Northern dairy feedbase 2001. 2. Summer feeding systems

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Abstract

The nutritional and environmental factors affecting the productivity of dairy cows during summer and autumn in the tropical and subtropical regions of Australia were reviewed. Though tropical grass pastures can support high stocking rates, the relatively low milk production per cow is one of the key limitations to productivity during summer and autumn. The low production is associated with a high fibre content in pasture and low dry matter digestibility. Various grazing management strategies have failed to increase the milk yield of Holstein-Friesian cows beyond 13 kg/cow/d. Current grazing methods appear to utilise a high proportion of the leaf produced by these pastures, and much of the unused pasture is stem of low nutritive value.

Heat stress appears to be a key limitation to productivity during summer and autumn, with Holstein-Friesian cows doing almost no grazing between morning and afternoon milking once daily maximum temperature exceeds 30 °C.

The further development of summer feeding systems will incorporate a change in fodder for cows and the methods of herd management. More emphasis will be given to legumes, particularly lucerne, clover and crop legumes, for grazing. Conserved fodders such as maize silage and lucerne hay will be a substantial component of the feed supply, for feeding during the day at shaded feed pads close to the dairy. Cows will graze during the night. Substantially higher levels of concentrate will be used as these have a similar milk output:cost ratio to forages, reduce heat load in cows and are well suited to dairy and feed pad feeding methods. The need to test new technology within realistic feeding systems was emphasised as milk production in tropical and subtropical Australia is a complex, multi-component production system.

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Introduction

An improvement in the summer feeding system should be characterised by increased profit, uncomplicated management procedures and low exposure to financial risk. In other words, systems should be simple and allow the farm manager to make more profit with the minimum requirement for capital outlay. Much of our attention in meeting these aims has focused on the feedbase, particularly in the development of pastures, though methods of avoiding heat stress have also received some attention. As the industry has developed, our approach has changed, from an emphasis on pasture yield to pasture quality. Concentrates are an integral part of feeding systems and levels of input are increasing. In this review, we will discuss much of the research into summer feeding systems completed since the last major review at Wollongbar in 1971 (Thurbon *et al.* 1971) and make recommendations on future research needs.

To summarise the key features requiring attention in a summer feeding system it is important to consider the variables affecting an individual cow during summer and autumn. A cow calving in September-October has a large part of her lactation in the January-May period. During this time the cow will graze pastures at least 60 cm in height (Cowan *et al.* 1986) and with a leaf content of 35% in the dry matter (Davison *et al.* 1985a; Cowan *et al.* 1986). The animal will select a diet of 35-60% leaf (Davison *et al.* 1985a) containing 11-15% crude protein (Davison *et al.* 1985a; Moss *et al.* 1992). The cell wall (fibre) content of the diet will be about 60–70% with an ME content of 7–9 MJ/kg DM (Moir *et al.* 1979; R.J. Moss, unpublished data). These pastures have the potential to support milk production of 12 L/cow/d without supplement (Stobbs 1971). The cow requires 10 h grazing daily to achieve the level of intake needed for 12 L milk (Stobbs 1973a; Cowan *et al.* 1986), but will reduce her grazing effort once daily maximum temperature exceeds 27 °C (Cowan 1975). The nett effect of the low pasture digestibility and high heat loads is a rapid fall in milk yield of cows during summer (Figure 1).

Feeding systems are being developed to overcome the constraints of low pasture quality. Concentrate feeding has increased substantially (Kerr and Chaseling 1992) and farmers often avoid calving cows during January and February. Increasing amounts of stored forage, especially maize silage, are being used (Kerr and Chaseling 1992). As the systems are developed, total milk output from the farm tends to increase.

Levels of milk production from summer forages

Stobbs (1971), in a review of earlier experiments utilising tropical pastures with milking cows, concluded the potential of these pastures for milk production by Holstein-Friesian cows was about 12 kg/cow/d. Many feeding systems utilising these pastures have now been evaluated (Table 1), and milk production per cow has been below 12 kg/d, or 3600 kg/lactation, in all experiments where pure grass pastures were used. Slightly higher production, about 13 kg/d, was recorded where a high proportion of tropical legume was present in the pasture. Jersey cows have milk yields 3–4 kg/d less than for Holstein-Friesians (Table 1) (Swain 1971; Cowan *et al.* 1974).

The tropical twining legumes have not been sustainable at stocking rates above 1.3 cows/ha (Cowan *et al.* 1975), but pure grass pastures have sustained high productivity per unit area, especially through the use of high levels of nitrogen fertiliser. With Holstein-Friesian cows calving in late spring on nitrogen-fertilised Gatton panic (*Panicum maximum* cv. Gatton) pasture, Davison *et al.* (1985b) considered a stocking rate of 3 cows/ha to be sustainable, with an average milk output over 3 years of 8550 kg/ha/yr. Higher stocking rates were not viable due to rapid liveweight loss by pregnant cows during the dry season (spring), and weed invasion in the pasture. Similar limitations to increased stocking rate have been shown to occur in south-east Queensland at 3.0 cows/ha (T. Cowan, unpublished data).

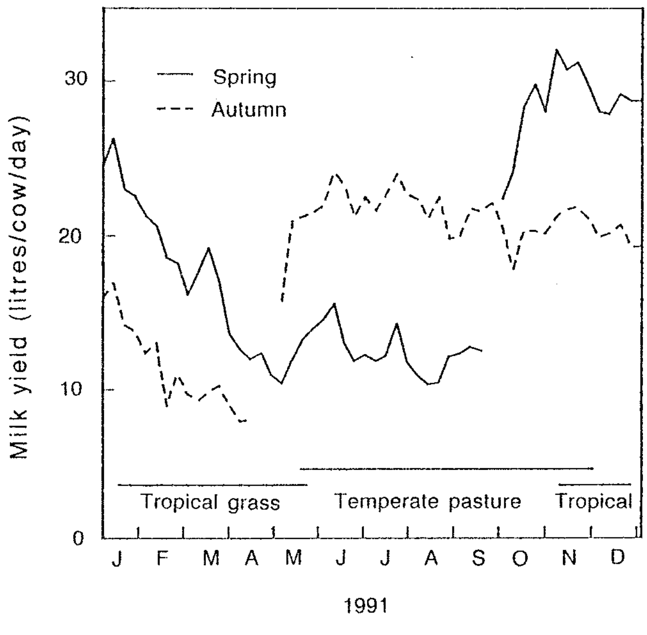

Figure 1. Decline in milk yield during summer and winter of cows calving in autumn and spring.

Table 1. Milk production at selected stocking rates on tropical pastures. Milk yields have been adjusted to zero supplement intake.

Pasture	Annual rainfall	Cow breed	Stocking rate	Milk production		Reference
	(mm)		(cows/ha)	(kg/cow/yr)	(kg/ha/yr)	
Dryland						
Grass-legume	1250	Friesian	1.1	4100	4510	Cowan *et al.*
		Jersey	1.1	2480	2730	(1974)
Grass-legume	1250	Friesian	1.3	3811	4954	Cowan *et al.*
			1.6	3345	5352	(1975)
Grass-legume + 100 kg N/ha/yr	1250	Friesian	1.9	3250	5175	Cowan & Stobbs (1976)
Grass + 200 kg N/ha/yr	1250	Friesian	2.5	2580	6450	Davison *et al.*
			3.0	2450	7350	(1985b)
Grass + 400 kg N/ha/yr	1250	Friesian	2.5	2980	7450	Davison *et al.*
			3.0	2850	8550	(1985b)
Grass + 0 N/ha/yr	800	Friesian	2.0	1123	2246	Cowan *et al.* (1987)
Grass + 300 kg N/ha/yr	800	Friesian	2.0	2254	4508	Cowan *et al.* (1987)
Grass + 300 kg N/ha/yr	1250	Friesian	2.6	3300	8580	Davison *et al.*
			2.5	2216	5540	(1989)
Kikuyu + 300 kg N/ha/yr	1140	Jersey-	3.3	2031	6702	Colman &
		Guernsey	4.9	1901	9315	Kaiser (1974)
Irrigated						
Pangola + 672 kg N/ha/yr		Friesian	5.9	3196	18856	Chopping *et al.*
			7.9	2468	19497	(1976)
		Jersey	5.9	1828	10785	
			7.9	1551	12253	

Where grass was irrigated, stocking rate could be substantially increased. Chopping *et al.* (1976) reported milk yields up to 19 000 kg/ha/yr at a stocking rate of 7.9 Holstein-Friesian cows/ha on pangola (*Digitaria eriantha*)-couch grass (*Cynodon dactylon*) pastures. However, individual cow production from these pastures was about 9 kg/d. In south-east Queensland, Lowe *et al.* (1991a) measured a milk yield from pasture of about 7 kg/d when Holstein-Friesian cows grazed irrigated rhodes grass (*Chloris gayana* cvv. Callide and Pioneer) and paspalum (*Paspalum dilatatum*)-couch (*Cynodon dactylon*) pastures. The pastures were stocked at 3.75 and 7.5 cows/ha, with little difference between stocking rates. The high dry matter production of the tropical grasses does enable the use of high stocking rates, as originally suggested by Payne (1963), but the individual animal production will be low, about 7–12 kg/cow/d.

These quality limitations of tropical pastures are also reflected in productivity on farms. The lactation curves for cows calving in winter in south-east Queensland show the classical peak and fall expected, whereas those for cows calving in summer show the reverse trend, an accelerated downward trend for the first 2 weeks of lactation followed by a linear fall in production, suggesting cows in early lactation are underfed during summer (Papajcsik and Bodero 1988).

Much less attention has been given to measuring the milk production from grass forage crops. In coastal districts there would appear to be little response as Rees *et al.* (1972) measured no increase in milk output of farms as the area of summer forage crops such as sorghums and millets increased from nil to 0.2 ha/cow.

Stobbs (1975a) concluded that summer grass forage crops had a similar nutritive value, in terms of milk production, to the tropical grass pastures. On the Darling Downs, where grass forage crops and lablab (*Lablab purpureus*) are the predominant feeds for cows during summer and autumn, milk production from these forages on 12 farms ranged from 6.5–10.5 kg/cow/d (Chataway *et al.* 1992). These farmers used an average of 21 ha grass crop and 19 ha lablab per farm. Hamilton *et al.* (1970) recorded 4 kg/cow/d more milk for cows grazing lablab compared with those grazing rhodes-setaria (*Setaria sphacelata* cv. Kazungulu) pastures in south-east Queensland.

Specialised feeding systems have been developed in which tropical pastures or forages are absent or are a minor proportion of the forage intake during summer and autumn. A small proportion of farms, for example in the Beaudesert area of Queensland, have the climate and area of irrigation (0.4 ha/cow) considered necessary for maintaining clover-dominant pastures year round. Haifa clover (*Trifolium* spp.) provides a large part of the cows' forage intake during late summer and autumn. Observations of farm production suggest individual cows produce 12–17 kg/d once allowance is made for the amount of concentrates fed.

There has been a 20% increase in the use of conserved forage, principally maize silage, each year over the past 6 years (Kerr and Chaseling 1992). Where this was included as a substantial part of the annual feed program, milk production during summer and autumn was increased 9% and 21%, respectively, compared with a total grazing system (Kerr *et al.* 1991). Cowan *et al.* (1991) showed that farms using maize silage tended to be larger and more productive than the average Queensland dairy farm.

Management of summer forages

Efficiency of pasture use

Very high pasture yields, particularly for grass pastures, are possible in the tropics and subtropics (Colman 1971), and it is sometimes suggested this represents a high potential for milk production. However under practical conditions, where pastures are defoliated at regular intervals, the levels of pasture and milk production achieved are modest and below those from temperate pastures. An exception is the work of Chopping *et al.* (1976) where milk output from irrigated, nitrogen-fertilised grasses in the true tropics was up to 19 500 L/ha/yr.

Very few specific studies of pasture utilisation have been conducted with tropical species. Stobbs (1975b) showed cows select grass leaf in preference to stem and Murtagh *et al.* (1980a) and Cowan *et al.* (1986) showed a reduction in leaf content of the diet from day 1 to day 7 of grazing a paddock. This reduction was associated with reduced milk production (Ottosen *et al.* 1975; Cowan *et al.* 1986). Murtagh *et al.* (1980a) estimated the stocking rate of 4.9 cows/ha used on kikuyu (*Pennisetum clandestinum*) by Colman and Kaiser (1974) was 58% of the carrying capacity of that pasture, based on measured growth of kikuyu leaf. The data of Murtagh *et al.* (1980a) suggest only one-third of the grass leaf was being consumed by cows on nitrogen-fertilised kikuyu.

There have been many independent estimates of milk production from tropical pastures and pasture dry matter yields. By comparing the mean values from these studies an approximate measure of utilisation is obtained. Table 2 gives 4 estimates, which suggest 30–50% of pasture is consumed by cows. In experiments utilising high stocking rates (Colman and Kaiser 1974; Chopping *et al.* 1976) there is insufficient leaf to account for the levels of milk produced. Leaf content of tropical pastures is often about 30–40% (Cowan *et al.* 1986), and at utilisation levels above this, stem will form an increasing proportion of the cows' diet.

Where nitrogen fertiliser has been used to increase the yield of grass on offer to cows, the average conversion of extra grass grown to milk has been 8 L milk/kg N, and the grass dry matter response 26 kg/kg N (Cowan *et al.* 1993). This represents a 20% conversion of DM to milk on a metabolisable energy (ME) basis. If expressed on the basis of grass leaf only, the conversion is 55%.

The utilisation of total pasture dry matter is low, though it would appear the utilisation of leaf is relatively high, except for kikuyu pastures

Table 2. Estimation of the efficiency of utilisation of pasture by cows grazing tropical pastures.

Pasture type	Pasture yield	Legume yield	Grass leaf yield	Utilisation		Reference
				Pasture	Leaf	
	(kg DM/ha/yr)	(kg DM/ha/yr)	(kg DM/ha/yr)	(%)	(%)	
Grass-legume	10 000	3 500	1 630	29	57	Cowan *et al.* (1975)
Grass-nitrogen	9 400	—	4 700	28	56	Cowan *et al.* (1987)
Grass-nitrogen	15 360	—	5 100	36	107	Colman and Kaiser (1974)
Irrigated grass-nitrogen	23 000	—	7 525	49	148	Chopping *et al.* (1976)

on volcanic soils where leaf growth was very rapid (Murtagh *et al.* 1980a). Leaf yield is a more satisfactory indicator of potential animal production from a pasture than is total pasture yield (Murtagh *et al.* 1980b; Cowan *et al.* 1986), and measured levels of leaf yield would suggest these pastures are capable of supporting only modest levels of milk production per hectare.

Standover pasture

In many situations, particularly on dryland farms, tropical pastures are used as standover feed, being consumed from April–July, some 3 months after growth has occurred. Legume-dominant pastures are well suited to this purpose (Luck and Douglas 1968), though they are now found on only a small number of farms with large, frost-free hill areas which can be removed from the grazing rotation during summer. The sweet sorghum (*Sorghum* spp.) hybrids are generally considered useful as standover feed in autumn and winter, and with beef cattle have been shown to maintain their content of digestible energy during this period (P.N. Thurbon, personal communication).

The majority of standover feed is tropical grass which is mature, seeded, with a low leaf content (25% or less) and high fibre content (75% NDF). The ME value of this grass is about 7 MJ ME/kg DM and provides only a maintenance level of energy intake to complement other scarce feed resources during late autumn–early winter.

Grazing management

The sensitivity of tropical legumes to defoliation (Jones and Jones 1978) means that grazing management must be adjusted to suit the legume rather than the grass. With the twining legumes, stocking rate is critical (Jones 1974; Cowan *et al.* 1975), with the desired system of grazing being frequent, light defoliation (Ottosen *et al.* 1975; Cowan *et al.* 1986). With lucerne (*Medicago sativa*) and leucaena (*Leucaena leucocephala*) a period of 4–6 weeks regrowth following grazing is essential to maintain the vigour of the legume (McKinney 1974; Leach 1978; Jones 1979; Lodge 1986).

With pure legume swards, primarily lablab, animals actively select leaf and intake is related to leaf yield (Hendricksen and Minson 1980; Hendricksen *et al.* 1981). Long growing or regrowth periods are necessary for leaf yield to be maximised, and defoliation of leaf is obtained through controlled grazing at low intensities (Hendricksen *et al.* 1981).

The most common method of grazing tropical grass pastures is to have a number of paddocks, approximately 10, and graze these in a rapid rotation (2–4 weeks) with light defoliation at each grazing. Under this system of grazing the animal is able to select a diet high in leaf content (Moss and Murray 1982; Davison *et al.* 1985b; Cowan *et al.* 1986), and pasture yield on offer builds up during the growing period. Once growth ceases around April, animals consume a diet of progressively higher stem and fibre content through until winter, when frost or the availability of alternative feeds removes tropical grass from the diet. This situation is shown in Figure 2 (R. Moss, unpublished data). Pasture yield increases rapidly from October to December, with a reduction in leaf content as the growing season progresses. High yields of stem are maintained through to May, whereas yield of leaf begins to decline from March. All indicators of pasture quality are much higher for leaf than stem. In leaf, IVDMD declines from 64% in October to 55% in May, and in stem, IVDMD falls from 55% in October–November to less than 50% in May. These changes were associated with differences in NDF content of pasture (Figure 2). The ratio of ADF:NDF in leaf and stem was consistent throughout the period of measurement, averaging 0.55 for leaf and 0.59 for stem. This indicates the proportion of indigestible fibre in the plant is relatively high early in the season and remains at this level. Crude protein content of stem was very low, decreasing from 11% to 6% over the season. In leaf, crude protein content was increased following nitrogen fertilisation in November to a maximum of 17% in December–February inclusive, then declined to 11% in May. Observations from other years show the high values for leaf crude protein in December and January are variable, ranging from 11–18% DM. Crude protein values in late autumn, and fibre and IVDMD values throughout the period are more consistent across years. Changes to the system of grazing and the use of techniques such as topping following grazing have been proposed to increase

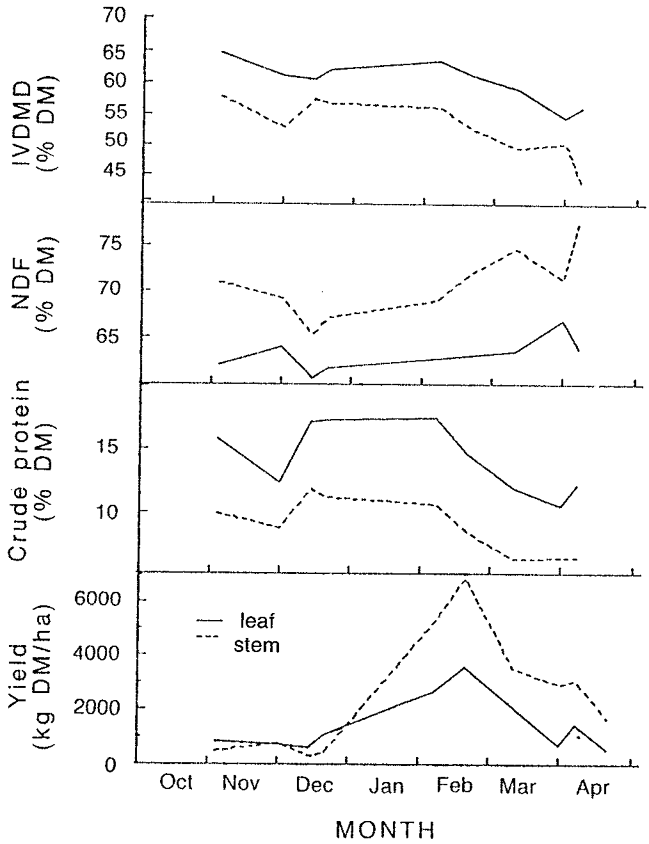

Figure 2. Changes in yield, crude protein, fibre and digestibility of rhodes grass during summer and autumn.

the quality of the diet available to cows (Stobbs 1971). In short-term studies it has been demonstrated that cows are able to select a diet of higher nutritive value from short, leafy swards than from tall, mature pastures (Stobbs 1973b; Davison *et al.* 1981). However in longer studies where milk production has been measured, there have been no benefits from either pasture manipulation or grazing methods different from continuous grazing. Ottosen *et al.* (1975) and Buchanan *et al.* (1985) showed strip grazing of tropical pastures reduced diet quality as cows were forced to consume large quantities of stem, and milk production was also reduced. Similarly, Chopping *et al.* (1978) and Woolcock (cited by Thurbon *et al.* 1971) measured a small reduction in milk and beef production with rotational grazing of pangola grass pastures compared with continuous grazing.

Davison *et al.* (1981) used the techniques of put-and-take grazing (variable stocking rate), slashing (topping) after grazing, rotational grazing, and rotational grazing followed by slashing in attempts to improve summer milk production from Gatton panic (*Panicum maximum* cv. Gatton) and brachiaria (*Brachiaria decumbens*) pastures. None of these treatments improved on continuous grazing of unmanaged grass in terms of milk production per cow. Recently Lowe *et al.* (1991b) maintained milk yield of Holstein-Friesian cows grazing pangola grass at 16 kg/cow/d for 3 months in early lactation without supplementary feeding. The pastures were managed to provide 15 kg green dry leaf of 4 weeks of age to cows daily. However even under this management, liveweight loss was high at 40 kg/cow, sufficient to account for 4 kg milk/cow/d (NRC 1989). This means pastures were supporting 12 kg milk/cow/d, a level consistent with the general results for milk production from tropical pastures referred to earlier and consistent with the estimated IVDMD values for young leaf shown in Figure 2. Major reductions in milk yield below this level are often measured, for example during autumn with cows grazing three tropical grasses (Lowe *et al.* 1991a). Interpretation is often complicated as the pasture is mature with a high stem content, yield is high, crude protein content is very low and fibre content high. Recent data show crude protein contents in the leaf of these pastures in autumn may be as low as 7% DM.

One aspect of tropical grass management which may warrant closer study is the associative effect of white clover and tropical grass in rumen digestion. Moir and Ebersohn (1983) gave evidence of an associative, or even synergistic, effect of a small amount of white clover in the diet of steers grazing pangola grass. This was associated with a marked increase in liveweight gain by steers. Since many dairy farms maintain a component of white clover (*Trifolium repens*) in pastures throughout the year (Ostrowski 1969) this effect may be significant in the utilisation of tropical grasses.

Conservation and supplementary feeding

The argument that conservation and supplementary feeding are high-cost options relative to pasture is no longer tenable (Table 3) and efficiency of the overall feeding system is the criterion on which decisions are made. Farmers have a range of feed options available, with relatively small differences in price, and the object is to use these feeds to maximise profit. Studies of farm productivity (Kerr and Chaseling 1992) and research experience (Cowan 1985) show gross margins are increased with increasing levels of feeding. Consequently farmers are increasing their use of grains and to a lesser extent silage, in order to increase the energy intake and milk yields of cows during summer. Details of responses to concentrates are given by Davison and Elliott (1993).

Table 3. Cost of various feed sources for dairy cows in Queensland (R.T. Cowan, unpublished data).

	Cost		
	(c/kg DM)	(c/MJ ME)	(c/kg CP)
Irrigated temperate pasture	10	0.9	40
Winter crop	4	0.4	24
Summer improved pasture	8	1.0	67
Sorghum grain	15	1.2	150
Cottonseed meal	35	3.2	83
Maize silage	9	0.9	112

Some dairy farmers are replacing part of their summer pasture area with a crop such as maize silage, and feeding this back during autumn. This has the effect of increasing the overall energy density of the diet (Davison *et al.* 1982) and increasing milk yield, but is associated with substantial cost and changes to the feeding system. Cowan *et al.* (1991) argued that maize silage would need to be used to boost productivity for a substantial part of the year to justify the costs and changes involved. It is unlikely the annual feeding system would be more efficient with small quantities of maize silage being made and used to fill short-term feed gaps, as the capital and operating costs and labour required to make and feed silage are such that a substantial boost to animal productivity is necessary to make the operation profitable.

A system more suited to filling short-term feed gaps is the use of round bale silage. This system has the flexibility required for making small amounts of silage, such as excess ryegrass, and feeding back small quantities in the summer.

Management of cows

Heat stress

In addition to effects on the feedbase, high summer temperatures, often associated with high relative humidity, have a direct effect on production (Bianca 1965; Mawson and White 1971; Collier *et al.* 1982) and reproduction (Fuquay 1981) in the cow. Since the predominant method of harvesting herbage is grazing, the need to walk up to 3 km to pasture or crop and then graze this area adds to the heat load of the cow (Blaxter 1962). The combined effects of high temperatures and the need to walk result in unique practical difficulties in herd management.

The food intake of Holstein-Friesian cows begins to decrease at ambient temperatures above 26 °C (Beede and Collier 1986) and in the grazing situation this effect is most marked in the time

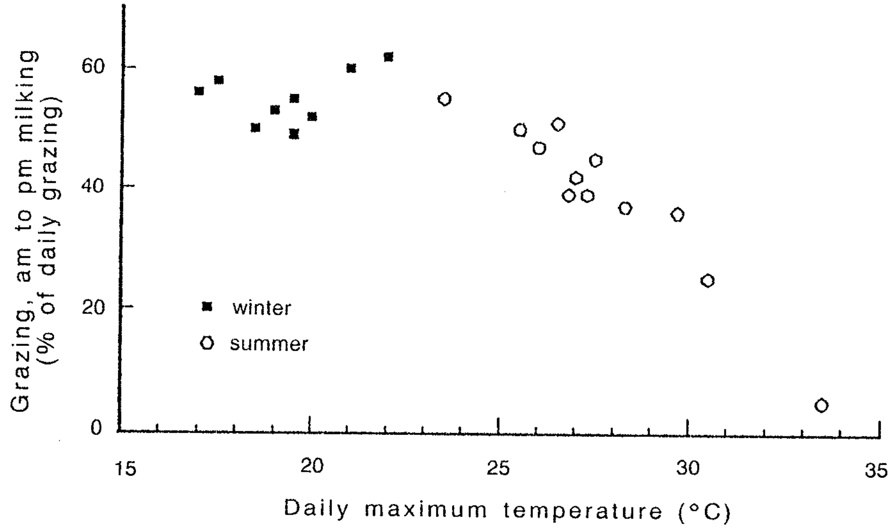

Figure 3. Association of the proportion of grazing done during the day with daily maximum temperature.

cows spend grazing. Goldson (1963) and Cowan (1975) showed cows markedly reduced the amount of grazing done during the day in summer, and the data of Cowan (1975) show this reduction begins to occur at about 26 °C. Subsequent data (R. Moss, unpublished data) show that, on days where maximum temperature is above 32 °C, cows do no effective grazing at all between morning and afternoon milking (Figure 3). At Mutdapilly Research Station in south-east Queensland over the past 2 summers, 21, 19 and 9 days have exceeded 32 °C in December, January and February, respectively. On these hot days total daily grazing time is also reduced as cows graze for a maximum of 7.5 h from afternoon to morning milking, compared with 10 h daily in cool weather.

It would be expected that the quality of night grazing would be important during summer and Rees *et al.* (1972) measured a 16% increase in annual milk fat production per cow as the proportion of the farm used for night grazing increased from 20% to 80%. There is a tendency to put cows on paddocks close to the dairy at night, and this would exacerbate the effects of heat stress on production by limiting the food intake at night.

In a thermoneutral environment, approximately 5-20 °C in Holstein-Friesian cows, the energy demands of walking are about 1.2 MJ/km on a horizontal plane, with an additional 0.02 MJ for each metre of vertical movement up slopes (Blaxter 1962). Higher values of up to 6 MJ/km have been quoted (Lean 1987). There is a rapid increase in the energy demands when animals are walking under heat stress, particularly if they are high-producing (Berman *et al.* 1963). However, there is very little information on these interactions, despite their fundamental importance to dairy animals in subtropical environments.

Shade has been shown to have a beneficial effect on body temperature and milk production of cows during summer. In a tropical upland environment rectal temperatures were reduced and milk production increased when tree shade was available during February and March (Davison *et al.* 1988). However, shade was only partially effective in preventing the decline in milk yield with high temperatures (Figure 4). Rectal temperatures above 40 °C have regularly been measured in grazing cows during summer in Queensland (Chopping *et al.* 1976; Davison *et al.* 1988; R. Moss, unpublished data). With a screen temperature of 33 °C at 1500 h, R. Moss (unpublished data) measured a mean rectal temperature of 41.8 °C in Holstein-Friesian cows grazing without shade in the paddock. Providing shade reduced rectal temperature to 40.9 °C. If drinking water was also freely available in the paddock, as distinct from being available only at the dairy, the rectal temperature was further

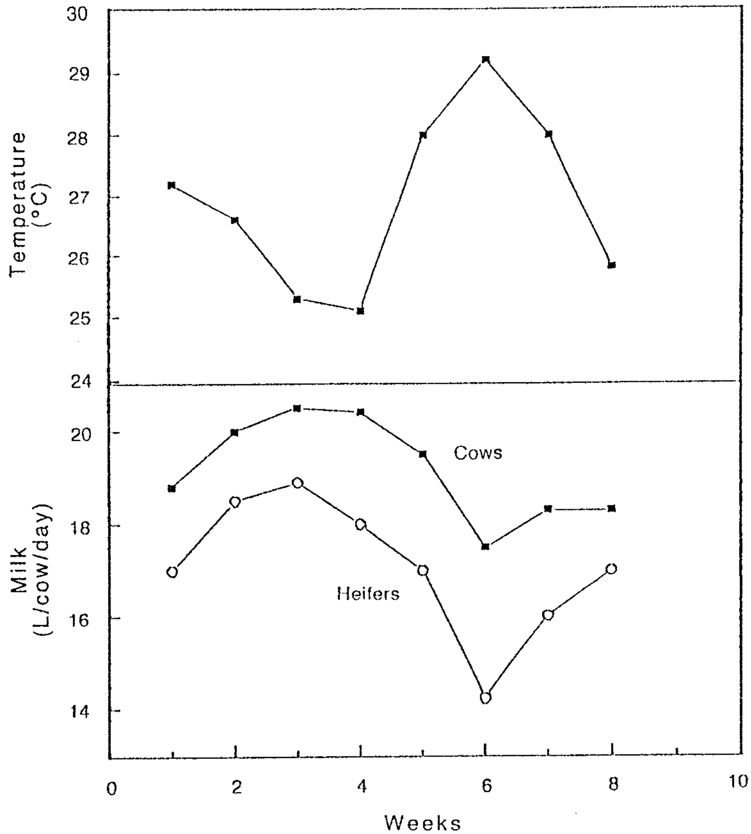

Figure 4. Daily maximum temperature and milk yields of cows and heifers over 8 weeks during summer in a tropical upland environment.

reduced to 40.0 °C. At 700 h and ambient temperature of 21 °C, all cow groups averaged 38.8 °C rectal temperature. At present many dairy farmers in northern Australia are interested in management of heat stress in United States dairies, and a number of study trips have occurred. However, the examples are entirely related to feedlot cattle and caution should be used in assuming similar benefits in grazing systems.

Nutritional history

With adequate temperate pasture or crop during winter and spring, cows due to calve in summer may build up body fat which can be utilised to maintain production after calving. This practice has been effective at low levels of milk production, but Cowan (1982) showed there is a reducing benefit as level of production is increased. At a mean milk yield of 10 L/cow/d, the expected response to preconditioning of cows is about 20%, but the effect is negligible when herd average milk yield approaches 20 L/d. Given that herd recorded cows in Queensland now average 16 L milk/cow/d, and this level is increasing, there seems little scope to use preconditioning to boost summer milk yields.

Summer feeding systems of the future

Tropical pastures appear to have a limited role in future summer feeding systems, as their potential for milk production per cow is below the level we consider will be necessary in a viable dairy farm. Manipulation of these pastures through grazing and pasture management would appear to have limited potential in increasing the quality of the cow's diet. Another important point is that cows grazing tropical pastures require long grazing times, 10 h/d, to eat their requirements, and this would necessitate grazing in the summer heat, and during summer cows reduce their grazing time to avoid the heat. Given that we now have a large amount of information on factors affecting milk production from tropical pasture, we suggest a reduction of research emphasis in this area.

Alternative feeds will be needed to increase production by cows during summer. The most obvious of these is grain. It is a high energy, palatable and economically competitive feed, with a lower heat increment than roughage and can be easily handled. It can be fed at higher levels than commonly used at present.

To sustain further increases in milk production, research should concentrate on alternative sources of roughage to tropical pastures. Maize silage is likely to be used in this manner, though it will need to be used in conjunction with a farm-produced legume if excessive protein costs are to be avoided. Potential summer legumes are the legume crops, lablab and soybeans, used for both grazing and conservation.

The increased levels of grain and conserved forage may be offered during the day from feed pads located in shaded areas close to the dairy. Cows will be fed these materials as a complete diet or separately and may be cooled through the use of sprinklers. Research into the interaction of feeding and heat stress is a priority.

Research priorities

To achieve these developments the following lines of research are recommended:

- *Legume crops for summer forage* — Legume crops offer the possibilities of a legume dominant sward for grazing or a high quality conserved forage. These legumes would be eaten in greater amounts than the tropical grasses, provide a more sustainable farming system than the use of nitrogen-fertilised grass, and provide protein to complement grain and maize silage. The potential of crops of soybeans and lablab needs to be assessed, and continued emphasis placed on extending the range of soil types on which lucerne can be grown.
- *Removal of heat stress from cows* — The effects of heat stress, in association with walking, need to be quantified and management strategies for overcoming these evaluated. The management strategies need to be integrated with feeding strategies.
- *Use of concentrates to their potential* — Concentrates, particularly cereal grain and molasses, are cost-effective feeds for cows. They have a high energy content, promote a lower heat load than forages, and are suited to stall or trough feeding. They can therefore be used to potential in a system where the cow consumes a large part of her daily ration from a feed pad.
- *Testing systems* — The suggested systems need to be developed and tested out on farms. These case studies can be used to collect scientific information and to demonstrate ideas to farmers. Without these on-farm tests of systems there is likely to be a protracted period where many aspects of technology are tested individually.

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