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# Northern dairy feedbase 2001. 1. Summer pasture and crops

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**Abstract**

There is a very high potential for forage growth during summer in the tropics and subtropics, but there are many problems associated with realising this potential in terms of milk production. The tropical grasses are capable of yielding 50*t* DM/ha/yr, though in practice yield is less than one-third of this, and the high structural fibre and low protein contents of these grasses severely restrict milk production during autumn. Twining tropical pasture legumes are unstable under commercial stocking rates and effort is now directed to species suited to heavy grazing, such as Pinto peanut (*Arachis pintoi* cv. Amarillo) and lotus (*Lotus pedunculatus* cv. Maku), and browse shrubs such as leucaena (*Leucaena leucocephala*). Lucerne (*Medicago sativa*) is recognised as an outstanding forage for grazing or conservation, but present varieties are unsuited to most soil types on dairy farms.

Water use efficiency is a high priority for research into summer forage crops. In dryland areas forage and grain sorghums (*Sorghum* spp.) are used to maximise dry matter production with limited moisture supply. There is a strong trend towards maize (*Zea mays*) for silage in irrigated areas, and areas requiring further research include delineation of areas suited to the crop, agronomy and integration into farming systems.

Legume crops promote higher intakes than grass crops, though at present there is heavy dependence on *Lablab purpureus* varieties developed over 20 years ago. Other crop legumes, including the soybeans, may be useful, particularly if combined with water-efficient cultural practices.

There is general concern at the cost of fertiliser inputs and their fate once they leave the pasture-soil complex. In particular, efficient methods of using nitrogen fertiliser are required. As the forage systems for the tropics and subtropics develop there will be a greater emphasis on quality of forage, emphasising characteristics such as low structural fibre content, high protein content, low degradability of protein in the rumen, a favourable amino acid composition of protein, and adequate mineral content.

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**Introduction**

Feed is the basic resource used by dairy farmers to produce milk. The number of cows in the herd will depend on the quantity of forage that can be grown on the farm, the quantity of feed purchased and the quantity of feed eaten by each cow.

$$\text{Number of cows} = \frac{(\text{Feed grown} + \text{Feed purchased}) - \text{Feed wasted}}{\text{Intake per cow}}$$

Milk production per cow will be controlled by genetic factors, stage of lactation and the quality of the feed supplied. The appetite of cows is not constant but varies between feeds, and the quantity eaten (voluntary feed intake) is the primary factor controlling daily nutrient intake and hence milk production. The second factor controlling milk production is the concentration of nutrients in the feed.

Hence:

$$\text{Milk production (kg/cow/d)} \propto \text{Nutrient intake (kg/d)}$$

$$\text{Nutrient intake (kg/d)} = \text{Intake (kg)} \times \text{Nutrient concentration (g/g)}$$

This review will start by considering the factors controlling dry matter production from summer forages and the scope for further research to increase yield of forage. The second half of the review will discuss the cause of the low quality of tropical forage and how these problems may be overcome by further research.

## Pasture yield and quality

### Plant species

*Perennial tropical grasses*. When well watered and fertilised, tropical grasses produce over twice the quantity of dry matter each year as temperate pastures and have the potential for carrying twice the number of cows. Tropical grasses have a more efficient pathway of photosynthesis but this accounts for only about a quarter of the higher dry matter production shown in Table 1. Most of the higher production is associated with the higher light intensity in the tropics.

**Table 1.** Mean production and energy conversion of light energy by well fertilised and watered temperate and tropical grasses (derived from Cooper 1970).

| Species | Temperate | Tropical | Difference (%) |
|---|---|---|---|
| No. of studies | 6 | 17 | — |
| Dry matter yield (t DM/ha/yr) | 22 | 49 | 125 |
| Potential carrying capacity (cows/ha) | 5.5 | 12.0 | 125 |
| Light energy conversion (%) | 2.3 | 3.0 | 30 |
| Photosynthetic pathway | $C_3$ | $C_4$ | — |

A large proportion (about 40%) of the carbohydrate photosynthesised in the day is lost by respiration during the night. Studies in the UK have shown that there is genetic variation in the night respiration of ryegrass (*Lolium* spp.) and that lines with slow dark respiration rates produced 11–13% more dry matter when grazed and 5–6% more under a cutting management regime (Wilson and Jones 1982). Comparable studies with tropical grasses have not yet been attempted but the CSIRO Division of Tropical Crops and Pastures is attempting to increase production of sugar cane by reducing dark respiration.

In practice the measured dry matter yield of tropical grasses is considerably below the potential of 50 t DM/ha/yr described by Cooper (1970). Colman (1971a) reviewed many of the cutting experiments on tropical pasture plants in northern Australia. Grass–legume mixed pastures produced from 2–10 t DM/ha/yr, with a value of 7–8 t being a reasonable average. Nitrogen-fertilised grasses produced from 11–24 t DM/ha/yr, with a mean of about 20 t. Higher rainfall, soil water holding capacity and level of nitrogen fertiliser were all associated with increased yield of grass (Buchanan and Cowan 1990). In a review of data from 31 sites, Teitzel *et al.* (1991) found grass yield increased with level of nitrogen, but the maximum yield was set by rainfall. In regions with an average rainfall of 1000 mm/year, maximum yield of 20 t DM/ha/yr was achieved with 600 kg N/ha/yr. With rainfall of 750 mm, maximum yield occurred at 400 kg N/ha/yr and was 14 t DM/ha/yr.

More frequent cutting reduces the DM yield of tropical grasses (Bryan and Sharpe 1965). Davison *et al.* (1981) attributed a reduction in milk yield of cows grazing regularly topped tropical grasses to the associated reduction in grass yield. Cutting pangola grass (*Digitaria eriantha*) at 6-week rather than 2-week intervals increased yield from 8 to 10 t DM/ha/yr (G. Chopping, personal communication). Bryan and Sharpe (1965) measured a similar yield with a 6-week intercutting interval and 21 t DM/ha/yr with a 12-week intercutting interval. Surprisingly, the change in nitrogen yield with cutting interval was small (Bryan and Sharpe 1965). Similar effects are evident in native tropical grass species (Scattini 1981).

Milk yield of cows has often been related to the yield of grass or grass on offer to cows (Cowan *et al.* 1986). These authors suggested 1 t/ha green grass leaf DM was required to enable cows to consume to appetite, representing a standing yield of grass on offer in the range 2.5–4 t/ha DM. In a study of the effects of level of nitrogen fertiliser on yield of pasture on offer to cows on 10 farms in south-east Queensland, pre-grazing yield increased by an average of 3.5 kg pasture DM or 1 kg leaf DM/kg N/yr (Buchanan and Cowan 1986). Where pasture yield was measured under grazing and in the absence of grazing, the incremental response to level of nitrogen fertiliser was 4.0 kg DM/kg N at each grazing and 25.6 kg DM/kg N/yr, respectively (Cowan *et al.* 1993). At 300 kg

N/ha/yr this represents an additional 420 kg/ha leaf DM at each grazing, or approximately 2 L extra milk/cow (Davison *et al.* 1985). Milk production plateaus at grass yields on offer of 3.5 t DM/cow (Cowan and O'Grady 1975; Cowan and Stobbs 1976; Davison *et al.* 1985), and may decrease above 5–6 t/ha DM on offer (Davison *et al.* 1993).

One aspect of tropical grass yield and quality which appears to warrant further investigation is the ability of these grasses to combine with the temperate legume, white clover (*Trifolium repens*). In coastal south-east Queensland white clover in mixtures with pangola and setaria (*Setaria sphacelata*) grasses yielded up to 10 t/ha/yr DM and was considered to fix up to 330 kg N/ha/yr (Ebersohn and Mulder 1980). More frequent defoliation of tropical grass is known to favour white clover growth during autumn (Jones 1984).

When compared under similar conditions at the same age of regrowth, differences between tropical grasses in voluntary intake and digestibility are small (Milford and Minson 1968a; Minson 1972; Minson 1990). Major differences in the quality of grass eaten are caused by the age of regrowth of the grass (Minson 1990) and the opportunity for the cow to select leaf (Cowan *et al.* 1986). Present evidence (Moir *et al.* 1979; Lowe *et al.* 1991; R. Moss, personal communication) is that tropical grass leaf has a potential ME value of 11 MJ/kg DM, but a more consistent value through the summer and autumn would be 9.5 MJ ME/kg DM. Stem is considerably lower at 7–8 MJ ME/kg DM.

*Kikuyu.* Kikuyu grass (*Pennisetum clandestinum*) grows well on high fertility soils in the high rainfall environments of coastal districts, particularly in northern NSW and south-eastern Queensland. Over the past 10 years, kikuyu has spread rapidly on the east coast of NSW, and provides 75% of the pasture grazed by milking cows in the summer/autumn period (Advisory survey, NSW Agriculture, 1992). Kikuyu is potentially well adapted to 0.86 million hectares in Queensland and these are mainly dairying districts (Weston *et al.* 1984).

Kikuyu's strengths are its rapid growth rate in summer, a high capacity to respond to nitrogen and rainfall, tolerance to grazing and persistence (Colman and O'Neill 1978). Kikuyu can produce up to 30 t/ha DM when nitrogen and water are not limiting (Colman 1971b). However, without nitrogen fertiliser, yields as low as 500 kg/ha DM have been reported (Kemp 1975). The growth pattern of kikuyu is dictated by temperature with growth ceasing below a minimum temperature of 10 °C. Potential productivity decreases with increases in latitude. Seasonal productivity can be extended by strategic use of nitrogen fertiliser (Kemp 1975). Mears (1970) reviewed a wide range of experiments which showed the response of kikuyu to nitrogen was in the range 13–27 kg DM/kg N. Pearson *et al.* (1985) produced dry matter yields under irrigation of 14.33 t/ha DM at Taree, 13 t/ha DM at Camden and 5.6 t/ha DM at Bega. Kikuyu can be managed to provide a higher protein content than other tropical grasses (Milford and Haydock 1965; Wilson and Haydock 1971).

Milk production from kikuyu pastures is limited by the decline in quality with advancing maturity. The key to obtaining high quality feed from kikuyu pastures is to remove the runners early in the growth season and maintain the sward in a leafy state (Anon. 1977). Digestibility of kikuyu is reasonable up to 4 weeks regrowth but declines rapidly from this point (Table 2).

Excessive growth can be controlled by slashing (Anon. 1977) but there is a strong case for developing techniques which will allow the material in excess of the requirements of the milking herd to be either grazed by dry followers or conserved as silage.

**Table 2.** Changes in protein content and digestibility (OMD) of kikuyu with time of cutting at two levels of nitrogen at Kiama (Anon. 1977).

| Regrowth period (weeks) | Nitrogen application rate: Nil | | 130 kg N/ha | |
|---|---|---|---|---|
| | Protein | OMD | Protein | OMD |
| | (%) | (%) | (%) | (%) |
| 3 | 17.0 | 74.0 | 22.5 | 73.0 |
| 4 | 16.5 | 72.0 | 19.0 | 70.0 |
| 6 | 13.7 | 71.0 | 14.0 | 65.0 |
| 8 | 12.8 | 68.8 | 11.0 | 60.0 |
| 10 | 12.0 | 64.5 | 9.8 | 57.2 |
| 12 | 11.7 | 50.0 | 9.5 | 57.0 |

The marked seasonality of production of kikuyu grass needs to be matched with species that grow at lower temperatures. Forage production can be augmented by direct drilling winter forage crops including annual ryegrass and oats (*Oryza sativa*) into kikuyu swards after suppression of growth with herbicides or slashing. Frequent application of fertiliser nitrogen is required for effective production of these oversown pastures (Read 1981).

Kikuyu is susceptible to the disease kikuyu "yellows" which can severely restrict the production through killing off a high proportion of plants (Wong 1983). The cultivar Noonan was selected for its tolerance of kikuyu yellows (Oram 1990), but is less productive than other cultivars. The fungicide triadimefon (Bayleton (R) Bayer) gave some control (Wong and Tesoriero 1990), and irrigation and fertiliser reduce the symptoms. Selection of resistant varieties would seem to be the most effective long-term solution.

*Research required on kikuyu pastures.* 1. Development of a better focused grazing management system so that the feed available for the milking herd from kikuyu will be at optimum quality. The system needs to be based on physiological/morphological indicators of the optimum time to graze. Grazing at the three leaf stage of development has been successful in optimising production from perennial ryegrass pastures (Davies 1960; Curtis *et al.* 1992). Intervals between harvests should be timed so that there is an effective compromise between the quantity and quality of pasture produced with maximum utilisation through grazing and conservation.

2. Development of management systems aimed at extending the seasonal production of kikuyu-based pasture with high levels of legumes in the winter–spring. Currently, winter–spring production is augmented by direct drilling annual ryegrass and applying up to 300 kg N/ha/annum. However, legume-based systems may be more sustainable. Maintenance of legumes in kikuyu pastures throughout the year should also improve feed quality in the summer–autumn period.

3. The quality of kikuyu could be improved by breeding (Oram 1992). The induction of brown-midrib mutants of kikuyu has the potential to increase its digestibility by up to 10 percentage units (Cherney *et al.* 1992). Such an improvement would significantly enhance the value of kikuyu to the dairy industry.

*Perennial tropical legumes.* Tropical pasture legumes are capable of high growth rates in the subtropics, up to 6 t/ha DM as pure swards (Colman 1971) and 2–4 t/ha in mixtures with grass (Colman 1971; Tow and Walker 1971; Jones 1974). When grazed at a low stocking rate on the Atherton Tableland, glycine (*Neonotonia wightii* cv. Tinaroo) in a mixed pasture grew at 20 kg/ha/d DM from April–July inclusive (Cowan and Stobbs 1976). However at higher stocking rates growth rate declined sharply, to almost zero at 2.5 cows/ha. Jones (1974) showed siratro (*Macroptilium atropurpureus*) yield was sensitive to height and frequency of defoliation, and at the extreme, plots cut each 4 weeks to 7.5 cm height were invaded by white clover while siratro disappeared. This sensitivity to frequent defoliation has meant tropical legumes are a useful feed resource only on farms with very low stocking rates, in the order of 0.5 cows/ha, or where large hill paddocks can be kept for autumn–winter grazing only.

Recently, emphasis has been given to selecting tropical legumes which may withstand heavy grazing. The legume Pinto peanut (*Arachis pintoi* cv. Amarillo) spreads by rhizomes and is showing promise as a permanent summer legume. K. Lowe (personal communication) measured lower dry matter yield in pasture containing this legume than in grass fertilised with nitrogen at 50 kg/ha/month, but equivalent levels of milk production. The apparent higher quality of the legume compared with grass is similar to the situation with white clover (Ostrowski 1972) where a minor component in the sward can increase the quality of the animal's diet during late autumn and winter. Tropical legumes do not persist on clay soils and there is an urgent need to find suitable perennial legumes.

*Browse legumes.* Perennial leguminous shrubs and trees have considerable potential as a source of edible dry matter in northern Australia. Yields of leaf dry matter up to 22 t/ha/yr have been reported for leucaena (*Leucaena leucocephala*) (Bray *et al.* 1988) and 9 t/ha/yr for gliricidia (*Gliricidia sepium*) (Bray *et al.* 1993). These yields are half those for nitrogen-fertilised tropical grasses, possibly due to the lower efficiency of the $C_3$ photosynthetic pathway present in browse legumes.

Browse legumes are sometimes difficult to establish. Establishment problems with leucaena and *Calliandra* are associated with weed competition and early nodulation, especially in direct-sowing situations, and acid soils, and the efficiency of nitrogen fixation in some situations is questioned. The potential production from these species warrants a greater research effort to establish their full potential for use in the dairy industry.

### *Temperate legumes with summer–autumn productivity*

*Lucerne.* Lucerne (*Medicago sativa*) makes a major contribution to ruminant diets throughout the world (Barnes and Gordon 1972) and a substantial amount of work has been done to adapt this information to local conditions. Lowe *et al.* (1985) measured the yield of 28 lines of lucerne at Biloela in central Queensland and at Gatton in south-east Queensland. Mean yields over 3 years were 21 t/ha DM at Biloela and 10 t/ha DM at Gatton, though weed yields were higher at Gatton and in general were inversely related to lucerne yields. Summer growth rates were high in both centres, reaching a maximum in December of 100 kg DM/ha/d at Biloela and 80 kg DM/ha/d at Gatton (Lowe *et al.* 1985; K. Lowe, personal communication). During winter the differences between semi-dormant and non-dormant varieties were greater at Gatton, with growth rates averaging 5 and 30 kg DM/ha/d respectively. Growth rates above 40 kg DM/ha/d were maintained throughout winter at Biloela. Subsequent introduction of new lines has increased yields in the cooler Gatton environment, with mean yields of 15–20 t DM/ha/yr (Lowe *et al.* 1987a; 1988).

Yields of lucerne are sensitive to cutting or grazing management and disease. Low cutting, to 2 cm, was shown by Lowe *et al.* (1985) to be advantageous and the hay with the highest protein content was cut at intervals of less than 6 weeks (K. Lowe, personal communication). Protein content in winter (30%) was much higher than in summer (19%). Control of leaf spot diseases increased yield by up to 90% (Lowe *et al.* 1987a) and yields of lucerne cultivars have been shown to be correlated with resistance to disease (Lowe *et al.* 1987b).

Lucerne is known to have a high intake factor (Minson 1990) and when fed with 3.5 kg of concentrates daily promoted milk yield of 18.1 L/d in Jersey cows, compared with 8.2 L/d for cows given chopped, tropical grass-legume pasture (Dale and Holder 1968). Compared with tropical grasses, lucerne is more rapidly degraded in the rumen and has a lower fibre content (R. Hovey, personal communication) and has a faster rate of passage through the rumen.

Dairying is developing rapidly in the lower rainfall parts of northern Australia and lucerne, because of its drought tolerance, could become a more important feed source in northern dairy production. A continued supply of varieties resistant to a range of disease will be important for this scenario to be realised.

*Lotus species.* Lotus (*Lotus* spp.) produces high protein feed in the summer–autumn period. This high quality material should be valuable in enhancing the diet of animals grazing pastures containing mixtures of these species and summer-growing grasses. Special management will probably be required to reduce grass competition during establishment and growth of these species.

The most successful lotus variety has been the *Lotus pedunculatus* cultivar, Maku. Maku is a tetraploid bred in New Zealand (Barclay and Lambert 1970). It grows well on wet acid soils where it can establish and grow effectively with minimum fertiliser input (Armstrong 1974). It will however respond to phosphorus and sulphur and possibly other nutrients (Lowther 1991).

Maku lotus has been most successful in wet situations and will not persist through severe moisture deficits. It is suitable for high rainfall areas (>900 mm) or under irrigation. Maku has a reputation of being slow to establish and slow to regenerate after grazing (Harris *et al.* 1993).

There has been little work on the grazing management required to successfully establish and maintain lotus in association with summer grasses. Recent work assessing the productivity of lotus in association with kikuyu under various management has shown high potential productivity of lotus with effective management (Fulkerson and Slack 1993). White clover and lotus varieties were established into kikuyu pastures with frequent mulching and then subjected to various combinations of defoliation frequency and intensity (Table 3).

The summer and winter growth of lotus should enhance the feed quality of the summer grass-based pasture in the autumn when grass quality is declining and milk production is falling (Armstrong 1974). John and Lancashire (1981) showed comparative liveweight gains of grazing sheep, using Huia white clover (100) as the standard, for Maku lotus (87) and red clover (78). *Lotus pedunculatus* can have a high tannin content. Tannin concentration in the range 2–4% of DM can provide bloat protection and enhance nitrogen digestion in ruminants. Levels in the

**Table 3.** Growth (kg DM/ha) of Haifa white clover, Maku and Sharnae lotus in association with kikuyu from sowing in early April to late December 1992 (Fulkerson and Slack 1993).

| Defoliation frequency | Cutting height (cm) | Legume | | |
|---|---|---|---|---|
| | | Haifa | Maku | Sharnae |
| 14 days | 5 | 9 442 | 8 870 | 7 963 |
| | 12 | 11 555 | 7 570 | 9 897 |
| Lower leaves | 5 | 13 354 | 10 767 | 10 141 |
| yellow | 12 | 11 892 | 8 771 | 10 305 |

6–8% range could affect carbohydrate digestion and voluntary intake in ruminants (Barry *et al.* 1986). Kelman and Blumenthal (1992) measured condensed tannin contents in lotus of 5.5–13.5% in NSW and Victoria, which suggest potential nutritional problems in pure swards. However, the tannin levels in *Lotus corniculatus* are usually lower.

*Lotus corniculatus* also offers some potential for drier areas and may be useful for improving areas grazed by dry cows and young stock. A breeding program developing persistent and productive lotus varieties from *L. pedunculatus* and with interspecific crosses of *L. pedunculatus* and *L. corniculatus* is proceeding in Canberra. This may produce material suitable for dairy pastures (Kelman and Blumenthal 1993).

*Research required on lotus.* 1. Grazing management guidelines are required to optimise lotus production and persistence. The effect of grazing on rhizome development and persistence in pure swards and in mixtures with summer-growing grasses requires attention.

2. Information on milk production from lotus-based pastures should be sought to fully clarify the potential of lotus and tannin-protected protein for the dairy industry.

3. Breeding is required to develop lotus varieties with greater seedling vigour to improve the rate of establishment, and more productive and persistent varieties for drier environments.

*Annual summer forage crops.* The summer forage crops, largely maize (*Zea mays*), sorghums (*Sorghum* spp.), millets and lablab (*Lablab purpureus*), are the predominant grazed feed on approximately 500 dairy farms in northern Australia. These farms are on the Darling Downs and South Burnett areas amid extensive grain cropping areas and where, despite serious run down of soil fertility over the past 50 years (Dalal and Mayer 1986), forage crops can be grown at lower cost than perennial pasture (G. Busby, personal communication).

Yield is the first consideration in growing summer forage crops, and the various forage sorghum and millet cultivars are capable of producing a high yield of dry matter quickly. The sudan grass types of forage sorghum are especially effective with yields of 4–6 t/ha DM within 8 weeks of planting and the ability to regrow following grazing (French 1981). The sweet sorghums have a relatively high sugar content and are well suited to standing over for autumn feed or ensilage, with yield in the order of 24 t/ha DM in a 4-month-old crop (French 1981). Mackenzie *et al.* (1982) measured a yield of 12 t DM/ha/yr from the hybrid forage sorghum, 'Silk', over 5 years. Yield was very responsive to nitrogen level with an incremental response of 47 kg DM/kg N applied. Similarly Aitkens (personal communication) obtained an increase of 30 kg DM/kg N in an irrigated forage sorghum crop and Chataway (personal communication) an increase of 28 kg DM/kg N in a dryland crop. Sorghum produces higher dry matter yields under drought conditions than maize (Cummins and McCullough 1969), making it a suitable crop for grazing or conservation on the Darling Downs.

*Maize.* The two major surveys of the Queensland dairy industry conducted in 1986–87 and 1990–91 show an increase from 2% to 7% of farms using maize silage. The amount of silage conserved per farm also increased from 345 to 477 tonnes of fresh silage (Anon. 1988; D. Kerr and J. Chaseling, personal communication). Currently, there appears to be an increasing farmer interest in maize silage production.

Maize is an effective crop because of:

(a) A high yield potential associated with the efficient use of water and sunlight (Pritchard 1987).

(b) The forage produced containing up to 50% grain mixed with fibre and roughage and possibly of high quality.

The potential of maize to produce high yielding, high quality crops will depend on selecting productive varieties and growing them with effective crop management and harvesting at the correct stage (Kaiser *et al.* 1992). Maize has the potential to produce more than 25 t/ha DM under favourable conditions. It should be possible to achieve more than 20 t/ha regularly under irrigation. Dry-land yields will be much more variable with complete failures possible. Graham (1987) measured maize silage DM yields in south-eastern Queensland of 7.9–14.5 (mean 11.9) t/ha in the period 1982–85. In northern New South Wales, Kaiser *et al.* (1992) reported a mean yield on 23 dairy farms over the years 1989–92 of 16 t/ha (range 4.8–24 t/ha).

Maize could significantly increase the productivity of dairy farms in the tropics and subtropics (Kerr *et al.* 1992). Areas suitable for maize production in Queensland have been delineated by Weston *et al.* (1984). Much of the high potential area covers dairying districts. The promising future for maize will be dictated by climatic constraints. Moisture deficits during crop growth can seriously restrict total dry matter yield and reduce the proportion of grain and hence feed quality, whereas excess rainfall may prevent harvest of the crop at the silage stage. This problem can be reduced with the use of minimum tillage systems. Very high temperatures at pollination can cause pollen "blast". With the pollen killed, seed set can be severely reduced and feeding value lowered.

Maize silage yield and feed quality can also be restricted by ineffective crop management. Land preparation must be adequate or minimum tillage used correctly. A population of 60 000 plants/ha for dry-land crops is required for maximum yield. Effective populations are obtained through sowing sufficient, high quality seed at the correct depth and ensuring that insect predators such as black beetles, wireworms and cutworms which can decimate seedlings, are effectively controlled. Effective weed control is required to reduce competition which can suppress yield and stress the crop during grain filling (Kaiser *et al.* 1992). Insects such as *Monalepta australis* which damage silks and reduce grain set may also need controlling during crop growth.

If irrigation is available and used effectively a major production constraint is minimised. Nevertheless correct crop management will still be required to obtain high yields.

Adequate N:P:K fertiliser should be applied to cover potential yield. A 20 t/ha DM crop can remove 200 kg N, 45 kg phosphorus and 200 kg potassium/ha. Nevertheless, maize is more efficient in responding to nitrogen fertiliser than tropical and temperate grasses (Cowan *et al.* 1991).

Kaiser *et al.* (1992) showed that the average metabolisable energy (ME) content of 52 farmers' crops measured over 3 years in NSW dairying districts was 10.2 MJ/kg DM. There was significant variation between sites in maize forage quality. Low values were generally associated with stressed crops, especially when stress occurred late in the crop's development during grain filling. The on-farm experiments showed that there was scope for increased yield and quality in farmers' maize crops which could increase milk production per ha from maize crops by 30–50%. The mean crude protein content of the same maize crops was 6.5% which compares to overseas values of 8–9%. This low protein content emphasises the need for feeding protein supplements where diets contain a high proportion of maize silage.

Maize variety can influence the yield and quality of silage produced. Late-maturing varieties can produce higher yields but usually have lower grain contents than mid-season and early varieties. Their longer growing seasons can delay the sowing of following winter–spring crops which seriously restricts their potential for early yield. The feed quality of forage maize increases with grain content and with stover digestibility. A successful maize forage variety should be well adapted to a particular district with suitable disease resistence and be selected for high grain content and stover digestibility. Stover digestibility can be improved by selection within the normal population or by incorporation of the brown-midrib gene (Kaiser *et al.* 1991).

Cowan *et al.* (1991) estimated the average cost of producing maize silage at 9 c/kg for both dry-land (range 6–13) and irrigated (range 6–11) crops. The cost of growing the maize crops is substantial and ranges from $500–700/ha depending on irrigation inputs and how labour is costed (Pritchard *et al.* 1990; Moore, personal communication; M. Gilbert, personal communication). Cost/kg can be reduced if high yields are obtained.

*Research required on maize.* 1. There is a need to demonstrate the impact of management on productivity of maize silage crops in Queensland, with particular emphasis on land preparation, plant population, insect control, weed control and fertiliser application. Higher plant populations than currently recommended need to be tested.

2. A clearer delineation of where maize can be reliably grown in dairying districts in Queensland is required. Suitable areas may be more accurately predicted from growth models similar to that developed by Muchow and Carberry (1991) and Kerr *et al.* (1987). Some field testing may be required to test actual yields and to validate the precision of the models.

3. Maize varieties specifically for forage production need to be developed. Characteristics for suitable varieties were outlined by Kaiser *et al.* (1991). Major emphasis should be placed on increasing grain content and stover digestibility. The brown-midrib gene could be an effective pathway to increasing stover digestibility.

4. Efficient farming systems should be developed which incorporate maize silage. Unless adequate quantities of protein supplements are available, the full potential for milk production cannot be achieved. The growing and feeding of maize silage needs to be incorporated into a whole-farm approach where the total feed supply is adequately balanced (Lawson 1992).

*Grain sorghum.* Grain sorghum (*Sorghum vulgare*) has a wide range of adaptation in Queensland (Weston *et al.* 1984). It has the potential to give more reliable production in areas where soil, rainfall, or humidity means maize may be marginal.

Grain sorghum has the potential to yield 6–24 t/ha of total forage dry matter in Queensland dairying districts (R. Henzell, personal communication). There is potential to increase the suitability of grain sorghum as a fodder source for the dairy industry through breeding and selection of improved varieties. Yield potential could be increased using taller hybrids, though these may have a lower grain content. Quality could be enhanced by breeding to increase stover digestibility. Incorporating the brown-midrib gene (Bm6) could reduce stover lignin content and increase digestibility (Porter *et al.* 1978). The "stay green" character has the potential to sustain grain fill for longer periods under dry conditions and increase production (Duncan *et al.* 1981). Suitable sorghum varieties should have highly digestible grain and low whole-plant tannin concentration so there is no reduction in protein digestion (Havilah and Kaiser 1992).

The protein content of grain sorghum is variable and depends on soil fertility and seasonal conditions. Goodrich and Meiske (1985) reported average protein contents for sorghum silage of 7.5% compared to maize at 8.3% and protein supplementation would be required. Grain sorghum agronomy is well understood. However, some modification may be required for silage production e.g. plant population.

The quality of forage sorghum is similar to that of tropical grasses at comparable stages of growth (Stobbs 1975), with rapid increase in the fibre content with age (Table 4). The figures in Table 4 suggest it would be very difficult to manage forage sorghum to maintain a low fibre level in the plant. As one of the major reasons for planting forage sorghums is to ensure a large yield of dry matter for standing over during periods of drought, much of the material is consumed when of low nutritive value, with NDF

**Table 4.** Changes in crude protein and fibre levels of the forage sorghum hybrid, Superdan, in relation to age of the crop (W. Orr, personal communication).

| | Age | | | | | |
|---|---|---|---|---|---|---|
| | Days from planting | | | Regrowth (weeks) | | |
| | 20 | 34 | 55 | 0–3 | 3–6 | 6–9 |
| Leaf (% DM) | 77 | 60 | 42 | 35 | 26 | 10 |
| Crude protein (% DM leaf) | 16.2 | 16.2 | 9.4 | 11.2 | 10.0 | 10.0 |
| Crude protein (% DM stem) | 10.6 | 10.0 | 3.1 | 3.1 | 2.5 | 6.9 |
| ADF (% DM leaf) | 22.2 | 31.2 | 38.2 | 37.8 | 38.0 | 35.5 |
| ADF (% DM stem) | 27.1 | 33.2 | 38.1 | 44.2 | 44.2 | 46.0 |

content in the order of 70% DM and an estimated ME content of 7.5 MJ/kg DM.

The major concern to animal health with forage sorghum is cyanide poisoning. Wheeler (1980) considered the fear of this was exaggerated, so that sorghums were often grazed at an advanced stage of maturity simply to avoid the risk of poisoning.

*Research required on sorghum.* 1. Development of varieties specifically for forage production, which retain disease and insect resistance and adaptation to a wide range of environments.

2. Determine the optimum stage of harvest of grain sorghum for silage with both high yield and quality.

3. Developing farming systems to produce the protein supplements required when feeding grain sorghum silage.

*Pearl millet.* In recent years new late flowering cultivars of pearl millet (*Pennisetum glaucum*) have gained favour. They have a higher leaf to stem ratio than the sorghums and are higher quality. The main practical problems have been establishment difficulties associated with coarse seedbed and unpalatability when forage grown on soils high in available nitrogen is stressed by drought (Minson *et al.* 1993).

*Annual summer-growing legumes.* While the forage sorghums and millet are seen as providing yield, or bulk, for summer grazing, legumes are seen as high quality plants, promoting high milk yield and soil improvement. Summer-growing grass pastures usually contain insufficient protein for maximum milk production. Annual summer-growing legumes have the high level of protein required and can either be grazed or conserved. Legumes which have been used for this purpose include lablab, cowpea (*Vigna* spp.), velvet bean, phasey bean (*Macroptilium lathyroides*) and more recently, soybean. Varieties and management systems are required which optimise the digestible protein produced from these specialised crops. Lablab and cowpea grown under dryland conditions should produce yields of 2–5 t/ha DM (Hendricksen 1981). Potential yields of annual legumes under irrigation are very high (Table 5).

All species of forage legume produce thick stems which lignify and become very indigestible as the plant matures. The low digestibility of mature stems has an adverse effect on quality when the legume is ensiled or made into hay. In contrast the grazing animal can select the leaves, improving digestibility and intake, reducing damage and allowing the plant to regenerate successfully after grazing (Hendricksen and Minson 1980).

Lablab is superior to cowpea in late autumn production (Wilson and Murtagh 1962). Lablab and cowpea are susceptible to pugging damage and grazing in wet periods can cause a large reduction in yield. Cowpea is more susceptible to diseases than lablab. Current cowpea varieties are more resistant to root disease but can still suffer significant production losses (Hendricksen 1981). Muldoon (1985) suggested that the high grazing potential of phasey bean types was due to superior bud development.

Cowpeas produce higher quality feed than lablab. After 61 days growth, dry matter digestibility was 63.8% for cowpea and 59.2% for lablab (Milford and Minson 1968b). A review of a number of experiments showed the mean apparent digestibility of cowpeas was 61.2% compared with 56.5% for lablab (Hendricksen 1981).

Soybeans are currently being used by farmers for silage production with DM yields of up to 9.6 t/ha (Desborough and Ayres 1988). These authors demonstrated high protein yields with crops harvested at different stages with *in vitro* digestibility in the range 56.3–67.5%. More information is required on cultivar selection, optimum sowing time, grazing management and the optimum stage of harvest for hay and silage.

**Table 5.** Cumulative yields (t DM/ha) for summer annual legumes grown under irrigation at Trangie and cut on 4 occasions (adapted from Muldoon 1985).

| Crop | Harvest weeks after sowing | | | | Cumulative regrowth (t DM/ha) | % of primary growth |
|---|---|---|---|---|---|---|
| | 7 | 13 | 19 | 24 | | |
| Cowpeas | 1.3 | 3.5 | 0.8 | 0.0 | 5.6 | 69 |
| Phasey bean | 1.3 | 5.1 | 2.9 | 0.8 | 10.1 | 125 |
| Lablab | 2.4 | 4.8 | 0.7 | 9.7 | 17.6 | |

The annual summer-growing legumes are usually sown into prepared seedbeds. This system may not be sustainable long-term as soil erosion can be severe where summer rainfall is high. Repeated cultivation on many soils has lead to soil structure deterioration.

*Research required on annual summer-growing legumes.* 1. A wide range of annual summer-growing legumes are available but their relative value as a source of protein supply in dairy farming systems needs to be evaluated. There are 3 potential sources of improved forage legumes:

(a) There is a wide variation in maturity and forage potential in soybean varieties. Detailed information is required on forage yield and feed quality of a range of types at different stages of harvest.
(b) There is a large reservoir of annual summer-growing legume species which have not yet been evaluated as forage crops. Genera include the African *Trifoliums, Arachis, Aeschynomene, Vigna* and the poisonous genera *Crotalaria* and *Indigophera* which could possibly be made safe by selecting or breeding lines low in the toxic compound.
(c) Lablab, cowpea, phasey bean, velvet bean and other annual legumes have been used in the past but there is a large variation which has not yet been exploited (Hendricksen 1981).

2. The potential of zero-tillage sowings of annual summer-growng legumes as a sustainable system to increase protein yields in summer-autumn requires further investigation.

3. Systems should be developed which will assess the potential of integrating annual legume production into current dairy farming systems based on grass.

## Pasture management

### *Nitrogen*

The potential growth of tropical grasses is very high. This high growth rate will be achieved only if all nutrients and water are not limiting. Of special importance is the level of *available* soil nitrogen. In 3 of the studies included in Table 1, fertiliser was applied at a rate of 1344 kg N/ha/yr. This quantity of available nitrogen cannot be achieved by the use of legumes or the breakdown of soil organic matter.

Of the nitrogen fertiliser applied to pasture only about 55% (27–81%) is actually recovered in the forage with differences up to 17% between types of fertiliser applied (Henzell 1971). Very little of the nitrogen "lost" could be found in the soil and it appears that most was volatilised into the atmosphere.

*Research required on nitrogen.* The main aim should be to improve the economics of fertiliser use by reducing the loss of nitrogen as ammonia and oxides of nitrogen. Not only is this of economic importance but the oxides of nitrogen have a deleterious effect on the ozone layer so any reduction in nitrogen loss would improve the environment. Specific issues are:

1. Integrating fertiliser application with climate prediction from models such as Rainman etc.

2. New techniques developed in the last 10 years provided a means of assessing sources and rates of transfer of different forms of N between different N-pools, including N available for growth of grass. These provide a means of developing better strategies (management procedures) for more efficient use and greater control of nitrogen losses. These include aspects related to environmental pollution due to N "passing through" a specific industry (e.g. dairy) with an effect on a wider community.

3. These new techniques could be used to more accurately assess N input from biological nitrogen fixation.

4. Increasing N recycling by developing economic methods of returning excreta deposited in the milking shed back to the pasture.

### *Phosphorus*

Many of the soils in northern Australia are low in phosphorus and phosphorus deficiency is recognised as a major factor limiting pasture production and milk output. This problem has been overcome on most dairy farms by applying large quantities of phosphorus fertiliser in the early stages of pasture improvement programs. Even after a tonne or more of superphosphate or its equivalent has been applied, annual maintenance dressing of at least 100 kg/ha of phosphorus fertiliser is generally recommended. The need for regular applications of phosphorus fertiliser appears to be associated with the poor ability of most pasture species to extract phosphorus from the soil. Some tropical legumes

(notably *Stylosanthes* spp.) have the ability to extract phosphorus and grow satisfactorily on soils with very low levels of total and available phosphorus. Transfer of this high efficiency of absorption to other legumes and grasses could:
(a) reduce fertiliser cost, and
(b) reduce the level of phosphorus in soils and hence the run off of phosphorus into waterways with the subsequent development of toxic algae.

### *Soil water*

A major constraint to pasture production on most dairying areas in northern Australia is a deficiency of water caused by the sporadic nature of the rainfall in most areas and the high loss of water during transpiration. In many areas, potential annual transpiration is 2–3 times the average annual rainfall. Traditionally, the effect of this limitation on pasture production has been reduced by concentrating dairying in the higher rainfall regions of Australia. In these areas it is often possible to irrigate pastures from rivers or dams.

Expansion of residential developments and hobby farms is gradually pushing dairy farms in northern Australia away from the well watered coastal zone into areas of lower rainfall and irrigation potential. To maintain sufficient pasture production there will be a need to produce forage varieties that utilise water more efficiently (i.e. a higher production of dry matter per kg of water). This might be achieved by selecting plants on their osmotic and stomatal adjustment and tolerance of high leaf-water deficit (Wilson 1984).

### *Maximum intake by cows*

Where forages are *cut* and fed to cows in either the fresh or conserved state, the quantity eaten each day is controlled only by quality factors. However, when grazed, intake can be limited by spatial factors that control bite size such as yield per unit area, height, leaf distribution, plant species in the mixture, etc.

There appears to be an upper limit to the time that dairy cows will spend grazing each day and the rate of biting (Minson 1990). This led Stobbs (1973) to suggest that the voluntary intake and milk production of cows is depressed if the structure of the sward prevents them harvesting about 300 mg organic matter in each bite. This effect is illustrated for a temperate pasture in Table 6. For temperate pastures, critical bite size is not reached until total yield of forage exceeds about 2 t/ha.

**Table 6.** Effect of forage height on behaviour, forage intake and production of lactating cows.[1]

| Attribute | Forage height (cm)[2] | |
|---|---|---|
| | 4.8 | 6.4 |
| Forage (kg OM/ha) | 1810 | 2734 |
| Tiller density ('000/m²) | 17 | 16 |
| Leaf proportion | 0.51 | 0.55 |
| Green forage allowance (kg OM/cow/d) | 17 | 21 |
| Digestibility of selected forage (OM) | 0.76 | 0.77 |
| Grazing time (min/d) | 575 | 565 |
| Grazing bites ('000/d) | 44.7 | 43.3 |
| Bite size (mg OM/bite) | 282 | 345 |
| Forage intake (kg OM/cow/d) | 12.7 | 15.1 |
| Milk yield (kg FCM/d) | 26.3 | 28.1 |
| Liveweight change (kg/d) | −0.67 | +0.15 |

[1] From Kibon and Holmes (1987).
[2] Determined with a falling plate exerting a pressure of 4.8 kg/m$^2$.

However, with tropical pasture there are usually very large differences in severance resistance between leaf and stem fractions and maximum bite size will probably be achieved only when the yield of leaf and total forage exceeds about 1 and 3 tonnes/ha, respectively. This is an important area of pasture management but no critical studies have been conducted with grazing dairy cattle in the tropics to define the quantities of forage required to obtain maximum intake.

## Forage consumption

The quantity of feed that an animal will eat (voluntary intake) is the most important factor controlling milk production from a forage, when forage is the sole component of the diet. Voluntary intake of tropical forages is controlled by the concentration of fibre and level of nutrients in the diet.

### *Fibre*

Where the fibre level of forage is high, voluntary intake of the feed is low. Since the digestibility of the dry matter (and energy) is also inversely related to the fibre level in the forage, there is a negative relationship between voluntary intake and DM digestibility. This is a statistical not causal relationship. If the physical structure of the fibre is destroyed by grinding and pelleting, voluntary intake is increased. The largest increases occur with forage containing the most fibre and lowest digestibility. Chewing has a similar effect to grinding, but on a smaller scale. The fibre in leaf has a lower resistance to chewing than the stem and this leads to leaf being eaten in much larger quantities (50%) than stem of similar fibre content and digestibility (Minson 1990). This has a very important effect on how pastures are managed. Rapidly grown pastures have little stem so they can be intensively grazed without depressing intake. However, when pastures contain a large proportion of stem, voluntary intake will be considerably reduced if cows are forced to graze the stem fraction. The traditional method of overcoming this problem is to use a 'leader-and-follower' management system with lactating cows having first use followed by dry stock. To our knowledge, the advantages of the 'leader-and-follower' management system have not been demonstrated for tropical forages in Australia. Mechanical topping is a wasteful way of removing the stemmy, residual forage and encouraging leafy regrowth.

### *Protein*

Voluntary intake of non-lactating ruminants is depressed when the diet contains less than about 7% crude protein (Minson 1990) but no data are available for lactating animals although the critical level is possibly higher than for dry ruminants. This depression is caused by both a shortage of ammonia for the rumen microflora and the low level of amino acid absorption from the small intestine. (Milk production requires large quantities of amino acids from the small intestine). If dietary protein is low and insufficient amino acids are absorbed, the energy in the forage appears to be diverted away from milk and into liveweight gain, a phenomenon widely reported in cows fed tropical feeds.

A deficiency of absorbed amino acids can often be directly attributed to a low protein content of the diet but can also be due to excess conversion of protein to ammonia in the rumen plus insufficient readily available carbohydrates (particularly starch) for the production of high levels of microbial protein that can be digested in the small intestine. The problem of low levels of amino acid absorption from the small intestine can be overcome by a number of strategies. Legumes contain a higher proportion of protein than grass and because the legumes rapidly pass through the rumen, more of the feed protein is absorbed from the small intestine. The quantity of protein passing undegraded through the rumen can be increased by the presence of *small* quantities of tannin which are present in many shrub legumes and species of *Lotus*.

### *Tannins*

High levels of tannin in browse legumes will depress digestibility (Mahyuddin *et al.* 1988). This depression is caused by the tannins present in the browse forming complexes with the protein. This problem has been overcome in mulga (*Acacia aneura*) by adding polyethylene glycol (PEG) to the drinking water, a treatment that increased voluntary intake by 40–50% (Pritchard *et al.* 1988). A similar improvement has recently been obtained by transferring rumen fluid containing tannin-active bacteria from goats to sheep eating mulga (S. Miller, personal communication). It is not yet known whether the voluntary intake of browse legumes can be improved in such a spectacular manner by inoculating dairy cattle with tannin-active bacteria or the effect this might have on milk production.

### *Minerals*

Voluntary intake will be depressed if the diet is low in essential mineral elements (cobalt, magnesium, phosphorus, selenium and sodium) *and* the labile reserves of that element in the cow have been depleted (Minson 1990). The size of these reserves has not been estimated but appears to vary from very low (1 day's supply) in the case of magnesium to very high (3 months' supply) for sodium. There is an urgent need for a review of this important aspect of the mineral nutrition of the dairy cow.

The concentration of most mineral elements depends on their availability in the soil and stage of growth of the forage. However, the level of sodium is under genetic control with differences of up to 50 times between sodium accumulating and non-accumulating species (Minson 1990). Some of our most important forages have low levels of sodium (Table 7) and cows offered these forages require sodium supplements if milk production is to be maximised.

**Table 7.** Mean sodium concentrations of some important forage species and requirements of cows (Minson 1990).

| Species | Na concentration (g/kg) |
|---|---|
| **Sodium concentrations in forage** | |
| Forage sorghum | 0.1 |
| Maize | 0.3 |
| Kikuyu grass | 0.3 |
| Lucerne | 0.4 |
| Italian ryegrass | 1.1 |
| White clover | 1.1 |
| Short-rotation ryegrass | 2.3 |
| Perennial ryegrass | 4.2 |
| **Requirements of Friesian cows** | |
| Maintenance | 0.5 |
| 10 L milk | 0.9 |
| 20 L milk | 1.2 |
| 30 L milk | 1.5 |

*Temperate versus tropical*

Tropical forages with their $C_4$ photosynthetic pathway and ability to grow at high temperatures contain more fibre than temperate forages (Figure 1).

This higher fibre causes a lower voluntary intake of tropical forages (Figure 2) in addition to the well recognised lower digestibility (Figure 3).

Tropical forages vary in their fibre content and some improvement in intake and milk production can be achieved by selecting forage on the basis of higher digestibility (Lowe *et al.* 1991).

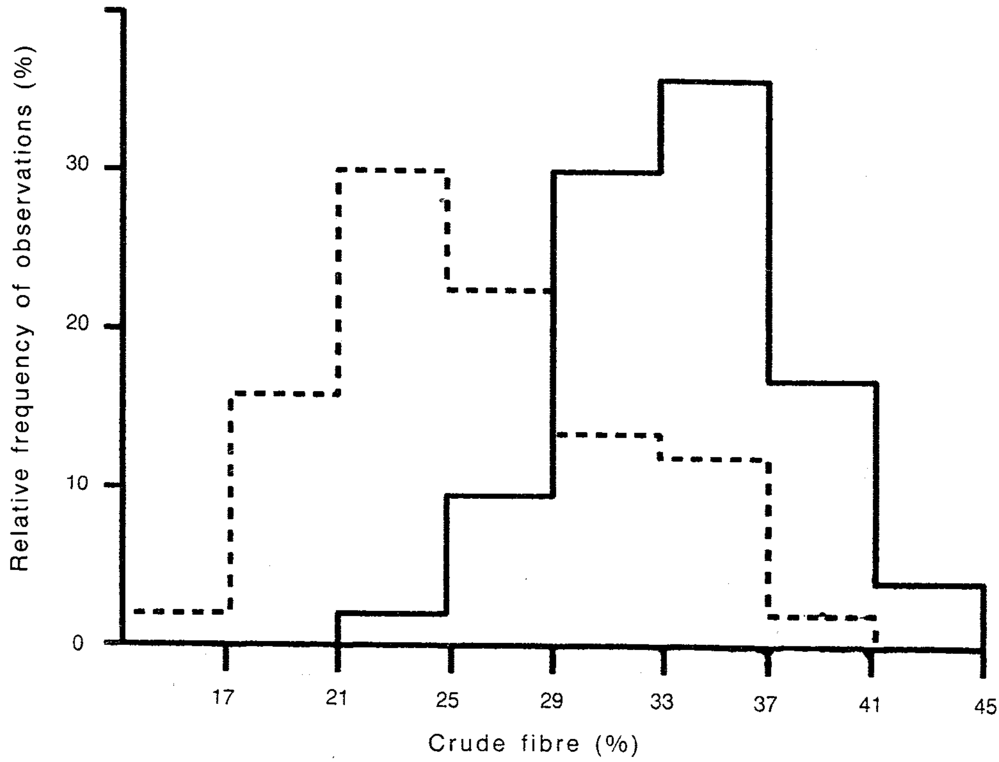


**Figure 1.** Frequency distribution of fibre contents in a wide range of tropical (————) and temperate (------------) grasses cut at many stages of growth (Minson 1980).

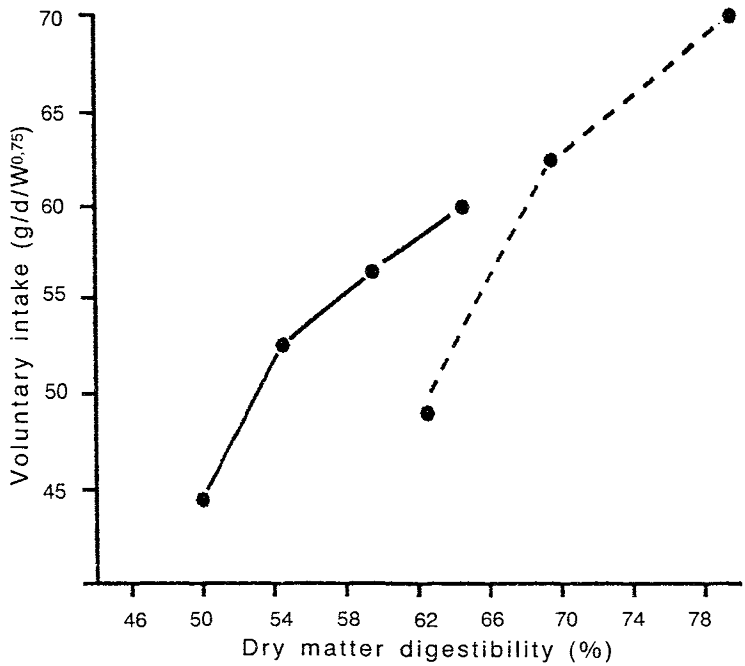


**Figure 2.** Relation between mean voluntary intake and dry matter digestibility for a wide range of tropical (————) and temperate (------------) grasses (Minson 1980).

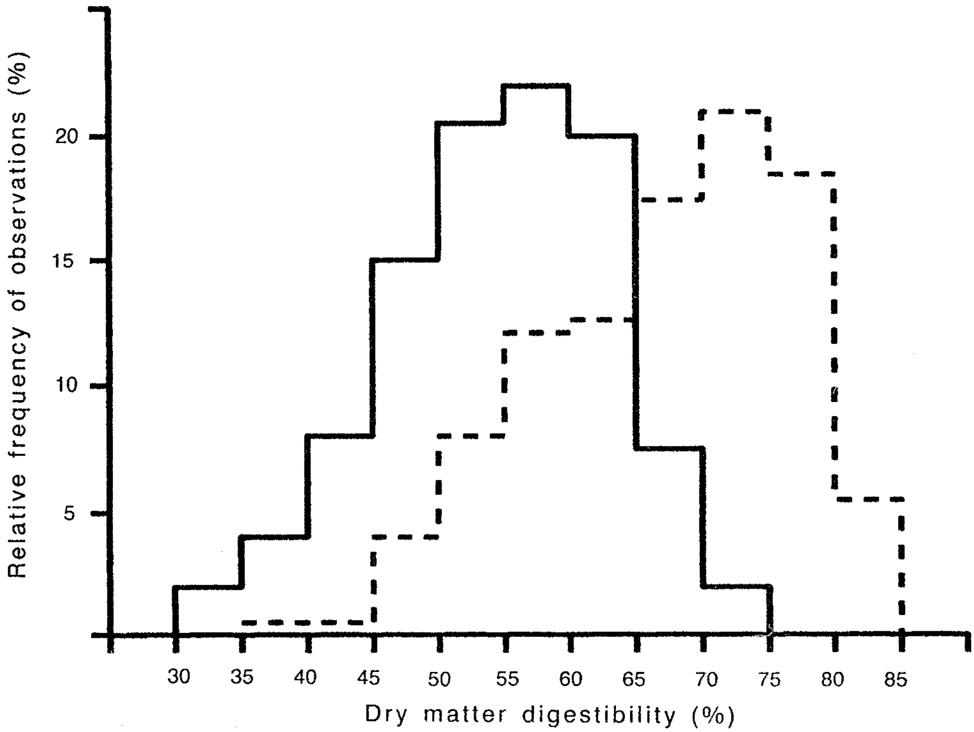


**Figure 3.** Frequency distribution of dry matter digestibility of tropical (————) and temperate (------------) grasses harvested at different stages of growth (Minson 1980).

*Pelleted versus long*

The intake of pasture plants is related to their fibre content but the physical form of this fibre is also important. By grinding and pelleting, the physical structure of the fibre is destroyed, and the feed passes through the rumen more rapidly leading to an increase in the quantity of tropical forage eaten (Table 8). However, this advantage is partly offset by a reduction in dry matter digestibility caused by the shorter time the bacteria are able to act on the feed while it is in the reticulo-rumen (Table 8). Pelleting of forage is not an economic way of improving the quality of tropical feeds.

*Leaf versus stem*

Structural differences are not confined to differences between chaff and ground forage but also exist between different parts of the same grass plant. It was generally believed that leaf and stem of the same digestibility were eaten in similar quantities. However, studies of the voluntary intake of separated leaf and stem fractions of a range of tropical grasses have shown that leaf is eaten in very much larger quantities than stem due to a shorter retention time in the reticulo-rumen (Table 9).

This shorter retention time is associated with a larger surface area, lower grinding energy and lower density and is not caused by differences in the level of cell contents, measured as the concentration of pepsin-soluble dry matter.

The large structural differences between the leaf and stem of tropical grasses have a marked effect on grazing behaviour. Cattle grazing tropical grasses show a marked preference for the leaf fraction, spending very long periods each day searching for leaf in the heterogeneous swards and taking very small bites. Breeding and selecting tropical forages for a higher proportion of leaf can improve voluntary intake and production but this is accompanied by a reduction in total yield and carrying capacity.

*Plant maturity*

As pastures mature, there is a decrease in voluntary intake (Figure 2). This decrease is caused by two factors: (a) an increase in the proportion of stem which has a lower intake than leaf of similar digestibility and fibre content, and (b) a

**Table 8.** Effect of grinding and pelleting on voluntary intake and dry matter digestibility of four tropical grasses (Minson 1980).

| | Voluntary intake ($g/d/kg^{0.75}$) | | | Dry matter digestibility (%) | | |
|---|---|---|---|---|---|---|
| Species | Chaff | Pellets | Differences | Chaff | Pellets | Differences |
| *Cenchrus ciliaris* | 45 | 64 | +19 | 56 | 45 | −11 |
| *Pennisetum clandestinum* | 50 | 70 | +20 | 62 | 56 | −6 |
| *Digitaria decumbens* | 48 | 73 | +26 | 56 | 51 | −5 |
| *Setaria sphacelata* | 48 | 73 | +26 | 56 | 51 | −5 |
| Mean | 48 | 70 | +22 | 60 | 53 | −7 |

**Table 9.** Mean voluntary intake of leaf and stem fractions of five tropical grasses each at three stages of growth (Minson 1980).

| | Plant fraction | | |
|---|---|---|---|
| | Leaf | Stem | Difference |
| Voluntary intake ($g/d/kg^{0.75}$) | 58 | 40 | −18 |
| Dry matter digestibility (%) | 53 | 56 | +3 |
| Rumen contents (g) | 6200 | 5900 | −300 |
| Rumen DM (%) | 11.5 | 11.5 | 0 |
| Retention time of DM (h) | 24 | 32 | +8 |
| Surface area ($cm^2/g$) | 130 | 40 | −90 |
| Grinding energy (J/g) | 240 | 410 | +170 |
| Density ($g/cm^3$) | 0.08 | 0.24 | +0.16 |
| Pepsin-soluble dry matter (%) | 23.0 | 23.4 | +0.4 |

decrease in the intake of both leaf and stem fractions as they mature (Table 10).

**Table 10.** Effect of plant maturity on the voluntary intake of leaf and stem fractions of five tropical grasses (Laredo and Minson 1973).

| Age of regrowth (days) | Voluntary intake (g DM/d) | |
|---|---|---|
| | Leaf | Stem |
| 52 | 69 | 49 |
| 75 | 51 | 41 |
| Mean | 60 | 45 |

The problem of the lower intake may be overcome in three ways:

(a) Frequent defoliation will keep the leaves young and prevent the development of fibrous stems. This method is successfully applied with temperate pastures where rainfall is uniform and the pasture species can persist under intensive grazing.

(b) Later flowering varieties of forage have a much smaller proportion of stem and are eaten in greater quantities. The recently introduced late-flowering variety of pearl millet is a good example of this method of reducing the adverse effect of forage maturity on milk production.

(c) The seeds of grasses are low in fibre and are eaten in large quantities. The digestibility and intake of the leaves and stem of maize are low but this adverse effect is offset in well grown maize when the grain can represent nearly 50% of the harvestable biomass. Unfortunately, the development of ears in maize is sensitive to the level of soil water and, if dry weather occurs after planting, the maize will contain little or no grain (Muchow 1989) and have the low quality expected of the mature tropical grass. Maize will be a successful feed in northern Australia only where there is an adequate supply of irrigation water to supplement the unreliable rainfall.

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