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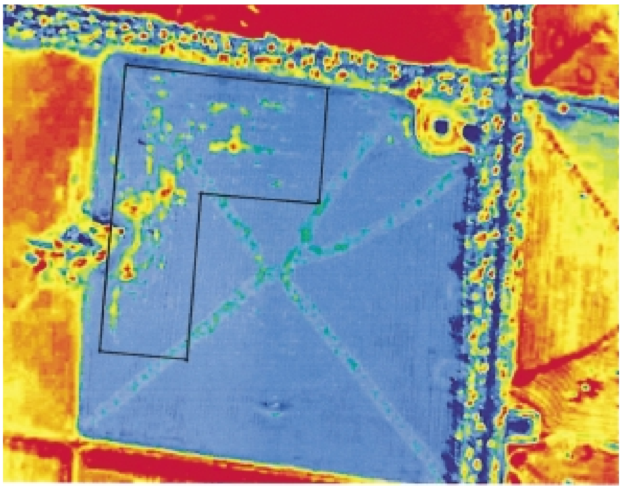

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Post-weaning growth of cattle in northern New South Wales 2. Growth pathways of steers

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Abstract. This paper describes the post-weaning growth of *Bos taurus* and *Bos taurus* × *Bos indicus*-derived steers grazing temperate perennial pasture in northern New South Wales. These cattle were either autumn weaners from spring-calving herds in summer rainfall environments, or summer weaners from autumn-calving herds in winter rainfall environments. Autumn weaners were grown out on 3 pasture systems: (i) pasture only (P1), (ii) pasture supplemented in late winter–early spring with formulated pellets of high protein content (P2), or (iii) pasture supplemented with a nitrogen-fertilised forage crop (P3) to provide different growth pathways towards entry to the finishing phase. Over the 3-year study, seasonal liveweight gain on P1 varied between –0.21 and 1.05 kg/head.day; liveweight gain was generally low (about 0.5 kg/head.day) in winter and high (about 0.8 kg/head.day) in spring. *Bos taurus* autumn weaners achieved feedlot entry specifications for the domestic market (300 kg liveweight) in 6–8 weeks by the end of winter, and feedlot entry specifications for the export market (400 kg liveweight) in 17–27 weeks by the end of summer. For *B. taurus* × *B. indicus*-derived autumn weaners, the period to feedlot entry was 19 and 33 weeks for domestic and export feedlot entry specifications, respectively. Supplementary feeding generally increased post-weaning growth in late winter–early spring and reduced the period to feedlot entry for export steers. Summer weaners were grown out on pasture in P1, P2 or P3 pasture systems, met domestic feedlot entry specifications on arrival, but did not reach export feedlot entry specifications before the onset of winter imposed liveweight stasis. The most effective grow-out system was based on *Bos taurus* autumn weaners with supplementary feeding in winter–spring to overcome the limitations of the winter feed gap.

Additional keywords: backgrounding, introduced pasture, supplementary feeding.

Introduction

Management of post-weaning growth to produce feeder steers that meet feedlot entry specifications is a major component of 'backgrounding'. Feedlot entry specifications include age, liveweight, frame size and body condition. For domestic feeders (i.e. cattle destined for the domestic market following feedlot finishing), feedlot entry specifications are 300 kg liveweight, 12–15 months of age, and 1–6 mm P8 (the intersection of a line from the *Tuber ischii* and a perpendicular line from the spinus process of the third sacral vertebra) rump fat thickness. For export feeders (i.e. cattle destined for the export market following feedlot finishing) specifications are 370–430 kg liveweight, 18–24 months of age, and 7–12 mm P8 rump fat. Yearling cattle need to be grown to these specifications at a prescribed rate of gain so that increase in liveweight and frame size occurs without undue increase in body fat (McKibbin 1995).

As projections show that markets for feedlot beef continue to expand (MLA 1999), the corresponding demand from the industry for feeder cattle is increasing. An estimated 600000 cattle currently in feedlots and the ongoing development of greater feedlot capacity in Australia (Boal 1999) are indicative of a firm demand of at least 1.5 million feeder cattle per year. To satisfy this demand and to achieve feedlot entry specifications, the industry needs to develop strategic nutritional practices that avert pasture

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feed-gaps and improve the feed-base for yearling cattle in the backgrounding phase.

On the Northern Tablelands of New South Wales, temperate pastures comprising introduced perennial grasses and legumes are considered to provide a suitable pasture base for intensive cattle and sheep enterprises (Anon. 1964). Cattle production systems typically utilise forage, hay, grain, silage or concentrate supplements to avert seasonal feed gaps (Hartridge and Parker 1979). Previous research undertaken at Glen Innes Agricultural Research and Advisory Station from 1962 to 1978 (Robinson and Hennessy 1978, 1981) evaluated a wide range of supplements and supplementary feeding strategies for: (i) beef cows to produce a high turnoff of weaned calves (Robinson 1966; Hennessy and Robinson 1974); and (ii) weaner cattle to maintain growth through winter (Hennessy and Robinson 1975, 1978).

The aim of the present study was to impose different pathways of post-weaning growth on both spring-born autumn weaners (from summer rainfall environments) and autumn-born summer weaners (from winter rainfall environments). Characteristics of the pasture base in this study are reported by Ayres *et al.* (2001); it was proposed that the limitations of the feed year include a feed gap in winter–early spring due to low herbage mass associated with winter cold, and a feed gap in summer–autumn associated with only moderate nutritive value of secondary regrowth pasture. The present paper reports the seasonal liveweight performance of yearling cattle, describes the effects of feed gaps on post-weaning growth, and discusses their significance for the production of feeder steers meeting feedlot entry specifications. Relationships between post-weaning growth, finishing performance and carcass composition are reported by Robinson *et al.* (2001).

Materials and methods

Location

The study was undertaken at the Glen Innes Agricultural Research and Advisory Station (29°44′S, 151°42′E; altitude 1057 m) centrally located in a cool temperate highlands environment on the Northern Tablelands of New South Wales, Australia. Environmental conditions at the study site are described in detail by Ayres *et al.* (2001).

The grazing area was 340 ha of improved pasture comprising a mixture of introduced species (tall fescue, *Festuca arundinacea*; phalaris, *Phalaris aquatica*; perennial ryegrass, *Lolium perenne*; cocksfoot, *Dactylis glomerata*) and legumes (white clover, *Trifolium repens*; and red clover, *Trifolium pratense*) typical of the perennial grass–perennial legume pasture type in summer rainfall environments of temperate Australia.

Cattle management

The cattle were 8–10-month-old steers, weaned in either autumn or summer and bred from herds with links to the BREEDPLAN (Sundstrom 1999) performance recording scheme. Autumn weaners comprised 3 cohorts of *Bos taurus* steers designated A94, A95 and A96 born in spring 1993, 1994 and 1995, and arriving at Glen Innes in autumn 1994, 1995 and 1996 respectively; and 1 cohort of *Bos taurus* × *Bos indicus*-derived steers designated T94, born in summer 1994 and arriving at Glen Innes in winter 1994. Summer weaners comprised 2 cohorts of *B. taurus* steers designated S95 and S96 born in autumn 1994 and 1995, and arriving in Glen Innes in summer 1995 and 1996, respectively. Up to 6 breeds (Angus, Murray Grey, Shorthorn, Hereford, Santa Gertrudis, Belmont Red) and 13 herds of origin from throughout eastern Australia were present in each cohort. The composition of cohorts (breeds, herds, numbers) is listed in Table 1. A schematic outline of the study, showing cohorts, intervals of supplementary feeding and backgrounding growth pathways is provided by Figure 1. The growth of a later cohort of autumn weaners (A97) is described by Robinson *et al.* (2001).

Liveweights of weaners in each cohort on arrival at Glen Innes varied according to herd of origin, age and arrival date. Mean ± s.d. initial liveweights (kg) were 243 ± 35, 236 ± 44, and 257 ± 39 for A94, A95 and A96, respectively; 219 ± 39 for T94; and 293 ± 39 and 311 ± 34 for S94 and S95, respectively.

Cattle were grown out to a target liveweight of 300 kg for subsequent finishing either in the feedlot or at pasture for the domestic market, or to a target liveweight of 400 kg for subsequent finishing either in the feedlot or at pasture for the export market (Korean or Japanese). Targets were deemed to have been achieved when the mean liveweight of all cattle in the cohort reached these liveweights.

Weaners were identified by ear tag and tattoo and treated to a standard health and husbandry protocol. This protocol included a 2–4 week period of yarding, handling, weighing, hay-feeding, anthelmintic and lice treatments, a 5 in 1 antibacterial vaccination program, exclusion and veterinary treatment of sick animals, and dehorning where necessary.

Table 1. The breed, and numbers of herds and animals in each cohort of weaner cattle

Breed	No. of herds	No. of animals
	A94 cohort	
Angus	5	204
Shorthorn	1	49
	T94 cohort	
Belmont Red	2	80
Santa Gertrudis	3	67
	A95 cohort	
Angus	5	175
Hereford	3	164
Murray Grey	2	116
Shorthorn	1	59
	A96 cohort	
Angus	6	221
Hereford	4	212
Murray Grey	2	118
Shorthorn	1	29
	S95 cohort	
Angus	4	192
Hereford	1	20
Murray Grey	1	39
Shorthorn	2	76
	S96 cohort	
Angus	4	208
Hereford	1	54
Shorthorn	2	85

Pasture systems

The pasture systems were: (i) pasture only (P1), (ii) pasture plus supplementary feeding with formulated pellets of high protein content (P2), and (iii) pasture plus nitrogen (N)-fertilised forage crop (P3). The grazing area was divided into 3 blocks based on topography. The 3 pasture systems were then randomly assigned to similar sized areas within each block and were not replicated. Both autumn and summer weaners were allocated across these 3 pasture systems on the basis of breed, herd of origin, sire, age and weaning weight (Robinson 1995). Pastures in the grazing areas of each system are described in terms of botanical composition, herbage mass and nutritive value by Ayres *et al.* (2001).

Supplementation with pellets in P2, or forage crop in P3, was provided to autumn weaners in late winter–early spring as alternative strategies for overcoming the winter feed gap. In P2, the pellets were fed from portable troughs within the P2 pasture areas. In P3, the forage crop was fed by grazing from a separate block adjacent to the P3 pasture areas. Summer weaners grazed their respective pasture system areas in summer–autumn without supplementary feeding, excepting P3 weaners in S95 that grazed the forage crop for a short period in autumn.

The stocking rate on each pasture area (i.e. excluding the area of the P3 forage crop) was identical and ranged from 1.0 to 1.5 steer equivalents/ha, depending on the time of the year. The grazing management used was 'intermittent grazing' in which cattle were moved between blocks within their respective pasture systems to maintain total herbage mass between 1500 and 2500 kg DM/ha in 1994 and 1995 (drought years), and between 2000 and 3000 kg DM/ha in 1996. Consequently, grazing periods typically ranged from 20 to 30 days, depending on block size and seasonal conditions.

Supplementary feeding

Formulated pellets. In 1994, By-Pro Pellets (Ridley Agriproducts Pty Ltd) were fed to P2 cattle in A94 and T94 cohorts from late winter to early spring (5 August to 17 October); in the first week the daily ration was 0.6 kg/head and thereafter it was increased to 1.0 kg/head. In 1995, By-Pro Pellets were fed to P2 cattle in A95 cohort from

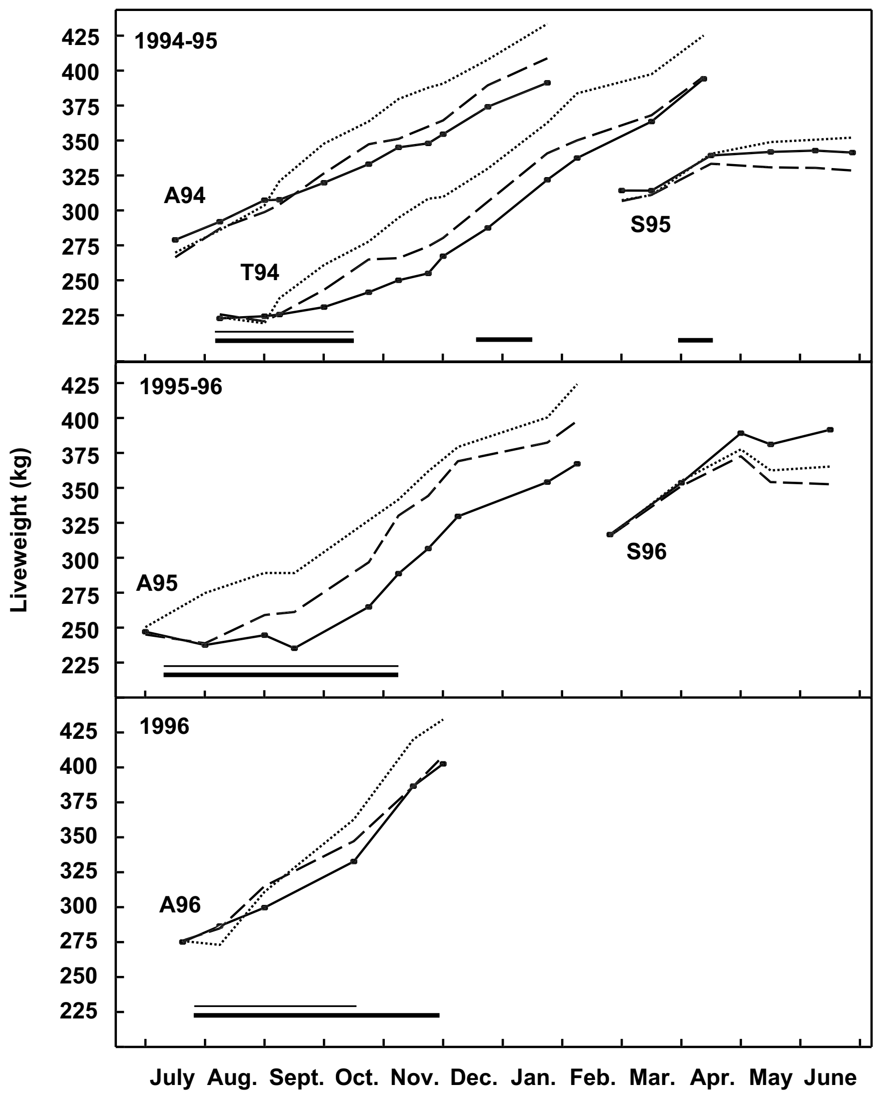

Figure 1. Post-weaning growth pathways and intervals of supplementary feeding (— pellets; ▬ forage) for *B. taurus* cohorts (A94, S95, A95, S96, A96) and *B. taurus* × *B. indicus* derived cohort (T94) on P1 (■ solid line), P2 (dashed line) and P3 (dotted line) pasture systems.

Table 2. The nutrient composition of formulated pellets fed to P2 cattle

Nutrient constituents (DM, dry matter; OM, organic matter; N, nitrogen; ADF, acid detergent fibre; DDM, digestible dry matter) were determined by near infra-red spectroscopy and ME (metabolisable energy) was estimated from ADF and DDM

Year of feeding	DM (g/kg)	OM (g/kg)	N (g/kg DM)	ADF (g/kg DM)	DDM	ME (MJ/kg DM)
1994, 1995	900	935	45	82	0.84	12.6
1996	911	904	32	130	0.77	11.6

mid-winter to late spring (10 July to 8 November); in the first week the daily ration was 0.4 kg/head, in the second and third weeks it was increased to 0.7 kg/head; thereafter it was 1.0–1.5 kg/head. In 1996, CRC Trial Pellets (Ridley Agriproducts Pty Ltd) were fed to P2 cattle in A96 cohort from late winter to mid-spring (23 July to 14 October); in the first week the daily ration was 0.6–0.8 kg/head, in the second and third weeks it was increased to 1.5 kg/head, and thereafter it was 2.0 kg/head. The By-Pro Pellets had a higher crude protein content, were more digestible, and had a higher metabolisable energy content than the CRC Trial Pellets. Both pellets are described in Table 2.

Forage crop. The first crop was sown in February 1994 on a 30 ha block and grazed progressively by P3 cattle in 3 equal subblocks from late winter to early spring (at the same time as P2 cattle were fed pellets). Sowing rates were 10 kg/ha Italian ryegrass (*Lolium multiflorum* cv. Concord) and 4 kg/ha red clover (*Trifolium pratense*) together with a fertiliser application rate of 250 kg/ha Starter 15 (Incitec Fertilisers product containing 14.2% N, 13.0% P, 11.2% S) on a prepared seed bed. Nitrogen fertiliser was applied annually at the rate of 135 kg/ha in 3 split applications. Superphosphate was applied at the rate of 250 kg/ha in April of the second year. A second forage crop was sown on the same block in February 1996 and grazed progressively in winter–spring 1996. Sowing rates for this crop were 10 kg/ha Italian ryegrass, 2 kg/ha white clover (cv. Haifa) and 1 kg/ha chicory (*Chicorium intybus* cv. Puna). Cattle on the forage crop were moved to the next subblock when total herbage mass on the grazed subblock declined below 2500 kg DM/ha (assessed visually by a trained observer). The grazing period on each subblock was about 10 days.

Composition, herbage mass and nutritive value of the forage crop are presented in Table 3. Botanical composition, total herbage mass and green herbage mass were estimated using the 'double sampling' method of Morley *et al*. (1964) and the BOTANAL program (Hargreaves and Kerr 1978). *In vitro* digestibility was estimated by the method of Ayres (1991). Nitrogen content was determined by the Kjeldahl procedure (AOAC 1980). In first-year crops (1994 and 1996), Italian ryegrass was the dominant species. White clover, annual grasses and broadleaf weeds were significant components in the second year (1995).

In 1994, the forage crop was grazed by A94 and T94 cohorts over 2 periods; for 10 weeks from late winter to early spring (8 August–17 October) and for 3 weeks in early summer (19 December–12 January 1995). In 1995, the forage crop was grazed by S95 and T94 cohorts for up to 3 weeks in early autumn (29 March 1995–18 April 1995 for crop management purposes) and by A95 cohort over 2 periods; for 9 weeks from mid-winter to early spring (10 July–14 September) and again for 3 weeks in mid-spring (16 October–9 November). In 1996, the forage crop was grazed by A96 cohort over 3 periods; for 5 weeks in late winter (22 July–29 August), for 3 weeks in early spring (6 September–29 September), and for 3 weeks in late spring (11 October–29 November).

Measurements

Unfasted individual liveweight was recorded between 0800 hours and 1000 hours on the day of movement of cattle between blocks, as determined by the grazing management protocol. P8 rump fat thickness was measured on autumn weaners at feedlot entry for the domestic and export market, and on summer weaners at feedlot entry for the export market by real-time ultrasound scanning (Robinson *et al.* 1992).

Table 3. Botanical composition, total herbage mass, green herbage mass, and nutritive value of the forage crop grazed by P3 cattle

In vitro digestibility was determined as described by Ayres (1991), nitrogen was determined using the Kjeldahl procedure (AOAC 1980)

Month	Botanical composition				Herbage mass		Nutritive value of total herbage mass		Nutritive value of green herbage mass	
	Ryegrass (%)	White clover (%)	Annuals (%)	Weeds (%)	Total (kg DM/ha)	Green (kg DM/ha)	*In vitro* digestibility	N (g/kg DM)	*In vitro* digestibility	N (g/kg DM)
					1994 (first-year crop)					
Aug.	100	0	0	0	3246	1820	0.75	17	0.83	21
Oct.	100	0	0	0	1868	835	0.71	19	0.75	24
					1995 (second-year crop)					
July	65	15	6	12	3149	1343	0.73	30	0.82	32
Oct.	51	24	6	19	2434	1985	0.78	33	0.78	34
					1996 (first-year crop)					
July	99	0	0	1	1551	940	0.84	25	—[A]	—[A]
Oct.	96	3	0	1	3499	3464	0.84	26	—[A]	—[A]

[A]Only total herbage mass was assayed because herbage mass was 100% green.

Data analysis

Mean liveweight data for cattle on each growth pathway (P1, P2 and P3) were plotted against time in Figure 1 to illustrate post-weaning growth pathways of each cohort. Liveweight (kg) was modelled over time separately in 18 subsets according to growth pathway (P1, P2, P3), target market (domestic, Korean, Japanese), and finish (feedlot, pasture). Each subset was modelled at the individual animal level using a cubic smoothing spline function in ASREML (Gilmour *et al.* 1998).

The model fitted was:

$$\mathrm{Wt} = \mu + day + spline(day) + animal + animal.day + animal.spline(day)$$

where *day* (fitted as a fixed covariate), represented the average linear growth rate of all animals, and μ was the mean intercept. All other terms were fitted as random effects, with a covariance between the animal intercept (*animal*) and slope (*animal.day*). The cubic spline [*spline* (*day*)] modelled systematic departures from the average group growth rate (μ + *day*). The splines were a series of cubic polynomials linked at 'knot points' with a continuous 1st and 2nd differential (Green and Silverman 1994); the 'knot points' were the dates when the animals were weighed. The remaining 3 random terms, *animal*, *animal.day* and *animal.spline (day)* modelled departures from the group growth profile at the individual animal level. Likelihood ratios were used to assess the significance of fitting individual animal splines; in all cases they were necessary. Potential outliers for individual animals were identified and corrected where necessary.

Growth rate (kg/head.day) was predicted from the spline growth curve for each animal using the 1st derivative of the continuous curve (Green and Silverman 1994). Predictions were made at 10-day intervals within critical periods of the pasture growth cycle. These periods were: summer regrowth, 1 January–15 March; autumn vegetative growth, 16 March–15 June; winter, 16 June–15 September; spring vegetative growth, 16 September–31 October; and spring onset of maturity, 1 November–31 December.

Subcutaneous fat thickness measurements over the P8 rump site for each cohort were analysed using GENSTAT 5 (Payne *et al*. 1987) to fit *pathway* × *market* and *age* as fixed effects and other terms (*sire*, *breed*, *herd*, *breed* × *market*, *herd* × *market*, and appropriate 3-way interactions) as random effects.

Direct statistical comparisons of pasture systems were not made because these systems were not replicated.

Results

Growth pathways

The post-weaning growth pathways for both autumn and summer weaners are illustrated in Figure 1.

Cohort A94 commenced backgrounding on P1, P2 and P3 pasture systems in mid-July 1994 at an average liveweight of 272 kg. This cohort gained weight throughout the period of supplementary feeding in winter and early spring, and continued to gain on pasture in spring and summer. Target liveweights for subsequent finishing for the domestic and export markets were reached in early September and in mid-December 1994, respectively.

Cohort T94 commenced backgrounding 3 weeks later than A94 at an average liveweight of 224 kg. This cohort gained weight on P2 and P3 pasture systems during the latter part of the supplementary feeding period but showed low weight gain on P1 at this time. Both A94 and T94 cohorts had high liveweight gain on P1, P2 and P3 pasture systems in spring and summer. Target liveweights for domestic or export finishing were reached by T94 cohort in mid-January 1995 and early April 1995, respectively. S95 export cattle and T94 domestic and export cattle gained greater weight on the P3 pasture system than on P2 or P1 pasture systems.

Cohort A95 commenced backgrounding in late June 1995 at an average liveweight of 247 kg. P2 weaners lost weight until late July and P1 weaners lost weight until mid-September, but P3 weaners generally gained weight throughout the whole of the backgrounding period. Target liveweights for domestic and export markets finishing were reached in mid-October 1995 and early February 1996, respectively.

Cohort A96 commenced backgrounding in mid-July 1996 at an average liveweight of 276 kg. Weaners in each pasture system gained weight and reached target liveweights for domestic and export finishing by late August 1996 and late November 1996, respectively.

Cohort S95 began backgrounding in late February 1995 at an average liveweight of 309 kg. Cohort S96 began backgrounding in late February 1996 at an average liveweight of 316 kg. Both exceeded the feedlot target entry liveweight for the domestic market at this time. Domestic market steers were turned off within 3 weeks of arrival and export market steers continued to gain weight until May. Thereafter, however, the rate of weight gain declined or was negative and the export market feedlot target entry liveweight was not reached before the onset of winter.

Seasonal liveweight gain

Predicted seasonal liveweight gain in P1, P2 and P3 pasture systems is presented in Tables 4 and 5. The overall range of liveweight gain by autumn weaners was –0.21–1.05, –0.01–1.28 and 0.14–1.35 kg/head.day for P1, P2 and P3 pasture systems, respectively. For autumn weaners on the P1 pasture system in 1994, there were marked seasonal differences in liveweight gain; liveweight gain was lowest in winter–early spring (0.51 kg/head.day) and highest in late spring (0.78 kg/head.day). In 1995 and 1996, liveweight gain was again lowest in winter (0.15 and 0.48 kg/head.day respectively). For autumn weaners on the P2 pasture system, liveweight gain was high in spring during the period of supplementary feeding with pellets (0.83, 1.04 and 0.93 kg/head.day in 1994, 1995 and 1996, respectively). For autumn weaners on the P3 pasture system, liveweight gain was high in late winter–spring during the period of grazing of the forage crop (0.83, 0.90 and 1.01 kg/head.day in 1994, 1995 and 1996, respectively). The mean liveweight gain of summer weaners in autumn was moderate (0.31 and 0.67 kg/head.day in 1995 and 1996, respectively).

Fat thickness

Mean P8 rump fat thickness of each cohort and growth pathway, for autumn weaners at target weights for commencing domestic and export market finishing, and for

Table 4. Predicted seasonal liveweight gain (kg/head.day) and number of steers (*n*) for each cohort of autumn weaners grazing P1, P2 or P3 pasture systems

ADG, average daily liveweight gain
Statistical comparisons of ADG between pasture systems were not made because they were not replicated

Period	P1		P2		P3	
	n	ADG	*n*	ADG	*n*	ADG
		A94 cohort				
Late winter (1 Aug.–15 Sept. 1994)	84	0.60	85	0.64	84	0.96
Early spring (16 Sept.–31 Oct. 1994)	49[A]	0.48	50	0.70	51	0.95
Late spring (1 Nov.–31 Dec. 1994)	49	0.71	50	0.86	51	0.74
		T94 cohort				
Late winter (1 Aug.–15 Sept. 1994)	50	0.54	48	0.44	49	0.74
Early spring (16 Sept.–31 Oct. 1994)	50	0.41	48	0.80	49	0.94
Late spring (1 Nov.–31 Dec. 1994)	50	0.84	48	0.85	49	0.92
Summer (1 Jan.–15 Mar. 1995)	33[A]	0.83	31	0.55	33	0.53
		A95 cohort				
Early winter (16 June–31 July 1995)	171	–0.21	173	–0.01	170	0.80
Late winter (1 Aug.–15 Sept. 1995)	171	–0.08	173	0.48	170	0.14[B]
Early spring (16 Sept.–31 Oct. 1995)	171	1.05	173	1.28	170	1.03
Late spring (1 Nov.–31 Dec. 1995)	116[A]	0.97	115	0.80	115	0.76
Summer (1 Jan.–5 Feb. 1996)	116	0.47	115	0.39	115	0.77
		A96 cohort				
Late winter (1 Aug.–15 Sept. 1996)	143	0.48	144	0.53	142	0.37
Early spring (16 Sept.–31 Oct. 1996)	95[A]	0.63	99	0.98	93	1.31
Late spring (1 Nov.–29 Nov. 1996)	95	0.96	99	0.87	93	1.35

[A]Numbers reduce in each cohort and pasture system as domestic market steers were transferred to finishing phase.
[B]Low ADG corresponds with very low herbage mass (Ayres *et al.* 2001).

summer weaners at the target weight for commencing finishing for the export market, are shown in Tables 6 and 7. For autumn weaners, feeder steers destined for finishing for the export market were generally fatter than domestic feeders. There was a trend for both domestic and export feeders from P3 to be fatter than those from P2 which were fatter than those from P1. Apart from A94 and T94, where herd of origin had the greatest influence, pasture system (P1, P2 or P3) was the greatest single source of variation in P8 rump fat thickness data. Herd of origin was generally the second most important factor, followed by sire or breed (Robinson *et al.* 2001).

Discussion

The data obtained in this study were derived from a farm-scale experiment with large numbers of yearling cattle of diverse origin grazing temperate perennial pastures. The pasture was comprehensively characterised in terms of botanical composition, herbage mass and nutritive value. The northern New South Wales feed year for this pasture type grazed by yearling cattle was shown by Ayres *et al.* (2001) to comprise 3 distinct phases: (i) winter dormancy, characterised by low availability of green herbage mass (750–1500 kg DM/ha except in drought years when green herbage mass was <500 kg DM/ha) but with high digestibility (0.75–0.80) and

Table 5. Predicted seasonal liveweight gain (kg/head.day) and number of steers (*n*) for each cohort of summer weaners grazing P1, P2 or P3 pastures without supplementary feeding

ADG, average daily liveweight gain
Statistical comparisons of ADG between pasture systems were not made because they were not replicated

Period	P1		P2		P3	
	n	ADG	*n*	ADG	*n*	ADG
		S95 cohort				
Autumn (16 Mar.–15 June 1995)	92	0.29	89	0.24	92	0.41
		S96 cohort				
Autumn (16 Mar.–15 June 1996)	115	0.86	114	0.53	118	0.63

Table 6. Mean subcutaneous fat thickness over the P8 rump site (mm) for each cohort of autumn weaners at domestic and export feedlot entry specifications and grazing P1, P2 or P3 pastures

Statistical comparisons of fat thickness between pasture systems were not made because they were not replicated

Cohort	P1	P2	P3
	Domestic feedlot entry		
A94	3.11	3.64	4.28
T94	3.45	4.07	3.91
A95	1.95	3.13	3.45
A96	1.85	2.58	3.27
	Export feedlot entry		
A94	6.20	7.31	7.96
T94[A]	—	—	—
A95	4.01	5.06	5.73
A96	6.00	6.50	9.28

[A]Fat thickness not measured.

high N content (20–30 g N/kg DM); (ii) spring primary growth, with high availability of green herbage mass (2500–4500 kg DM/ha) of very high digestibility (0.80–0.85) and very high N content (about 30 g N/kg DM); and (iii) summer–autumn regrowth, where there is a high availability of green herbage mass (2500–4000 kg DM/ha) but with only moderate nutritive value (0.65–0.70 digestibility, 15–20 g N/kg DM). These data are compatible with knowledge of the growth cycle of introduced pasture in this environment (Cotsell 1958; Begg 1959), and build on data for introduced pasture grazed by sheep (McPhee *et al.* 1997).

In the present study, the seasonal pattern of liveweight change for yearling cattle, without supplementary feeding and stocked at a commercially relevant rate (about 15 dry sheep equivalents/ha) showed a close correspondence with the changing pasture conditions (Ayres *et al*. 2001) and the seasonal pattern of liveweight change for wether sheep (Ayres *et al*. 1999). In winter, liveweight gain was generally low, about 0.5 kg/head.day, although liveweight loss occurred under severe drought conditions in 1995. In spring, liveweight gain was high, typically about 0.8 kg/head.day. In summer it was highly variable and ranged from 0.5 to 0.8 kg/head.day.

Table 7. Mean subcutaneous fat thickness over the P8 rump site (mm) for each cohort of summer weaners at export feedlot entry specifications and grazing P1, P2 or P3 pastures

Statistical comparisons of fat thickness between pasture systems were not be made because they were not replicated

Cohort	P1	P2	P3
S95	2.87	2.89	3.31
S96	5.23	3.92	4.18

It has traditionally been accepted that the primary nutritional limitation for the growth of yearling cattle in winter–early spring in this environment is lack of digestible energy. Accordingly, a wide range of energy-based supplements (forage oats, cereal grain, pasture hay, pasture silage) and management strategies (stocking rate, forage rationing, grazing management to reduce internal parasites) were investigated in a series of experiments between 1962 and 1978 by Hennessy and Robinson (1975, 1978) and Robinson and Hennessy (1978, 1981). Their results showed that without supplementary feeding in winter, introduced pastures can support 1.2 cows/ha provided that calves are weaned and turned off before winter. Weaners grazing introduced pasture even at a relatively low stocking rate were found to make poor growth through winter–early spring. Sustained growth through winter was achieved only with grazing management that maintained a high quality green pasture or with supplementary feeding of grain and/or forage oats. Their conclusions were that: (i) introduced pasture alone could not sustain growth of yearling cattle through winter–early spring even at a relatively low stocking rate, (ii) forage oats was an unreliable source of high quality feed, (iii) supplementary feeding with high quantities of oats grain consistently increased liveweight, (iv) a target liveweight of 270 kg was achieved only with the feeding of forage oats and oats grain together, and (v) there was a need for research placing greater emphasis on feed quality limitations. It was contended that legumes, either in the form of legume-based pasture or legume forage crops, could provide the best means of averting the winter feed gap in a sustainable way (G. G. Robinson pers. comm.).

Among the requirements for a soundly based supplementary feeding strategy are the determinations of whether the diet of grazing animals is sufficient in quantity and quality, and whether a deficiency is one of energy, N, or some other constituent (Wheeler 1981). In our study, alternative supplementary feeds (formulated pellets fed at a restricted level of intake, N-fertilised forage crop grazed *ad libitum*) were provided to respective pasture systems (P2, P3) in late winter–early spring to overcome the winter feed gap in each of 3 successive years. Pasture conditions (green herbage mass, and digestibility and N content of green herbage mass) were similar in all pasture systems (Ayres *et al*. 2001). These supplementary feeding strategies clearly placed P2 and P3 steers on different growth paths to that of steers on P1 (Fig. 1).

Predicted seasonal liveweight gain for autumn weaners (Table 4) shows that growth on P1 was generally much lower in winter–early spring than in late spring. In 1994 liveweight gain increased from 0.51 kg/head.day in late winter–early spring to 0.78 kg/head.day in late spring. Equivalent increases for 1995 and 1996 were from –0.15 to 1.05 kg/head.day and from 0.56 to 0.96 kg/head.day, respectively. Growth on P2 was high in early spring. In 1994 liveweight gain increased from 0.54 kg/head.day in late winter to 0.75 in early spring. Equivalent increases for 1995 and 1996 were from 0.24 to 1.28 kg/head.day and from 0.53 to 0.98 kg/head.day, respectively. Growth on P3 was generally high in both winter and spring. Liveweight gains for this period were 0.88, 0.68 and 1.01 kg/head.day in 1994, 1995 and 1996, respectively. The period of low growth on P1 corresponds with the winter feed gap in which there was a decline in total herbage mass from 4000 to 750 kg DM/ha (Ayres *et al*. 2001).

Seasonal liveweight gain in summer and autumn (Tables 4 and 5) was generally less than in spring, even though green herbage mass in summer and autumn was high. For example, growth of steers on P2 declined from 0.85 to 0.55 kg/head.day and growth of steers on P3 declined from 0.92 to 0.53 kg/head.day in the period from late spring 1994 to summer 1995. This was despite a green herbage mass of more than 3000 kg DM/ha (Ayres *et al*. 2001). Similarly, in the period from late spring 1995 to summer 1996, growth of steers on P1 declined from 0.97 to 0.47 kg/head.day, and growth of steers on P2 declined from 0.80 to 0.39 kg/head.day, despite a green herbage mass of more than 2000 kg DM/ha. This decline in liveweight gain on P1 and P2 corresponds with a summer feed gap in which there is a decrease in *in vitro* digestibility of green herbage mass from 0.80–0.85 to 0.65–0.70, and in N content of green herbage mass from 30 to 15–20 g N/kg DM (Ayres *et al*. 2001).

In a preliminary consideration of the Northern Tablelands feed year, Dicker *et al*. (1998) hypothesised that the decline in pasture quality that accompanies onset of phenological maturity in late spring and continues through summer–autumn would be unlikely to sustain high levels of cattle production without supplementary feeding. The present data supports this hypothesis. Avoidance of dietary insufficiency rests on the ability of cattle to preferentially graze legume or green components of the pasture. This may be possible in a mild and moist summer–autumn where green herbage mass remains high, but it is unlikely where moisture stress in summer promotes leaf senescence.

Seasonal influences have been shown to impose limits on the pasture environment for achieving feedlot entry specifications (Fig. 1). *Bos taurus* autumn weaners from northern summer rainfall environments, that commenced backgrounding on pasture from early winter, grew to domestic feeder steer liveweight in 6–8 weeks by the end of winter, and to export feeder steer liveweight in 17–27 weeks by the end of summer. Under less favourable conditions (1995) however, these grow-out periods were extended to 16 and 32 weeks for domestic and export feeder steers, respectively. In contrast, *B. taurus* × *B. indicus*-derived autumn weaners from northern subtropical environments were not available to commence backgrounding until late winter, and periods for them to reach feedlot entry liveweight were 19 and 33 weeks for domestic and export feeder steers, respectively. *Bos taurus* summer weaners from southern winter rainfall environments that commenced backgrounding from mid-summer already met domestic feedlot entry liveweight but failed to grow out to export feedlot entry liveweight before winter conditions imposed liveweight stasis.

In conclusion, for the Northern Tablelands pasture environment which is characterised by 2 discrete feed gaps (low green herbage mass in late winter–early spring, and only moderate pasture quality in summer–autumn), the most effective backgrounding system for both domestic and export market feedlot entry specifications was based on *B. taurus* autumn weaners from northern temperate summer rainfall locations. For these cattle, grown out without supplementary feeding and in non-drought years, liveweight gain was 0.54 kg/head.day through winter, and 0.76 kg/head.day through spring. These gains resulted in the achievement of feedlot entry specifications for domestic feeder steers by the end of winter, and for export feeder steers by the end of summer. Supplementary feeding in winter–early spring was necessary to overcome the limitations of the winter feed gap and reduce the period to feedlot entry for export feeder steers. For the backgrounding of *B. taurus* summer weaners from southern winter-rainfall locations, there remains the need to investigate the nutritional limitations of summer–autumn secondary regrowth pasture and to develop supplementary feeding strategies to achieve feedlot entry specifications for export feeder steers before the onset of winter.

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