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Rearing heifers in the subtropics and tropics: nutrient requirements and supplementation

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Abstract

Dairy herd productivity is influenced by the age and live weight of heifers at calving, yet the importance of adequate nutrition and management of replacement heifers is often overlooked, and production losses associated with slow growth are not fully recognised. In northern Australia, few heifers calve by 2 years of age, and very few would achieve what is considered to be optimal size at calving. The relatively slow growth of heifers is associated with the use of tropical pastures, which support growth rates in the order of 0.25 kg/d in unsupplemented calves. These low growth rates result from the high fibre content, low dry matter digestibility and low protein : energy ratio of tropical grasses. Supplementary feeding is necessary to increase this growth rate above 0.6 kg/d. Environmental factors can also affect performance, and growth rates are consistently less during the warm, wet season than the dry season. Heat stress, high humidity and internal and external parasites reduce intake and hence growth rate.

If heifers are to achieve their potential within the herd, they need to calve at around 85% of their mature size. Live weight of cows at maturity increases with their level of feeding, so growth targets will increase with herd production, requiring higher concentrate inputs and improvement of the basal forage. Too rapid growth in pre-pubertal heifers may cause excessive fattening and impair milk production but this is unlikely to occur with tropical pastures. Heifers compete with the milking herd for feed resources and optimum live weight of heifers on a particular farm will be dependent on the level of milk production, and hence live weight of cows on that farm.

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Introduction

The prime objective in rearing dairy heifers is to grow the animals so that they can be successfully mated 9 months before they are required to enter the milking herd and are of adequate body size and condition to maintain a high lactational performance and longevity of production (Ternouth 1974). The importance of adequate nutrition and management of replacement heifers is often overlooked and production losses associated with slow growth are not fully recognised.

Feeding standards have been compiled to describe the nutrient requirements of dairy heifers (Roy 1970; ARC 1980; NRC 1989) but are more easily applied to hand-fed animals. It is difficult to assess the actual nutritional status of the grazing animal as its level of intake is uncertain and animals can select a diet with nutrient levels considerably different from those in the pasture on offer (Moss and Murray 1984; 1992) (Figure 1).

In northern Australia, dairy farming is based on perennial tropical grass pastures. Higher quality temperate pastures or crops are used to maintain feed supply and increase milk production, but limited area restricts their use to the milking herd. Competition between lactating and non-lactating animals for scarce feed resources invariably results in heifers being reared on poorer quality perennial forages supplemented with concentrates and conserved forages. Tropical pastures have a low nutritive value with high fibre (60–70% NDF) and low energy (7–9 MJ ME/kg) contents (Figure 1) and cannot support high growth rates in young animals

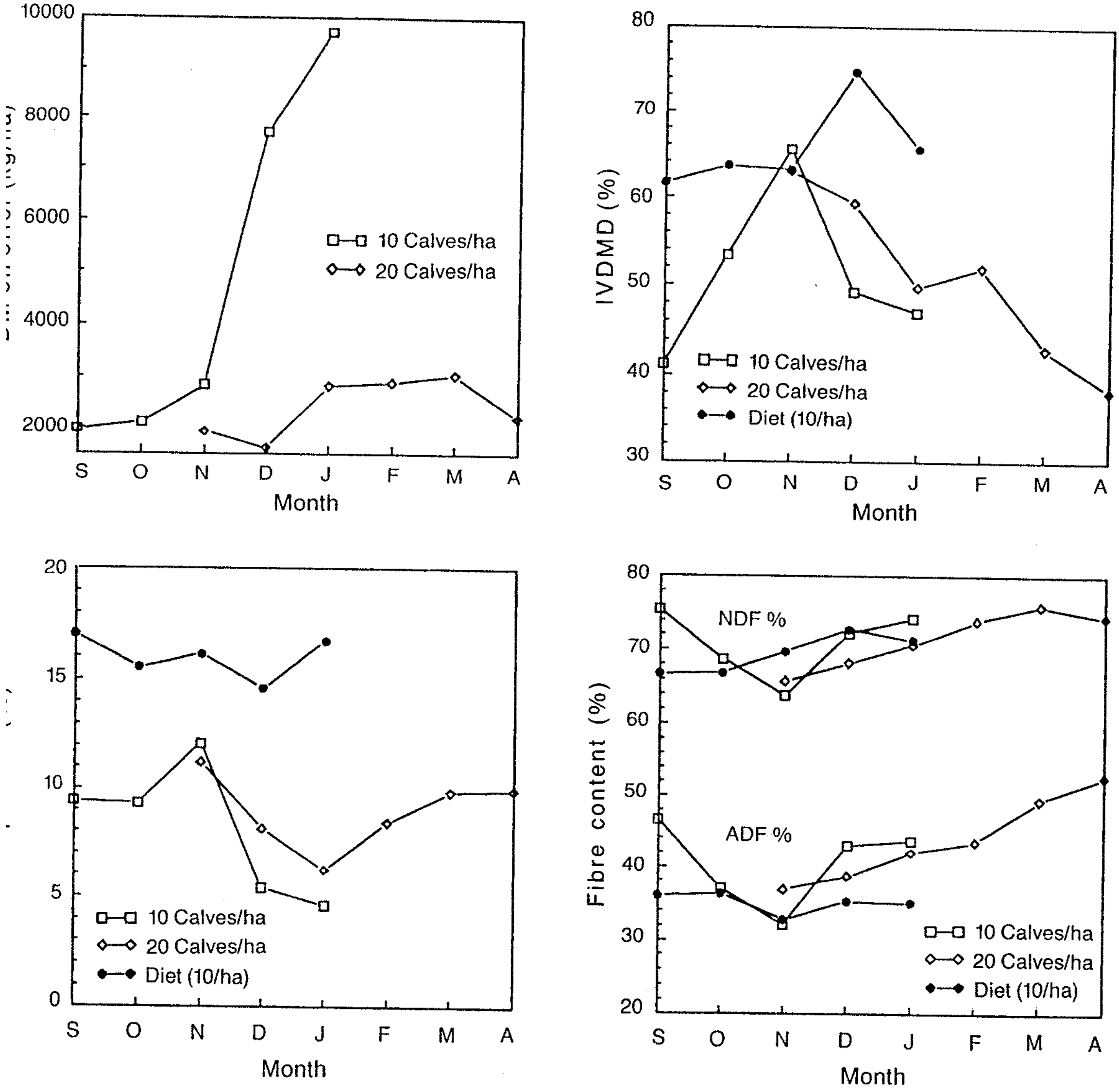

Figure 1. Dry matter yield and chemical composition of (i) pasture on offer from an irrigated tropical grass pasture stocked at 10 (□) and 20 (◇) calves/ha; and (ii) diet selected by oesophageally fistulated Holstein-Friesian weaner calves (●) at 10 calves/ha (Moss and Murray 1992).

(Moss and Murray 1992). Adverse seasonal conditions, parasites and disease can further reduce expected performance (Moss *et al.* 1984; Moss and Goodchild 1992).

Traditionally, dairy heifers have been mated to calve between 2–3 years of age, actual age being determined by the heifer's rate of growth and the age at which she reaches puberty. Our research has allowed us to develop nutritional programs using energy and protein concentrates with tropical pastures, to grow heifers to an adequate size for mating by 15 months to calve at 2 years of age (Moss and Buchanan 1983; Moss *et al.* 1983).

Age at calving

What is the optimum age at first calving? Low growth rates by heifers will delay sexual development as puberty occurs at a certain stage of development more closely related to live weight than to chronological age. Holstein-Friesian heifers reach sexual maturity at about 250kg (207–342kg) live weight (Joubert 1963). This can occur at 9–24 months of age, depending on the plane of nutrition. Reducing the age at first calving has numerous economic advantages as animals spend less of their lives unproductive, and productive life and total lifetime milk production are increased. Genetic improvement from selective breeding is accelerated as the generation interval is shortened. A major effect on farm profitability is the ability to increase herd size or productivity per cow, by reducing the number of non-productive animals competing for feed resources (Gartner 1981; 1982a; 1982b).

Effects of age at calving on production are small. In north Queensland, Cowan *et al.* (1974) found no relationship between age at first calving and milk yield for heifers calving between 19–43 months. In Western Australia, Bettenay (1985) mated heifers at 12, 15, 18 and 24 months. Although milk production over 4 lactations increased with age at initial mating, production per day of age was highest for heifers mated at 15 months. He did not recommend mating at 12 months as heifers did not reach target live weights at calving and produced less milk than heifers mated later.

Rate of growth

High rates of gain in young heifers can adversely affect milk production as fat deposition may impede alveolar (milk secretory tissue) development in the udder. Earlier breeding when heifers achieve a suitable joining weight may minimise negative effects of rapid growth and allow high producing herds to increase feeding levels and calve heifers at heavier live weights. Amir (1974) found that breeding well grown heifers as early as 9 months only slightly depressed first lactation milk yields compared with normally reared animals and lifetime production was higher. However, if heifers were not mated till 16 months, rapid growth would depress milk yields and increase costs. Early breeding can reduce milk yields and increase the incidence of dystocia at first calving. Amir and Kali (1975) concluded that feeding heifers to achieve liveweight gains between 450–700 g/d had little effect on subsequent milk production, but feeding to produce gains in excess of 800 g/d would depress milk yields. Sniffen (1992) has challenged current concepts for heifer growth, recommending very high average growth rates (up to 1.0 kg/d) with earlier calving (18–20 months). Highest growth rates are sought after mating.

In South Australia, Valentine *et al.* (1987) examined the effects of short periods (15 weeks) of rapid or slow growth in weaners (4–5 months old) and pregnant heifers. Heifers were fed to gain at 0.2 (low), 0.6 (normal) or 0.94(high) kg/d and mated at 300 kg. Pregnant heifers reared normally (0.6 kg/d) to mating were subsequently fed for low (0.2), normal (0.6) or high (1.0 kg/d) growth rates in mid-gestation. Rapid growth in heifers before puberty reduced first lactation milk yields but rapid growth during pregnancy had no adverse effects on yield or milk composition. Slow growth before puberty delayed mating, increasing age at calving.

Live weight

In northern Australia, traditionally heifers have been poorly grown. Low quality pastures and inadequate nutrition have restricted growth rates, increasing age at mating and limiting live weight of heifers at calving. Queensland studies have shown a close relationship between live weight and milk production in herds grazing tropical pastures. Cowan *et al.* (1974), in a study of heifers in north Queensland, found that first lactation milk yield was increased by 7.3 kg for each 1.0 kg increase in live weight of heifers at calving, and this effect persisted for 3 lactations. In a subsequent study of dairy herds on the Atherton Tableland, Brown *et al.* (1982) found that average milk production per cow increased by 9.0 kg for each 1.0 kg increase in mean live weight of the herd, with lactating cows weighing between 400–540 kg. They also found that farmers with heavier herds calved heifers at a younger age. In a similar study in southern Queensland, Reeve (1986) found a mean increase of 5.7 kg milk per 1.0 kg increase in live weight for dairy herds in the Beaudesert region where mature live weight of the herds was between

550–700 kg. If heifers are to produce to their potential, they need to achieve 85% of their mature size before calving. As herd production is increased with improved nutrition, target live weights for heifers must also be increased to maintain the relationship of 85% of mature size for first calf heifers (Figure 2). This figure suggests there is an optimum liveweight target for any given level of production. Poorly grown heifers will limit herd productivity, but there may be little advantage in growing replacement heifers much above the herd optimum unless nutrition levels can also be improved for the milking herd.

We have recommended that Holstein-Friesian heifers reach a live weight of 500 kg before calving requiring an average growth rate of about 0.6 kg/d. This is an acceptable target for herds producing 4000–5000 l/cow (Table 1). By comparison, with production levels around 10 000 litres, dairy producers in the United States are advised to grow heifers to 600 kg live weight before calving at 2 years (Figure 2) — an average liveweight gain above 0.7 kg/d (Hoffman 1992) (Table 1). Sniffen (1992) recommended that top producers should feed for rapid growth and early mating to achieve a live weight post-calving of

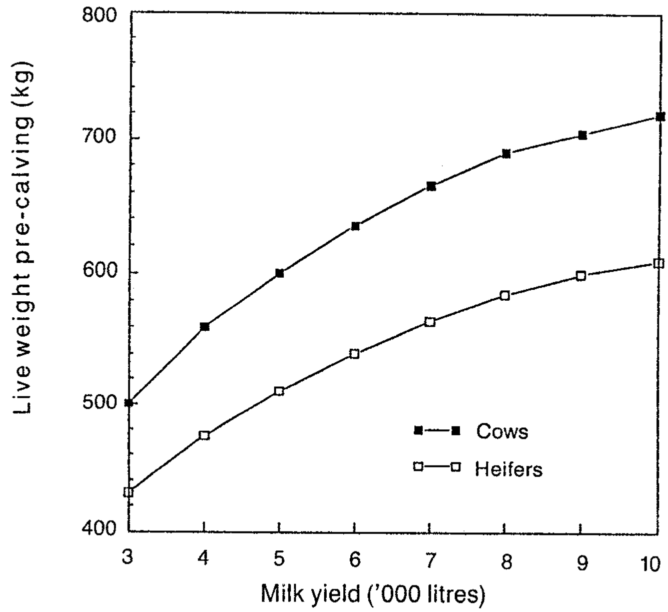

Figure 2. Suggested relationship between herd productivity (litres/cow/lactation) and live weight of cows and of heifers at calving.

Table 1. Live weight, age and growth requirements for dairy replacement heifers to meet differing herd production targets.

	Herd average milk production			
	Australia		United States	
	<5000 litres	5000–8000 litres	>8000 litres (Hoffman 1992)	High production (Sniffen 1992)
Birth weight (kg)	38	40	43	43
Mating weight (kg)	300–330	330–360	350–380	340–380
Mating age (mth)	15	12–15	12–15	9–12
Pre-calving weight (kg)	500-530	530-580	600+	630-650
Calving age (mth)	24	21–24	21–24	18–21
Av. daily gain (kg/d)	0.60+	0.70+	0.77	~1.0

570–590 kg at 18–20 months, requiring gains up to 1.0 kg/d. Although northern Australian producers are not yet at this level of production, farmers seeking high production must adopt higher growth targets for replacement heifers, and must substantially increase feeding levels for heifers.

Effect of age on nutrient requirements

Energy and protein requirements for young calves are very high and are not met by tropical pastures (NRC 1989; Figure 3). Although energy is the primary limitation for growth of heifers grazing fertilised tropical pastures, additional energy supplements can be inefficiently utilised unless adequate protein is also available (Moss and Murray 1992; Moss and Goodchild 1992). As the heifer grows and matures, dietary nutrient concentrations required to sustain consistent growth decrease and protein needs can be met by the pasture. Energy supplementation may be tailored to achieve desired growth levels according to forage quality on offer.

To achieve a minimum live weight of 500 kg at 2 years of age, Holstein-Friesian heifers need to gain at least 0.6 kg/d. We have developed feeding programs to achieve this target using tropical pastures and concentrates (Table 2). The early weaned calf will require a diet supplying

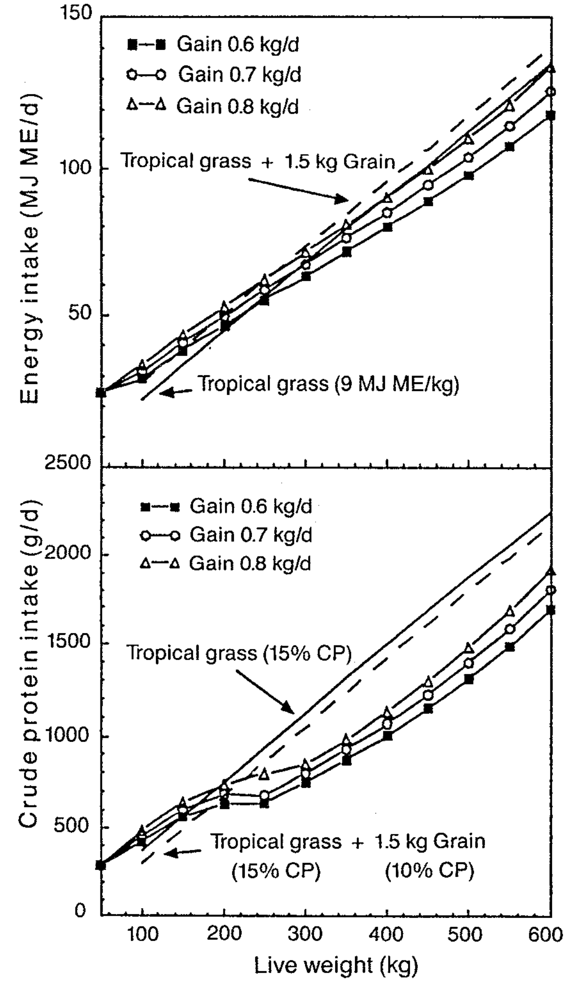

Figure 3. Predicted dietary energy (MJ ME/d) and crude protein (g/d) requirements of dairy heifers at various rates of gain (NRC 1989) and the ability of tropical grass pastures to satisfy these requirements. Assumed voluntary intake of pasture ≈ 2.5% live weight (Moss and Goodchild 1992).

Table 2. Effect of grain and protein supplementation on liveweight change (kg/d) of dairy calves and heifers grazing tropical grass or legume forages.

	Pre-wean		Post-wean	Yearling		1–2 yrs	
Age (months)	0–1	1–2	2–6	6–12	6–18		
Live weight (kg)		60	60–150	130–280	130–350	300–500	Reference
(a) Tropical grass-nitrogen pasture							
(i) 4.5 kg milk + pasture or legume hay							
Nil supplement	0.33	0.57					Moss (1977a; 1977b)
Ad lib. maize grain ~0.5 kg/d	0.31	0.65					
(ii) Tropical grass (15% CP) (irrigated + N)							
Nil supplement			0.23				Moss and Murray (1992)
Maize — 1.0 kg/d (10% CP)			0.53				Moss and Goodchild (1992)
Maize — 1.5 kg/d (10% CP)			0.53				
5M:1CSM — 1.0 kg/d (15% CP)			0.55				
5M:1CSM — 1.5 kg/d (15% CP)			0.64				
(iii) Paspalum hay (8% CP) & minerals (salt/DCP)							
Grain/CSM @ 1.5% live weight (15% CP)			0.52				B. Amenu (pers. comm.). Various levels grain/molasses — N.S.
Molasses/urea/CSM @ 1.5% live wt (15% CP)			0.50				
(iv) Tropical grass (irrigated + N) (12/ha)							
Nil supplement				0.41			Moss *et al.* (1982)
Maize — 1.5 kg/d (10% CP)				0.60			
Molasses + Phosphorus — 1.8 kg/d (6% CP)				0.60			
(v) Tropical grass (irrigated + N) (7.4/ha)							
Nil supplement					0.50		Deans *et al.* (1976)
Maize — 1.4 kg/d (10% CP)					0.62		
(vi) Tropical grass (raingrown + N) (kikuyu) (2.5–4.2/ha)							
Nil supplement					0.52		Cowan *et al.* (1976) — Various stocking rates — N.S.
(vii) Tropical grass (irrigated + N) (7.4/ha)							
Nil supplement						0.70	J. Evans (pers. comm.)
(b) Legume pasture or hay							
(viii) Tropical grass-legume							
Maize — 0.9 kg/d (10% CP)			0.45				Byford *et al.* (1978)
Maize/blood meal — 0.9 kg/d (18% CP)			0.56				
(ix) Lucerne hay + concentrate + minerals (salt/DCP)							
Sorghum — 1.2 kg/d (11% CP)			0.71				Tabrett *et al.* (1991)
Sorghum/CSM — 1.2 kg/d (15% CP)			0.73				
Molasses — 1.5 kg/d (6% CP)			0.64				
Molasses/CSM — 1.5 kg/d (11% CP)			0.69				
(x) Lucerne hay (2–12m)							
Maize @ 1.5% live weight (10% CP)				0.73			H. Deans (pers. comm.)
(xi) Trop. grass-legume + milk (suckled 0–10m)							
4 calves/cow				0.62			Moss (1973)
2 calves/cow				0.70			
2 calves/cow							
Nil supplement			0.82	0.80			Moss *et al.* (1978)
Maize — 2.0 kg/d (8–10m)			—	0.88			
(xii) Tropical grass-legume (1.3/ha)							
Nil supplement (steers: 130–500 kg)						0.65	Winks *et al.* (1970)
Nil supplement (steers: 300–500 kg)						0.79	Winks *et al.* (1979)

about 11 MJ ME/kg DM and 15% crude protein. Tropical pastures can supply only about 7-9 MJ ME/kg DM and support liveweight gains of 0.2–0.4 kg/d from weaning to about 150 kg live weight (Kaiser 1975; Kaiser and O'Neill 1975; Cowan *et al.* 1976; Moss 1983; Moss and Murray 1992). Energy supplementation as grain is efficiently utilised with a conversion of 0.25 kg gain per 1.0 kg concentrate, but protein is necessary with increased levels of feeding (Byford *et al.* 1978; Moss *et al.* 1984; Moss and Goodchild 1992) (Table 2; Table 3).

Protein concentration required decreases with age and by 150 kg the heifer is able to satisfy most of her protein requirements from tropical pastures. These animals are also better able to utilise the less digestible fibre components of pasture and liveweight gains from pasture are higher (Table 2). In an experiment at Ayr, 6-month-old calves (128 kg live weight) were reared on irrigated tropical grass pasture and offered equivalent levels of maize or molasses at 0, 0.5, 1.0 or 1.5 kg/head/d.

Below 150 kg live weight unsupplemented calves gained only 0.24 kg/d. Supplementation increased growth by 0.3 kg/d for maize and 0.2 kg/d with molasses, with no difference between levels of supplementation, suggesting that dietary protein was limiting. Above 150 kg live weight, unsupplemented animals gained 0.5 kg/d and there was a linear response to increased level of energy supplementation as maize or molasses (Figure 4). Overall the liveweight response to energy supplementation as maize or molasses was described by the equation:

$$Y = 0.44 + 0.13X$$

$$(\text{s.e.b} \pm 0.02;\ P<0.01;\ \text{RSD} \pm 0.06)$$

where Y = average daily liveweight gain (kg/d), and X = level of supplementation (kg DM/d).

Studies with dairy and beef cattle grazing tropical pastures in northern NSW and Queensland indicate that, below 300 kg live weight, gains of 0.6 kg/d cannot be sustained without concentrate supplementation (Kaiser and O'Neill 1975; Deans *et al.* 1976; Cowan *et al.* 1976; Moss *et al.* 1982; Moss and Goodchild 1992) but this target is achievable above that weight (J. Evans, personal communication; Winks *et al.* 1970, 1979) (Table 2). Growth rates of 0.7 kg/d are required for heifers entering high producing herds but are difficult to achieve with young animals grazing tropical pastures (Table 2; Figure 3). Growth rates may be increased by improving the quality of forage or by increasing the level of supplementation or the nutrient density of the supplement.

Forage quality

In contrast with our experience on tropical pastures, Kaiser (1973) in a review of growth studies, calculated a mean post-weaning liveweight gain of 0.64 kg/d for calves grazing temperate pastures. Gordon (1973) in Northern Ireland also concluded that Friesian heifers could be reared to calve at 2 years on temperate pastures with minimal concentrate supplementation. In north Queensland, H. Deans (personal communication) grew heifers at 0.73 kg/d between weaning and 12 months on lucerne hay *ad libitum* plus maize grain at 1.5% of live weight. Tabrett *et al.* (1991) also achieved liveweight gains of 0.7 kg/d post-weaning with lucerne hay plus 1.2 kg concentrates as grain or molasses plus cottonseed meal and minerals (salt/DCP) (Table 4). However feeding similar supplements at 1.5% of live weight, B. Amenu (personal communication) could achieve a

Table 3. Effect of supplementation (kg/d) and protein concentration in the supplement on liveweight gain of weaner calves and time taken (d) to reach 130 kg live weight (Moss and Goodchild 1992).

Supplement	Supplement level (kg/d)	Liveweight gain (kg/d) 70–110 kg	110–130 kg	70–130 kg	Time taken (d) 70–130 kg
Tropical grass	Nil	—	—	0.23*a*	—
Maize	1.0	0.49	0.60	0.53*b*	115*a*
Maize	1.5	0.49	0.60	0.53*b*	111*a*
5M:1CSM	1.0	0.54	0.60	0.55*b*	104*ab*
5M:1CSM	1.5	0.62	0.74	0.64*c*	99*b*
s.e.m		0.027	0.047	0.024	4.2
Significance		**	*	**	*

*P<0.05 **P<0.01. Means in columns followed by a common letter are not significantly different.

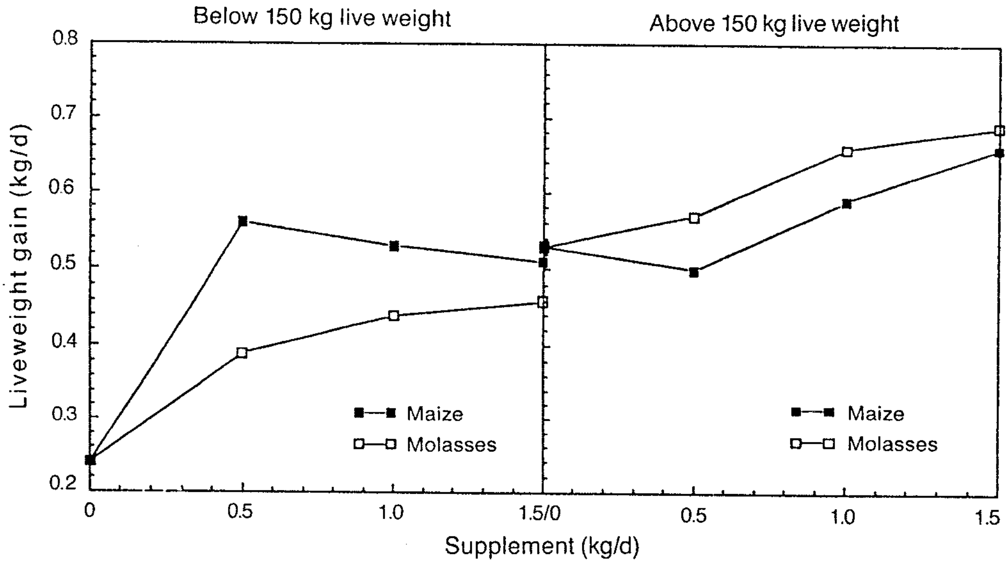

Figure 4. Effect of level of supplementation as maize or molasses on liveweight gain of Holstein-Friesian weaners grazing irrigated tropical grass pastures. Adapted from Moss *et al.* (1982).

Table 4. Effect of molasses, grain and cottonseed meal on growth of weaner calves fed lucerne hay (19% CP) plus minerals (6:1 salt/DCP) from 3-6 months of age (Tabrett *et al.* 1991).

Supplement (kg)			Wean. wt (kg)	Final wt (kg)	Liveweight gain (kg/d)	
Grain	Molasses	CSM			3-4 mths	3-6 mths
—	1.5	—	72	129	0.68	0.64
—	1.3	0.2	72	131	0.76	0.69
1.2	—	—	71	132	0.66	0.71
1.0	—	0.2	70	128	0.79	0.67
S.D.					0.066	0.099

growth rate of only 0.5 kg/d with paspalum grass hay (Table 5). Tropical grass-legume pastures may also support higher liveweight gains than fertilised grass. Winks *et al.* (1979) on the Atherton Tableland achieved liveweight gains of 0.7 kg/d in unsupplemented yearling Friesian steers grazing green panic (*Panicum maximum* var. *trichoglume*) — Tinaroo glycine (*Neonotonia wightii* cv. Tinaroo) pastures (Table 2).

As dairy farmers increase herd productivity, they have changed from tropical pastures for the milking herd to higher quality forages i.e. temperate pastures and silage. To maintain this momentum, tropical pastures will also decline as a component for replacement heifers. Maize silage, a high energy forage, is being increasingly used to increase milk production. If fed to heifers it would also support increased growth rates by increasing the energy content of the diet. Attention to protein requirements will be important.

Molasses

Molasses is a cheaper alternative to grain in coastal dairy regions. In older animals and lactating dairy cows, molasses has been shown to be equivalent to grain when fed at equal dry matter intakes (Cowan and Davison 1978; Moss *et al.* 1982). However, poor growth post-weaning has restricted its use for young calves (R. Moss, unpublished data). Peron (1971a; 1971b) also observed that growth in early weaned calves was twice as rapid with concentrates as with molasses and there were marked differences in rumen development. Nutrient and mineral imbalances and lower total energy intake may be contributing reasons. On high molasses-low forage diets, molasses toxicity (cerebrocortical necrosis) may occur (Preston 1972) and this problem could be greater in young animals. In early weaned calves, maximum voluntary intake of molasses is about 1.5 kg/d as fed, less than for grain but still about 50% of the animal's diet. In recent research where the animal's protein requirements have been satisfied by cottonseed meal or high quality forage and minerals (salt/DCP) provided, molasses has supported liveweight gains equivalent to grain at the same level of feeding (Tabrett *et al.* 1991; B. Amenu, personal communication) (Table 4; Table 5). However, relatively low voluntary intake of molasses will prevent animals achieving high growth rates with tropical pastures or low quality forage. With higher quality diets, substitution of molasses for grain may allow cheaper feeding of heifers. Longer-term and neurological effects of feeding high levels of molasses will need to be examined.

High energy concentrates — fats/oil seeds

In early weaned calves reared on tropical grass pasture, voluntary intake may be as low as 2.5% of live weight (Moss and Goodchild 1992), and concentrates fed at 1.5 kg/d initially represent almost *ad libitum* feeding with 60% of the diet supplied by the concentrate. If tropical pastures are used as the forage, higher liveweight gains may be achievable only if the energy density of the diet is increased. Dietary fats or oil seeds (cotton seed, canola) might be used to do this. Dietary fat could also be used to increase energy intake with higher quality forages to achieve rapid growth. Our knowledge in these areas is limited and more research is warranted. There are suggestions that on high quality diets, polyunsaturated fats (oil seeds) might minimise the risk of excessive fat deposition in the udder of heifers at high growth rates and increase the fertility of lactating heifers.

Stress

Any set-back to growth in the young heifer is difficult to recoup, as compensatory gain in the pre-pubertal animal is low. Mating is delayed and/or liveweight targets are not achieved if heifers can not maintain desired growth rates because of stress, parasites or disease. Preweaning is a critical period. Milk is the most effective nutrient for calves and liveweight gains can be increased with higher levels of milk intake. However, intake of dry feed is reduced, delaying rumen development and increasing the risk of scouring and post-weaning set-backs. Hence feeding management is a compromise aimed at achieving early rumen development with acceptable liveweight gains. Environmental stress can reduce the efficiency of utilisation of feed. In tropical Queensland, high temperatures, humidity and prolonged rainfall reduce liveweight gains in summer and animals may not maintain satisfactory growth rates (Moss and Goodchild 1992) (Figure 5). Lowered growth in summer may be due to reduced forage quality, reduced intake or increased energy demand by the stressed animal (Moss and Goodchild 1992) (Table 6). Internal parasites will reduce liveweight gains and increase mortalities in weaned calves (Moss *et al.* 1984) (Table 7). Management and

Table 5. Effect of substitution of molasses for grain in concentrates (16% CP) fed at 1.5% live weight with *ad lib.* paspalum hay (8% CP) plus minerals (6:1, salt/DCP) on growth of Friesian weaner calves (B. Amenu, personal communication).

Proportions of sorghum and molasses in energy component	Wean. wt	Live weight		Live weight gain	
	2 mths	+ 6 wks	+ 18 wks	wean + 6 wks	wean + 18 wks
	(kg)	(kg)	(kg)	(kg/d)	(kg/d)
100% sorghum grain	62	84	128	0.53	0.52
85 G/15 M	66	84	130	0.44	0.51
70 G/30 M	63	86	129	0.53	0.52
55 G/45 M	63	83	128	0.47	0.51
40 G/60 M	65	86	127	0.50	0.50
100% molasses	65	83	128	0.43	0.50

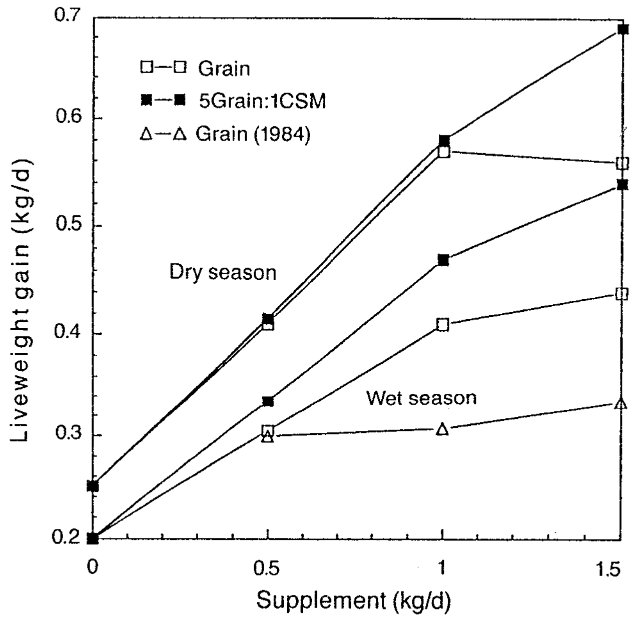

Figure 5. Effect of season on response to grain and protein supplementation in weaned calves grazing irrigated tropical grass pastures (Moss *et al.* 1984; Moss and Murray 1992; Moss and Goodchild 1992).

Table 6. Effect of season on estimated energy consumption and pasture intake by weaned calves (Moss and Goodchild 1992).

Supplement	Level of feeding (kg/d)	Total ME intake[1] (MJ ME/d)	Pasture intake[2] (kg DM/d)	Total intake as % LWt
		Dry season (Spring–Summer)		
Maize	1.0	28	1.7	2.6
Maize	1.5	28	1.1	2.5
5M:1CSM	1.0	29	1.9	2.8
5M:1CSM	1.5	31	1.3	2.8
		Wet season (Summer–Autumn)		
Maize	1.0	23	1.2	2.1
Maize	1.5	24	0.7	2.1
5M:1CSM	1.0	24	1.3	2.3
5M:1CSM	1.5	26	0.9	2.3

[1] Calculations based on energy requirements for observed liveweight gains (ARC 1980).
[2] Pasture intake was calculated as (total ME intake — ME in supplement)/ME in pasture. Assumed pasture provided 9 MJ ME/kg DM (Moss and Murray 1992).

feeding strategies need to be identified and integrated if high growth rates are to be sustained at all periods of the year.

Conclusions

Improving the economic efficiency of milk production by using concentrate supplementation for more rapid growth and earlier mating of heifers is a valid objective. To minimise the effects of live weight and age on production, heifers should achieve 85% of their mature size by calving. Final target weights therefore will vary according to the level of feeding and production of the herd, but all animals reared should exceed 500 kg live weight at calving at 2 years of age. Optimum age and live weight

Table 7. Effect of stocking rate (animals/ha), grain supplementation (kg/d) and anthelmintic on calf mortality, live weight (kg) and liveweight gain (kg/d) of Holstein-Friesian weaner calves grazing irrigated, tropical grass pastures at different periods of the year (Ayr, north Queensland) (Moss *et al.* 1984).

Treatment		Deaths	Live weight		Liveweight gain				
SR[1]	Grain supp.		Start	Finish	Summer	Autumn	Winter	Spring	12 months
8.25	0.5	1	86	239	0.23	0.37	0.22*a*[2]	0.64	0.42
8.25	1.0	3	83	259	0.23	0.41	0.35*b*	0.68	0.46
10.75	1.0	1	87	248	0.18	0.41	0.33*b*	0.61	0.42
10.75	1.5	3	83	261	0.20	0.47	0.29*ab*	0.69	0.46
s.e.m			4.4	8.2	0.036	0.032	0.028	0.033	0.025
Drench		2	82	257	0.23	0.45*a*	0.34*a*	0.66	0.45
Nil		6	88	246	0.19	0.38*b*	0.26*b*	0.65	0.42
s.e.			3.26	5.8	0.026	0.022	0.020	0.024	0.018

[1] Stocking rate.
[2] Means in columns followed by a common letter are not significantly different, P>0.05.

relationships for heifers for differing production systems must be determined. Tropical pastures will not support high growth rates in animals below approximately 300 kg live weight. Research is required to determine how nutrient requirements for heifers to gain at or above 0.7 kg/d may be met using tropical pastures or higher quality forages. To maintain high annual growth rates, effects of the environment in summer must be minimised. Maximum advisable growth rates prior to mating must be determined as earlier studies have shown that growth rates above 800g/d in pre-pubertal heifers were detrimental to subsequent milk production. Rapid gain after mating will not impair milk production. By balancing nutritional inputs to closely fit animal requirements throughout their period of growth it is possible to grow heifers to 600 kg live weight by 2 years of age maintaining consistent growth which does not cause excessive fattening.

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