poisoning is increased in drought conditions and in high temperatures and high humidity. Feeds that are affected include peanuts, peanut by products, maize, sorghum, and bakery waste (particularly in moist storage conditions). Peanut hay from failed crops can contain sufficient aflatoxin to produce residues in milk.

Symptoms include a reduction in feed intake, weight loss, a dramatic reduction in milk yield, an increased susceptibility to stress, drying and peeling of the muzzle, mucous in the manure, loss of liver function, potential prolapse of the rectum and ultimately death.

Prevention is best through contract assurance, where feeds are guaranteed to meet Queensland stockfeed standards for aflatoxin levels. Particular caution is needed with peanuts and it is best to restrict peanut hay with pods to less than 10% of the total diet. Store all feeds in dry conditions and regularly clean feed bins and feed out machinery.

**Budgeting**

Budgeting is planning ahead for feed and operational funds to run the dairy enterprise.

**Feed budget**

Feed budgeting is a farm assessment to identify feed requirements based on the number and class of livestock to be fed and the production levels that are targeted. A feed budget is generally used as an outline of the feed supply and demand over a 12-month period, a feed year plan.

**The process of feed budgeting**

Refer to table 14.2.

- Calculate how many tonnes of dry matter your herd requires for the year.
- How much pasture, grain, silage and hay can you produce on your farm over a year (Table 14.3)?
- Calculate the yearly requirements of concentrates and/or byproducts used consistently through the year (Table 14.4).
- Calculate the amount of extra feed you will need to purchase.
- Check the diet against cow requirements, milk production and composition each time there is a substantial change in feeding regime. This may influence your purchases.
- Work out which purchased feeds are most cost effective and can be used in the diet mix for optimum supply of nutrients.
- Convert the DM required to be purchased to an as-fed (wet) basis to calculate the actual amount of feed to purchase.

### Table 14.2. The process of feed budgeting.

<table>
<thead>
<tr>
<th>Step 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed per cow (A, kg DM/day)</td>
<td>2.0% liveweight + 30% milk yield</td>
</tr>
</tbody>
</table>
| Number of cows (B) | Milking  
 + 0.5 dry cows  
 + 0.3 growing heifers |
| Annual needs kg DM (N) | $A^*B^*365$ |
Step 2  
Pasture/forage grown  
(C, includes grazing and ensilage)  
Sum species DM * yield (Table 14.3)  
Grain (D)  
Crop DM * yield (Table 14.4)  
Annual home production (H)  
C + D  
Step 3  
Concentrate level (kg DM/cow/day)  
E  
Byproduct level (kg DM/cow/day)  
F  
Annual requirement  
(E+F)*B  
Step 4  
Annual purchases (P)  
Annual needs (N) – annual home production (H)  
Concentrate/byproduct purchases  
(E+F)*B –D  
Forage purchases  
P – [(E+F)*B-D]  
Prior to purchasing feed, it is recommended to assess the ration and balance for nutrients.  
➢ An energy deficiency requires grains or molasses.  
➢ A protein deficiency is met with protein meals or high protein forages.  

Table 14.2. Indicative yields of forages and grains grown on dairy farms.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Yield (t DM/ha/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rain grown</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>-</td>
</tr>
<tr>
<td>Oats</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Barley</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Lucerne</td>
<td>3 - 10</td>
</tr>
<tr>
<td>Kikuyu</td>
<td>3 - 8</td>
</tr>
<tr>
<td>Forage sorghum</td>
<td>8 - 12</td>
</tr>
<tr>
<td>Lablab</td>
<td>2-6</td>
</tr>
<tr>
<td>Maize</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Sorghum grain</td>
<td>3 - 9</td>
</tr>
<tr>
<td>Barley grain</td>
<td>2 - 5</td>
</tr>
</tbody>
</table>

Table 14.3. The moisture content of some byproducts.

<table>
<thead>
<tr>
<th>Product</th>
<th>Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molasses</td>
<td>85</td>
</tr>
<tr>
<td>Bakery waste</td>
<td>70</td>
</tr>
<tr>
<td>Citrus/pineapple pulp</td>
<td>22</td>
</tr>
<tr>
<td>Brewers grains</td>
<td>22</td>
</tr>
<tr>
<td>Maize silage</td>
<td>35</td>
</tr>
<tr>
<td>Round bale silage</td>
<td>60</td>
</tr>
<tr>
<td>Grain/protein meals</td>
<td>90</td>
</tr>
</tbody>
</table>

Feed costing  
It is important to cost feeds on a dry matter or nutrient basis so that different feeds can be compared on an equal basis. Some feeds supply just one nutrient whereas others supply energy, protein and minerals (Feed Cost Calculator - New South Wales Department of Primary Industries).
Table 14.4. Comparing feeds on a dry matter basis.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Calculation ($/t) (DM%)</th>
<th>Cost ($/t DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley grain</td>
<td>250/ (90)</td>
<td>275</td>
</tr>
<tr>
<td>Brewers grain</td>
<td>50/ (20)</td>
<td>250</td>
</tr>
</tbody>
</table>

Forward purchasing
A forward contract is a legal agreement between a feed supplier and a feed buyer for a transfer of feed at a specified cost, and at a specified time in the future. There is usually a storage fee on top of the ‘locked-in’ price but this is generally quite small in relation to the variation in feed costs.

There are both advantages and risks with forward purchasing feeds (Table 14.6). The advantages may become more evident as the level of production or herd size increases, and it is imperative that high quality feed or large amounts of purchased feed be consistently available to the herd.

Table 14.6. Assessing the benefits and risks to forward purchasing feed.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can lock in a price over a 12 - 18 month period.</td>
<td>The market price may recede below the ‘locked-in’ contract price.</td>
</tr>
<tr>
<td>Avoids price fluctuations occurring within the market, including sharp increases in feed price.</td>
<td>Required to take delivery of the feed as stated in the contract.</td>
</tr>
<tr>
<td>The contracted feed can be defined by the farmer’s specific requirements in terms of feed quantity and quality, and subsequently produced to those specifications.</td>
<td>Stress involved if product does not meet the required expectations, as the buyer’s only recourse is through legal action.</td>
</tr>
<tr>
<td>Little to no costs to sign a contract.</td>
<td></td>
</tr>
</tbody>
</table>

Monitoring costs
Feed related costs are 45 - 70% of total income. It is the largest cost on the farm and provides opportunities for rapid increases or decreases in profit. Monitoring of these costs on a monthly and annual basis is essential to maintain overall farm profitability.

Monitoring of feed costs is usually completed on the basis of efficiency of feed use. The main measures used are feed related costs (c/L). Margin over feed costs (MOFC, c/L). In practice these efficiency measures have a close relationship to measures of farm profitability, such as dairy operating profit ($/cow) and return on assets (%).

- Feed related costs are all those costs incurred in producing and offering feed, including purchased feed, processing costs, and seed, fertiliser, water and other costs associated with home produced feed. They do not include farm overhead costs, depreciation or interest charges.
  - Margin over feed costs is the amount of total farm income left after paying for all of the feed related costs. The aim is to keep feed-related costs below 60% of total farm receipts, and on efficient farms it is <50%. On subtropical farms MOFC is often related to milk production per cow, being at a maximum in the range 6500-7000 L/cow (Figure 14.2).

It has consistently been shown that increasing the amount of forage grown and used on the farm is the most
effective way of increasing MOFC. The additional costs of growing more forage are usually outweighed by the value of the extra milk production. For example irrigated ryegrass has a relatively high cost per hectare but feed cost per litre of milk is similar to that produced from tropical grasses.

![Graph showing the relation between MOFC and milk production on Queensland dairy farms](image)

**Figure 3.2.** The relation between margin over feed related costs (MOFC) and milk production on Queensland dairy farms in (Murphy and Simpson 2010).

**Nutrition of heifers**

The objectives in rearing dairy heifers are to achieve an adequate growth rate for animals to be mated and calved at the target age, often 15 months and 2 years respectively, but avoid overfeeding and consequent fatty deposits in the udder, especially in the months before puberty. Once heifers enter the milking herd their capacity for DMI and hence milk production is related to their live weight and target calving weight is 85% of mature live weight.

**Pre-weaning**

**Colostrum**

The newborn calf must receive 3 - 4 L of colostrum within 6 hours of birth. This provides the calf with maternal antibodies to help it resist disease organisms in its environment. These antibodies can only be absorbed from colostrum through the stomach (abomasal) wall into the calf's bloodstream in the first 12 - 18 hours following birth. After colostrum is consumed calves can be taken off their mother’s and hand reared.

**Rumen development**

The initial feeding program is aimed at rapidly developing a fully functioning ruminant digestive system (Figure 14.3). Growth rate is a secondary consideration at this age.

**Milk**

The newborn calf is dependent on milk for nutrition and growth as initially only the hind stomach, the abomasum, is functional. Milk bypasses the undeveloped rumen via the oesophageal groove and goes directly to the abomasum. If this mechanism fails (e.g. over feeding) and milk passes directly into the rumen it ferments and the calf scours.
Feeding method
Calves can be fed milk individually using buckets or teats and groups can be fed using calfeterias. Regardless of the feeding method employed, hygiene, fresh feed and shelter are essential to prevent digestive upsets (scours) and disease. Calves can be fed milk once daily from about one week old. Large breed calves require 4 - 5 L of milk a day and smaller calves 2 - 4 L. Do not dilute milk with water. From 2 weeks of age a small amount of concentrate can be offered to encourage intake of solid feeds. Free access to clean fresh water is essential. Strategies to foster healthy calves include:

- Make sure milk replacers fed to young calves must be based on milk, (not milk substitutes such as soybean protein) as the pre-ruminant calf (under three weeks) cannot digest non-animal protein.
- Using spray dried powders rather than roller dried. Excess heat treatment in the manufacture of milk replacer powders will reduce their nutritional value.
- Providing clean fresh water, it is essential for growth and health of the calf and must always be available.

Figure 14.3. Relative size of each stomach compartment for a newborn calf and mature cow.
Solid feeds such as cereal grains and forage are necessary for rumen development enabling the calf to be weaned onto pasture and concentrate without experiencing a digestive disorder. Concentrates and good quality forage/hay should be fed ad libitum until weaning.

**Concentrate and roughage**

While long roughages >5 – 10 cm ‘stretch’ the rumen, digestible dietary carbohydrate as starch (grain), sugars and hemi-cellulose (forage) is necessary for development of the rumen papillae (rumen wall) which in turn are essential for rumen function and absorption of nutrients. Coarsely cracked cereal grain (maize, barley, wheat or sorghum), maize silage or pellets are used with forage (pasture, hay, straw, silage) to increase digestible energy supplied to the rumen. Generally calves require some encouragement and persistence to commence eating.

While digestible forage is important for growth and development, very high protein forages (>20% CP) should be avoided for young calves. Low quality (low digestibility) roughages are of limited value and mouldy hay should not be fed.

Intake of concentrate is a useful indicator of whether the rearing management is achieving the goal of rumen development. The calf needs a balance of concentrate and fibre (roughage). Some calves can develop a taste for pellets, possibly more likely if roughage is restricted, less digestible or of poor quality. Concentrate intakes pre-weaning should not exceed 2 kg per calf daily. Calves can be better managed and their feed intakes controlled if animals in a group are of similar size, age and vigour to reduce competition.

Salt can be beneficial if natural levels in water and feed are low. Deficiency is more common on red basaltic soils and kikuyu farms, where calf bloating may be a problem. Mineral supplements including salt (mix at 1% in grain) have been beneficial.

**Weaning**

Weaning at 8 - 10 weeks of age is normally practised. A target live weight of 60 - 70 kg at weaning (8 weeks), achieved with milk, ad libitum concentrates and a digestible roughage will ensure minimal post-weaning setback.

Early weaning (5 - 8 weeks) may be adopted to reduce the milk feeding period and labour required for calf rearing. This will require a specific feeding program using lower levels of milk feeding and high-energy, high-protein concentrates, preferably pelleted, to stimulate rumen development. Milk or milk replacer is reduced from about 3 weeks of age to encourage the calf to consume and maximise intake of dry feeds pre and post-weaning.

**Scours**

Diligent management is essential to ensure animal health is maintained. Digestive upsets leading to scours are the main cause of mortalities in young calves. Problems can be minimised by:

- Ensuring calves receive adequate colostrum within 6 hours of birth. Maternal antibodies absorbed from colostrum give the newborn calf some resistance to disease organisms in their environment.
- Feeding the correct amount of milk, not too much or too little, often a result of competition with other calves.
- Recognising and treating scouring animals early.
- Maintaining hygiene and cleanliness of feeding utensils and the environment.
- Providing shelter to protect the calf from cold or wet conditions.
- Rotating rearing pens continually to prevent disease; yards surfaced in soil or small paddocks can become heavily contaminated.
Separate sick animals to avoid cross infection. Most scour incidents can be treated simply by use of electrolyte replacers fed several times per day to prevent dehydration. Milk may be reduced or omitted for 1 - 2 feeds, but fresh water, concentrates and forage must continue to be provided. Antibiotics should not be used to treat scours resulting from over feeding or digestive upset. Blood scours (coccidiosis) require veterinary treatment and management changes to improve hygiene.

Post weaning
Weaning to 8 months (live weight 60 - 200 kg)
After weaning, the heifer is dependent on solid feed for nutrition and growth and a large proportion of nutrients are supplied as microbial protein from fermentation of feed in the rumen. By understanding the heifer's requirements in proportion to her size and age, how much feed she can eat and the nutritive value of feed options, the amount of supplement needed can be calculated.

Fertilised tropical grass supplies only 8 - 9 MJ ME/kg dry matter (DM) and will only support gains up to 0.2 - 0.5 kg/day by weaners. The weaned calf is able to consume leafy tropical pasture at about 2% of live weight, or pasture plus concentrate to about 2.8% of live weight per day.

Requirements
Usually the target live weight gain is in the order of 0.7 kg/day, and to maintain this the weaned heifer needs a diet supplying 16% CP and 11 MJ ME/kg DM (Figure 14.4). In spring and summer a concentrate containing 16 - 18% CP is required, fed at 1.5 - 2 kg/heifer/day. Declining quality of mature pastures in autumn may necessitate additional concentrate or an increase in the protein content of the concentrate. Whole cottonseed can be gradually introduced at levels up to 0.5 kg/heifer/day to provide both protein and digestible energy. Although urea can be used with digestible carbohydrate to increase protein available through rumen microbial fermentation, most of the heifer's protein requirements need to be supplied as true protein (concentrate meal, forage). Unimproved pastures cannot meet the needs of these animals.

Molasses is limited in its potential for use post-weaning as its high level of potassium may cause health or neurological problems in young animals at >30% in the diet. It can be partly substituted for grain but generally is not recommended for heifers younger than 6 months of age. It is not suitable as a supplement with high potassium forages such as ryegrass.

Mineral supplementation with calcium (Ca) and phosphorus (P) (e.g. DCP - 20 g/day), and possibly sodium (Na) (salt - 5 g/day per 100 kg live weight) should be provided in concentrates. Sufficient sodium is usually available in feed and drinking water; an exception being where environmental levels are low, for example on red, basalt derived soils, typically growing kikuyu pastures.

In winter, when tropical pasture is frosted or not growing, additional forage as green crop, irrigated pasture, hay or silage (oats, lucerne, temperate pasture) is necessary to maintain live weight gain above 0.6 kg/day. If only mature or senescent tropical pasture is available, higher levels of protein and energy concentrates are required.

Maize silage can be substituted for grain or used as an alternative to tropical pasture. This will meet the heifer's requirement for energy but will not supply sufficient protein. If fed ad libitum, the intake of a complete ration based on maize silage plus supplementary protein can exceed 3%
of live weight, with live weight gains above 1 kg/day. This could result in over-conditioned heifers with lower milk productivity, feeding levels need to be restricted to approximately 2.8% of live weight to avoid excess conditioning. Diets too high in energy: protein ratio favour fat deposition rather than muscle growth, thereby exacerbating this problem. Excess conditioning is of greater concern pre-puberty (heifers below 250 kg).

Part of a graph showing the relationship between live weight gain and different diets for dairy replacement heifers at various stages:

**Postwean**
- 16% CP
- 11 MJ ME/kg DM

**Yearling**
- 14% CP
- 10 MJ ME/kg DM

**Pregnant**
- 12% CP
- 9 MJ ME/kg DM

**Figure 14.4.** Protein and energy requirements for optimum growth of dairy replacement heifers at each development phase, and capacity of forage and concentrate combinations to meet these requirements.

### 8 - 15 months (mating - live weight 200 - 350 kg)

When the Holstein Friesian heifer reaches about 200 kg live weight (8 - 9 months) she requires a dietary energy density of 10 MJ ME/kg DM and a protein content of 14% CP (Figure 14.4). Leafy tropical pasture can satisfy her protein needs, but energy levels in tropical grass pasture (8.5 - 9 MJ ME/kg) will only support live weight gains of 0.4 - 0.5 kg/day and additional energy supplementation is needed to maintain growth rates of 0.7 kg/day. This can be achieved with cereal grain fed at 1.5 - 2.0 kg/day. Molasses plus minerals (Na, Ca, P) can be substituted for cereal grain at the rate of 1.25 kg molasses : 1 kg grain. Additional protein or urea may need to be included with molasses to ensure that dietary protein is maintained at 14% CP.

More digestible forages such as oats, lucerne, ryegrass and clover pastures can provide higher nutrient levels to ensure that growth targets are met, minimising the need for concentrates.

Maize silage is suitable as a supplement or as a partial or complete substitute for pasture if rations are balanced for protein and feed intake is controlled to avoid rapid growth or fattening. Fast grown heifers may be mated earlier than 15 months to prevent excess fattening before calving.

Urea (non protein nitrogen) can be used as a rumen nitrogen source when pasture protein is low, fed at up
to 30 g/heifer a day with a readily digestible carbohydrate source such as molasses, grain or maize silage. Urea requires careful mixing to avoid toxicity. Allow animals to empty a molasses trough before adding more urea and remove surface water following rain.

15 - 24 months (mating to calving - live weight 350 - 550 kg)

Greater than 300 kg live weight (12 months of age) the heifer can achieve live weight gains up to 0.7 kg/day on good quality tropical grass pasture supplying 9 MJ ME/kg DM plus 12 % protein. However, pasture growth is usually during the warm-season hence concentrate supplementation should be supplied.

The mated heifer (>350 kg) is building up body condition in readiness for lactation, and the requirement for protein to energy in the diet is lower. It is still higher than the adult dry cow as the heifer is continuing to grow muscle tissue as well as provide the nutrients for the developing foetus. A dietary intake of 12% CP and 9 MJ ME/kg DM will meet requirements. These requirements can be met by fertilised, green tropical pasture, or with supplements such as molasses, grain or whole cottonseed fed at 0.5 - 1.5 kg/day. Concentrate supplements are not required with higher quality forages (oats, ryegrass, lucerne) if the quantity of feed is not limiting (Figure 14.4).

Molasses is a convenient and cheap supplement for growing cattle, allowing less frequent feeding. When forage supply is adequate, molasses intake is self-limiting, but excess intakes will occur if pasture is restricted. Molasses intakes above 25 - 30% of the diet should be avoided because of its high potassium content (as KCl). Also, it is less suitable for use as an energy supplement in the last month of pregnancy as it may interfere with cation/anion balance, predisposing the animal to metabolic disease (hypocalcaemia (milk fever) or hypomagnesaemia) at calving. Risks are greater if fed with high potassium pastures such as kikuyu and ryegrass. **Live weight targets and feed requirements**

Table 14.7 shows expected dry matter intakes for Holstein Friesian heifers of increasing weight and their metabolisable energy (MJ ME/day) requirements to maintain growth rates of 0.7 kg/day. Use this table to calculate how much concentrate or forage supplement needs to be fed to heifers at differing stages of growth to achieve growth targets.
Table 14.7. Feed intake and metabolisable energy (MJ ME/day) required to maintain live weight gains of 0.7 kg/day for Holstein Friesian heifers.

<table>
<thead>
<tr>
<th>Liveweight (kg)</th>
<th>DM intake (kg/day)</th>
<th>Required metabolisable energy intake (MJ ME/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2.8</td>
<td>32</td>
</tr>
<tr>
<td>200</td>
<td>5.0</td>
<td>50</td>
</tr>
<tr>
<td>300</td>
<td>7.0 - 7.5</td>
<td>70</td>
</tr>
<tr>
<td>400</td>
<td>9.0 - 10.0</td>
<td>85</td>
</tr>
<tr>
<td>500</td>
<td>11.0 - 12.0</td>
<td>105</td>
</tr>
<tr>
<td>550</td>
<td>13.0</td>
<td>115</td>
</tr>
<tr>
<td>600</td>
<td>15.0</td>
<td>126</td>
</tr>
</tbody>
</table>

Responses to supplementary feeding while grazing

The systems of milk production in subtropical areas have become more diverse than in the past. Traditionally grazing pasture or forage crop was the primary means of forage feeding and this was supplemented with conserved forage or concentrates. On many farms the amount of conserved forage has increased markedly. One aspect of this change has been in the approach to nutrition management.

When the intake of an animal is known it is possible to assess the total diet and make changes in line with the nutritional requirements. Farms where a large proportion of the forage intake is from conserved fodder, it is possible to formulate complete diets to meet intake and nutritional needs.

However, where grazing is the primary source of forage it is more difficult to estimate intake and consequently formulate rations. Much more reliance has been placed on the measured responses when supplements are fed with the grazed forage. From practical trials and farm experience a large array of responses were measured to various supplements, and these can be used to estimate likely milk response to supplements on dairy farms using substantial grazing.

Energy supplements

Table 14.8. A summary of measured milk responses to grain based concentrate for herds of different milk production and pastures of different quality.

The milk response to energy supplements such as grains varies with the level of current milk production, the length of the feeding period and the pasture condition (Table 14.8). Low producing cows are less responsive than high producing cows, with measured responses reaching 1.7 L milk/kg concentrates in high genetic herds. Measured responses never reached the theoretical level of 2 L/kg and this is considered due to losses of energy through substitution and increased maintenance requirement.

Initial response is often low, especially with well fed and high producing cows, as the initial change is a reduction in pasture intake, or substitution. However, this reduction is only partial and gradually milk production increases, stimulating an increase in total feed intake. Over a period of 4 - 12 months responses invariably increased to a level reflecting the milk production level of the herd, from 1 - 1.6 L milk/kg.

The increase in milk response over time is strongly influenced by the pasture condition. Where pasture condition is very poor responses over 1.4 L/kg grain will be measured within 4 weeks, whereas on abundant, lush pasture the response may take 6 months to develop.
Feeding concentrates during early lactation increases milk yield and consequently appetite, and this effect may persist through lactation when concentrates are reduced. For example cows grazing tropical pastures responded with 0.7 L additional milk/kg supplement when fed 3.6 kg maize during the first 50 days of lactation. When this supplement was withdrawn after 50 days the milk advantage persisted and over the full lactation the response was 3 L/kg where pasture was plentiful. However when pasture was restricted the effect did not last.

Although the effects are variable, the average results of 22 trials showed slight increases in milk protein percentage and decreases in milk fat percentage with additional supplementary energy concentrates.

Alternate energy supplements to grain generally have smaller responses than grain. Molasses as fed produces 70% of the milk response of grain, and pineapple pulp, citrus pulp and brewers grain produced 80% of the grain response on a dry matter basis. Maize silage as a supplement to grazed pasture produced 0.6 - 0.8 L milk/kg DM.

### Protein supplements

Protein level in the diet needs to be adequate for cows to use energy supplements efficiently. Once the diet contains this level of protein additional protein will simply be used as energy, with a similar efficiency to grain. The required level of protein is predicted from average milk production, being 14% for cows at 16 L/day and increasing to 16% for higher producing cows. When diets are below these protein levels responses to grains and other energy supplements are restricted.

Irrigated pastures usually contain an excess of protein and a milk response to additional protein in the diet is unlikely. However, with dryland tropical pastures there may be periods of the year when protein content of the pasture is below requirements and protein needs to be added to the grain supplement to ensure an efficient milk response.

A survey of farms across Queensland measured crude protein of the milkers diet on two occasions, Figure 14.5 showed that very few farms are feeding <14%.
Figure 14.5. Crude protein (% of DM) for whole of diet from Queensland dairy farms sampled in winter 2011 and summer 2012. Shaded area represents desired crude protein content (C4Milk project).

Supplements for growing heifers
The growth response in dairy heifers to feeding energy supplements ranges from 0.1 to 0.2 kg live weight gain per kg supplement. The higher values are measured on poorer quality pastures. Generally supplements are fed to maintain growth rate at 0.7 kg/day.

References and further information
Nutrition Plus technical note series.
Chapter 15. Feeding systems

Feeding systems are formed by putting together the various feeds available to meet farm targets. Generally in the dairy situation the targets relate to achieving a certain level or increasing milk production, as it is consistently found that increasing milk production increases financial benefit. However, this is not always true and at times of very high feed costs it may be desirable to withdraw certain feeds or change to lower quality feeds to maintain an economic margin over feed costs.

Planning

Feeding systems are normally planned for one or more years ahead and are revised periodically, perhaps each 3 months through the year to take account of deviations from expected feed production on the farm and purchased feed costs (Table 15.1). Daily adjustments are made to optimize the match between cow feed requirements and feed available. An annual review of the feeding system is used to assess success in feeding cows and impact on whole farm profitability. Since feed cost is about 60% of total farm costs and can be altered, unlike many overhead and labour costs, the productivity of the feeding system has a large and direct effect on profit. Increased profit is invariably related to improved productivity in the feeding system.

Table 15.1. A summary of the objectives for reviewing the feeding system at various times.

<table>
<thead>
<tr>
<th>Time</th>
<th>Assessment</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 10 years</td>
<td>Capability</td>
<td>Farm development</td>
</tr>
<tr>
<td></td>
<td>Land, water, cows, climate</td>
<td>Infrastructure spending</td>
</tr>
<tr>
<td></td>
<td>Feeds available for purchase</td>
<td>Support additional family members</td>
</tr>
<tr>
<td>Annual</td>
<td>Matching desired milk production with feed</td>
<td>Plan work programs</td>
</tr>
<tr>
<td></td>
<td>available</td>
<td>Maximize efficiency of feed use</td>
</tr>
<tr>
<td>Seasonal</td>
<td>Reformulating the ration</td>
<td>Maximise efficiency of feed use</td>
</tr>
<tr>
<td></td>
<td>Changed forage base</td>
<td>Purchasing of feeds</td>
</tr>
<tr>
<td></td>
<td>Changed purchased feed</td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>Feed allocation</td>
<td>Fine tuning the match of feed and herd</td>
</tr>
<tr>
<td></td>
<td>Feed production</td>
<td>requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Implementing the forage production plan</td>
</tr>
</tbody>
</table>

The long term planning is essential for dairy farms as it is not possible to change feedbase quickly. Investments in dairies, irrigation equipment and cows are large and cannot be quickly redirected to other activities. It also takes some years for the full benefits of major investment to become realised. It is also imperative that the right decisions be made and rate of change matches projected increase in production, an incorrect decision here will not be rectified by ongoing management and labour efforts. Water availability, climate suitability for the proposed feeding system and reliable supply of major purchased feed items are examples of issues that need careful consideration at this stage.
Annual and seasonal reviews are about book keeping, in that the numbers are calculated to ensure the feed supply matches cow requirements. Modest modifications are made to the feeding system, such as altering the amount or type of purchased feed, changing the winter or summer forages grown or reformulating the concentrate ration.

Daily assessment of the feeding system is routine, but has a major impact on overall efficiency and profit. The objective of daily decisions is to implement the feeding plan efficiently, and this is based on allocating feed efficiently and growing forages effectively. Efficient allocation of feed ensures the ration is balanced and adequate, but refusals and wastage are minimal. A 5% additional wastage on a large dairy farm represents over $20 000 loss annually. Similarly if forages are grown to achieve optimal yield and quality the production and financial aims of the feeding plan will be met, but delays in implementing the plan can reduce profits.

Timeliness is a key point in efficient home grown forage production. For example, a delay of 2 weeks in planting ryegrass in April resulted in a 10 - 15% reduction in annual forage production. Delays in one season often impact on the next. Delays in weed control will reduce water available to the forage crop, perhaps reducing yield and the length of the growing season, which in turn necessitates greater feeding of purchased feeds in the period after this crop. In this way the daily implementation of a feeding system has a cumulative effect on production and profit, either positive or negative.

A substantial benefit of planning the feeding system is that the interactions between feeds can be identified and managed to maximize efficiency. These interactions can be with the paddock through competition for land or water, with purchasing feed to ensure the correct balance of energy and protein is bought, and with the cow to ensure best use is made of grown and purchased feed. Some examples are:

- Where water is scarce a relatively low quality forage may have to be grown on the farm such as forage sorghum, and this may require the purchase of a higher protein mix in purchased feeds.
- A final grazing on tropical crops or pastures may need to be foregone to enable timely establishment of annual temperate crops and pastures.
- If large amounts of maize silage are used purchases of protein will increase.
- When high quality pasture or crop is available for cows it is normal to reduce supplementary feeding to enable maximum efficiency to be made of the forage.
- The formulation of the concentrate or PMR will vary between the seasons of the year, reflecting the forage grown and availability of purchased feeds.

**Resource assessment**

The first resource assessment in long term planning for a dairy is the feeding system as this will drive the production and profit from the farm. Other resources such as markets, capital, labour and management skills are also important, and will have to be considered before the plan is implemented, but unless there are resources to feed cows it is not possible to develop an efficient dairy farm.

Deciding on a long term feeding system is a result of assessing feed resources available to the farm. The on-farm factors are hectares, soil quality and water availability. Off farm the supplies of forage and concentrate must be sufficient and reliable. Many farms will identify a major resource around which other aspects of the feeding system will fit. For example a
large area of fertile land or large water entitlement would provide an assured home grown forage supply, and purchased feed would complement this. On the other hand some farms identify an off farm source of feed, such as byproducts, that can be contracted in large quantities, and home grown forage may be used to complement this resource.

The suitability of the feeding system to the farm environment needs to be assessed, to avoid undue stress on cows, the environment and the farm family. For example a feedlot type farm in a wet area may be difficult to manage, and in peri-urban areas the effects of farm operations on the environment and neighbours’ comfort are important.

Long term planning of feeding systems is based on gross quantities and quality of feeds. If the amounts of feed available and the feed quality are known, the cow requirements can be compared with these and potential capacity of the system determined (Table 15.2). In the example in Table 15.2 the home grown forage is the primary feed source, setting capacity, and purchased forage and concentrates are added to that to make a productive feeding system.

Table 15.2. An example of initial calculations to determine the capacity of a feeding system, based on the dry matter yield (t) and crude protein content (%) of forage and concentrates. Cow capacity calculated to be 7 t DMI/year.

<table>
<thead>
<tr>
<th>Feed source</th>
<th>Forage</th>
<th>Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home grown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage a</td>
<td>500 (26%)</td>
<td></td>
</tr>
<tr>
<td>Forage b</td>
<td>450 (24%)</td>
<td></td>
</tr>
<tr>
<td>Total forage</td>
<td>1150 (60%)</td>
<td></td>
</tr>
<tr>
<td>Concentrates required (t DM)</td>
<td>764 (40%)</td>
<td></td>
</tr>
<tr>
<td>Purchased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage c</td>
<td>200 (10%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>a 690 (36%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b 74 (4%)</td>
</tr>
</tbody>
</table>

A common consequence of long term planning of the feeding system is that present resources are not sufficient to feed the number of cows envisaged. Modern dairy cows have large appetites and the tonnages of forage required grows rapidly with cow numbers. In this situation it may be possible to expand the resource base e.g. buying or leasing land, capturing overland water, increase the productivity of the resource e.g. cropping rather than using pastures, or relocating to an area with greater resources. Alternatively an upper limit may be placed on cow numbers and the feeding system changed to reduce costs e.g. grazing high quality pastures and using low protein concentrates. Generally the options for reducing costs are considerably less than those for increasing production.
The feed year

The total tonnages may be sufficient for the feeding system envisaged, but it is important to ensure cows are fed each month of the year. The tried and proven means of doing this is through a feed year plan. The plan shows the source of feed to cows in each month of the year, and is then manipulated to ensure a continuous supply of feed. In the simplest form the source of feed in each month is identified (Table 15.3), but it is usually useful to attempt to quantify the intake in each month (Table 15.4). Other aspects of the annual management of feed, such as planting times, harvesting times, conservation times and spray/plough out times can be nominated on the chart (Figure 15.1).

Table 15.3. A feed year plan for a subtropical dairy farm showing the sources of feed in each month of the year.

<table>
<thead>
<tr>
<th>Month</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical grass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ryegrass</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Maize silage</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Concentrates</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

The primary purpose of the feed year plan is to assess the continuity of the feed supply to cows. Where deficiencies or excesses in feed supply are identified the plan can be changed, for example earlier introduction of silage or reduced feeding of grain, or plans can be made to conserve excess forage. In most subtropical farms the demand for feed is reasonably consistent through the year, but where seasonal or batch calving are practiced the demand will change as well as the supply. In this case a demand line can be added to the feed plan showing the target DMI in each month, and the feed supply is manipulated to meet this pattern of demand.

Table 15.4. A feed year plan for a subtropical dairy farm, showing the daily intake (kg DM) of a cow producing 19 L milk. Plan 1 identifies a gap in forage supply in autumn, and the plan is modified to remove this gap (plan 2).

<table>
<thead>
<tr>
<th>Month</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Tropical grass</td>
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<td>10</td>
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<td>4</td>
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<td>12</td>
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<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Maize silage</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
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<td></td>
</tr>
<tr>
<td>Concentrates</td>
<td>7</td>
<td>7</td>
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<td>7</td>
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<td>6</td>
<td>6</td>
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<td>7</td>
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<td>17</td>
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<td>15</td>
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<td>18</td>
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<td>18</td>
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<td>16</td>
<td>17</td>
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<td>Plan 2</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>10</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>4</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize silage</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Concentrates</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>18</td>
<td>18</td>
<td>17</td>
<td>16</td>
<td>17</td>
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</tr>
</tbody>
</table>
M2 - limited irrigation pasture based system

<table>
<thead>
<tr>
<th>Calving pattern</th>
<th>Reproduction - AI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some cows are dry</td>
<td>Some cows are dry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planting irrigated crops</th>
<th>Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryegrass</td>
<td>Sorghum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conservation</th>
<th>Fertiliser program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
<td>S + W</td>
</tr>
<tr>
<td>Intensive</td>
<td>S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Greatest HG Feed</th>
<th>Conserved fodder required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryegrass</td>
<td>if possible</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highest milk production</th>
<th>Highest milk price</th>
</tr>
</thead>
<tbody>
<tr>
<td>if possible</td>
<td>if possible</td>
</tr>
</tbody>
</table>

Figure 15.1. A calendar of operations and farm activities (M5 information series).

Tools

Ration formulation is a useful tool in designing feeding systems because it will indicate the mix of feeds that best meets the nutrient needs of cows. The formulation is useful on an annual basis to indicate gross effects on nutrient supply. For example if a large amount of maize silage is to be fed there may be a need for substantial purchases of protein meals.

However, it is also essential to formulate rations on a seasonal basis, as nutrients which balance each other on an annual basis may not be available to the cow concurrently. For example, the high protein in ryegrass balances the low protein in maize silage on an annual basis, but during winter and early spring when ryegrass is being grazed it is unusual to be feeding large amounts of maize silage. Potential for heat stress during summer may also impact on the planned ration at that time.

In the example of Table 15.5, small differences of less than 10% between nutrient requirements and supply are ignored, as the science of ration formulation is not exact. The main notable difference here is the lack of protein during summer and autumn if only grain is fed (10% CP). It will be necessary to boost the protein content of the grain mix to about 17% DM to meet the requirements. The additional protein can be purchased as protein meal or a grain concentrate formulated to 17% CP.

For planning purposes it is usually sufficient to formulate for energy and protein supply, and fine tuning on these and mineral supply is done at the time of feeding.

Table 15.5. An example of ration formulation for each season of the year to determine needs for additional feed purchases, using the example in Table 90.

<table>
<thead>
<tr>
<th>Cow requirements</th>
<th>Feed supply</th>
<th>Tropical grass</th>
<th>Maize silage</th>
<th>Grain</th>
<th>Total</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer ME (MJ/d)</td>
<td>CP (kg/d)</td>
<td>Summer ME (MJ/d)</td>
<td>CP (kg/d)</td>
<td>Summer ME (MJ/d)</td>
<td>CP (kg/d)</td>
<td>Summer ME (MJ/d)</td>
</tr>
<tr>
<td>163</td>
<td>2.5</td>
<td>163</td>
<td>2.5</td>
<td>163</td>
<td>2.5</td>
<td>163</td>
</tr>
<tr>
<td>90</td>
<td>1.2</td>
<td>9</td>
<td>0.12</td>
<td>80</td>
<td>0.7</td>
<td>+9</td>
</tr>
<tr>
<td>80</td>
<td>0.7</td>
<td>80</td>
<td>0.7</td>
<td>69</td>
<td>0.6</td>
<td>+26</td>
</tr>
<tr>
<td>170</td>
<td>1.9</td>
<td>157</td>
<td>1.7</td>
<td>189</td>
<td>2.4</td>
<td>+16</td>
</tr>
</tbody>
</table>

S = summer, W = winter fertiliser program
/ = dependant on seasonal conditions
\ = varies with processor supplied

Tools

Ration formulation is a useful tool in designing feeding systems because it will indicate the mix of feeds that best meets the nutrient needs of cows. The formulation is useful on an annual basis to indicate gross effects on nutrient supply. For example if a large amount of maize silage is to be fed there may be a need for substantial purchases of protein meals.

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Table 15.5. An example of ration formulation for each season of the year to determine needs for additional feed purchases, using the example in Table 90.
**Dairy predict**

There are many computer packages used by nutritional consultants and farmers to plan feed requirements and formulate rations. One developed specifically for the subtropics is Dairy Predict ([www.dairyinfo.biz](http://www.dairyinfo.biz)). It has many features common to all feed system planning tools, but has specific information on tropical feeds and uses nutritional and financial calculations tried and proven in subtropical Australia.

The benefits of this program include:
- An easy to use computer interface.
- A logical progression through forage production, supplementary feeding, herd structure, cow requirements, milk production and gross margin.
- An ability to draw on large amounts of information from related databases and to include other complementary models in the calculations.
- An ability to easily rework feed plans many times until the output meets expectations.

**Mixer wagons**

The biggest change to subtropical feeding systems in recent years has been the growth in use of crops for conservation and the associated changes in feeding. The changes include greater use of planning and ration formulation and higher milk production. However one of the most important aspects of the change has been the adoption of mixer wagons as the means of feeding conserved and other feeds to cows. There are differences of opinion on the economics of purchasing a wagon, though almost universal acceptance is that it provides the capacity to feed out and mix feeds for higher milk production.

The primary purpose of a mixer wagon is to mix a number of stored feeds so they can be fed in a feed pad, trough or along a fence line. As feeding levels are increased and as a wider range of feeds are used in rations, wagons offer the advantages of enabling more accurate ration formulation and reducing metabolic disorders such as acidosis.

When mixer wagon feed out is used in addition to grazing during the day the system is referred to as partial mixed rations (PMR). When all feed is through the wagon it is referred to as total mixed ration (TMR). Generally the benefits of feeding a mixed ration increase as the feeding system moves closer to substantial PMR or TMR. It is recommended to assess the effectiveness of a wagon by completing a partial budget (Table 15.6). Not all of these costs may be incurred on the farm, but those which are can be budgeted and compared with the potential change in income.

The key benefits of using a mixer wagon in a PMR and TMR system are:
- An increase in milk production (5 - 20%) and fat percentage (5%), though no change in protein percentage.
- Less metabolic diseases, especially acidosis, due to less selective eating and a longer feeding period for concentrates.
- Less feed wastage (3 - 15%).
- Higher labour efficiency and more specialized and careful labour.
- Greater control over the feeding program.
- A wide range of stored feeds can be added to the ration and mixed thoroughly and evenly.
- Fits well with computer based ration formulation programs.

Potential drawbacks from using a mixer wagon are:
- High cost of the wagon and associated equipment (may include a feed mill, front end loader, commodity bays, effluent disposal system).
- More skill required in ration formulation.
- Increased manure build up in feed out and loafing areas.
Table 15.6. The economic parameters for completing a partial budget on the potential purchase of a mixer wagon on a dairy farm.

<table>
<thead>
<tr>
<th>Additional capital costs</th>
<th>Additional returns</th>
<th>Additional operating costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixer wagon with weigh scales</td>
<td>Increased milk yield (5-20%)</td>
<td>Added feed for the increase in DMI</td>
</tr>
<tr>
<td>Front end loader</td>
<td>Increased fat percentage (0-5%)</td>
<td>Change in labour requirements (hours and payment rate)</td>
</tr>
<tr>
<td>Feed mill</td>
<td>Reduced wastage (3-15%)</td>
<td>Fuel and maintenance of machinery</td>
</tr>
<tr>
<td>Commodity bays</td>
<td>Sale of redundant equipment</td>
<td>Nutritional consultant fees, feed analyses and computer programs</td>
</tr>
<tr>
<td>Feed bunkers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fencing, feed and water troughs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effluent disposal system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Economics**

The simplest way of monitoring feeding system costs is to routinely complete a year to year comparison of farm accounting data, as in the QDAS system. In systems such as this the annual income and costs are tabulated under relevant headings, broadly categorized as operating, management, administration, overheads and finance, and various ratios calculated for efficiency and profitability. Performance levels can also be compared with benchmarks for the farm, district or total industry. The feed related costs can be compared with income and other costs, and within the feeding system the contribution of purchased and home grown feed compared. The categories used in QDAS for collating financial data are:

- Income (milk, stock sales, other).
- Feed related costs (purchased feed, fertilizer, fuel & oil, seed, irrigation costs, repairs and maintenance, other).

- Variable costs separate to feed costs (animal health, herd improvement, dairy shed electricity and chemical costs, cartage, levies, other).
- Farm details (cow numbers, milk production and composition, land areas, labour units, farm value).

Using this information a gross margin statement and profit map are produced. From these various assessments are possible by comparing performance with previous years, industry benchmarks and district averages. Examples of some financial and performance ratios are shown in Table 15.7. Higher performing farms do tend to have a higher milk price (1.8 c/L in 2010) but also have lower feed costs/L of milk and higher milk output per labour unit. Often lower feed costs/L of milk is associated with greater total spending on feed related items, such as irrigation and fertilizer.
Table 15.7. Indicative measures of financial and performance ratios for subtropical dairy farms (Murphy and Simpson 2010).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Average herd</th>
<th>Top 25% of herds*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profitability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return on assets (%)</td>
<td>4.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Dairy operating profit ($/cow)</td>
<td>754</td>
<td>1490</td>
</tr>
<tr>
<td>Solvency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity</td>
<td>85</td>
<td>83</td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liabilities ($/cow)</td>
<td>2705</td>
<td>2810</td>
</tr>
<tr>
<td>Milk production (L/cow)</td>
<td>6248</td>
<td>6849</td>
</tr>
<tr>
<td>Feed costs (c/L)</td>
<td>29.1</td>
<td>26.1</td>
</tr>
<tr>
<td>Margin over fed cost (c/L)</td>
<td>27.1</td>
<td>31.8</td>
</tr>
<tr>
<td>Labour (L/unit)</td>
<td>281 000</td>
<td>325 000</td>
</tr>
</tbody>
</table>

* Top 25% chosen on basis of profit per cow.

Examples of subtropical feeding systems
From 2000 to 2005 five very different feeding systems, each of which was considered to be applicable to subtropical Australia, were run concurrently at Muddapilly Research Station. Each 20 cows farmlet was a model of a commercial scale farm, designed from farmer experience and professional input. These farms provide the most useful guide to date on the capability and performance of dairy feeding systems in the subtropics.

The basic outline of each feeding system is shown in Table 15.8. Much of the variation between systems was in the amount of irrigation, and as more irrigation became available there was a choice between intensive grazing of pastures or feedlot using conserved crops. The choices of stocking rates and forage species were linked to these options.

Results showed the high levels of milk production possible from subtropical systems (Table 15.9), ranging from 6000 9000 L/cow for the raingrown pasture system to the feedlot. Milk production per hectare was substantial for the raingrown system at 12 000/ha, but was increased dramatically with irrigation to 20 000 and 39 000 L/ha for the fully irrigated pasture and feedlot systems respectively.

Feed related costs were reduced slightly in the higher producing systems and margin over feed cost increased from 19 c/L for the nil or limited irrigation systems to 22 - 24 c/L for the heavily irrigated systems. The limited irrigation and cropping system also recorded relatively high margin over feed cost. Operating profit per cow reflected these differences in production and cost and increased from $47 for the rain grown system to $823/cow for the feedlot. Overall the most profitable systems were those with the highest inputs and highest milk production. In particular feedloting showed relatively high profitability despite relatively high input costs.
Table 15.8. An outline of the five feeding systems evaluated at Mutdapilly over 4 years, using farmlets of 20 cows and modelling of commercial scale farms (M5 project - Chataway et al. 2010b).

<table>
<thead>
<tr>
<th>Farm</th>
<th>Description</th>
<th>Calving pattern</th>
<th>Stocking rate (cows/ha)</th>
<th>Winter forage</th>
<th>Summer forage</th>
<th>Off farm feeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Rain grown, pasture</td>
<td>50% spring/50% autumn</td>
<td>1.9</td>
<td>oats</td>
<td>Rhodes grass</td>
<td>3 t conc./1 t hay or silage</td>
</tr>
<tr>
<td>M2</td>
<td>Limited irrigation, pasture</td>
<td>50/50</td>
<td>2.8</td>
<td>ryegrass</td>
<td>Rhodes grass</td>
<td>3/1</td>
</tr>
<tr>
<td>M3</td>
<td>Limited irrigation, crop</td>
<td>30/70</td>
<td>1.4</td>
<td>Ryegrass, oats, lucerne</td>
<td>Forage sorghum, lablab, lucerne</td>
<td>3/0</td>
</tr>
<tr>
<td>M4</td>
<td>High irrigation, pasture and crop</td>
<td>30/70</td>
<td>2.8</td>
<td>Ryegrass, prairie, fescue</td>
<td>Lucerne, forage sorghum</td>
<td>3/0</td>
</tr>
<tr>
<td>M5</td>
<td>Feedlot</td>
<td>Year round</td>
<td>4.3</td>
<td>Maize, Lucerne and barley silages</td>
<td>Maize, Lucerne and barley silages</td>
<td>3/0</td>
</tr>
</tbody>
</table>

Overall the findings showed:
- Highly productive and profitable systems are feasible in the subtropics.
- The production of home grown forage drives production and profit.
- The tropical forages are useful in summer as a feed source and to utilize water and nitrogen in the soil.
- Water efficiency was highest in the summer crops cut for silage (maize and forage sorghum).
- High concentrate inputs are profitable when combined with high intakes of home grown forage.

Table 15.9. The performance of the five feeding systems over four years at Mutdapilly (M5 project - Chataway et al. 2010b).

<table>
<thead>
<tr>
<th>Farm</th>
<th>Milk (L/cow/year)</th>
<th>Milk (L/ha/year)</th>
<th>Feed related costs (c/L)</th>
<th>Margin over feed costs (c/L)</th>
<th>Operating profit ($/cow/year)</th>
<th>Return on assets (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>6100</td>
<td>12 000</td>
<td>17.7</td>
<td>18.9</td>
<td>47</td>
<td>0.9</td>
</tr>
<tr>
<td>M2</td>
<td>6500</td>
<td>17 700</td>
<td>17.9</td>
<td>19.5</td>
<td>160</td>
<td>2.9</td>
</tr>
<tr>
<td>M3</td>
<td>6800</td>
<td>9 300</td>
<td>15.8</td>
<td>22.1</td>
<td>357</td>
<td>6.3</td>
</tr>
<tr>
<td>M4</td>
<td>7400</td>
<td>20 800</td>
<td>15.9</td>
<td>22.5</td>
<td>438</td>
<td>6.7</td>
</tr>
<tr>
<td>M5</td>
<td>9100</td>
<td>39 400</td>
<td>16.8</td>
<td>24.1</td>
<td>823</td>
<td>13.9</td>
</tr>
</tbody>
</table>
References

Chapter 1


Chapter 2


Chapter 4


Chapter 5


Chapter 7


Chapter 8


Chapter 9


Chapter 10


Chapter 11


Chapters 12, 13 and 14


Chapter 15

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