CSIRO PUBLISHING
www.publish.csiro.au/journals/an
Animal Production Science, 2009, **49**, 177–191

A systems evaluation of high-input management using fortified molasses for beef production in Australia's dry tropics

Geoffry Fordyce[A,I], *Ruth Coates*[B], *Megan Debney*[C], *Stan Haselton*[D], *Robert Rebgetz*[E], *Alan R. Laing*[F], *Neil J. Cooper*[B], *Rebecca Hall*[B], *William E. Holmes*[G] and *Vivienne J. Doogan*[H]

[A]Department of Primary Industries and Fisheries, PO Box 976, Charters Towers, Qld 4820, Australia.
[B]Department of Primary Industries and Fisheries, Swan's Lagoon, MS 54, Ayr, Qld 4807, Australia.
[C]Department of Primary Industries and Fisheries, PO Box 1333, Mt Isa, Qld 4825, Australia.
[D]34623 Bruce Highway, Giru, Qld 4809, Australia.
[E]Thalanga Station, Balfes Creek, Qld 4820, Australia.
[F]Department of Primary Industries and Fisheries, PO Box 591, Ayr, Qld 4807, Australia.
[G]Department of Primary Industries and Fisheries, PO Box 1085, Townsville, Qld 4810, Australia.
[H]Department of Primary Industries and Fisheries, Locked Bag 4, Moorooka, Qld 4105, Australia.
[I]Corresponding author. Email: geoffry.fordyce@dpi.qld.gov.au

Abstract. The potential of beef producers to profitably produce 500-kg steers at 2.5 years of age in northern Australia's dry tropics to meet specifications of high-value markets, using a high-input management (HIM) system was examined. HIM included targeted high levels of fortified molasses supplementation, short seasonal mating and the use of growth promotants. Using herds of 300–400 females plus steer progeny at three sites, HIM was compared at a business level to prevailing best-practice, strategic low-input management (SLIM) in which there is a relatively low usage of energy concentrates to supplement pasture intake.

The data presented for each breeding-age cohort within management system at each site includes: annual pregnancy rates (range: 14–99%), time of conception, mortalities (range: 0–10%), progeny losses between confirmed pregnancy and weaning (range: 0–29%), and weaning rates (range: 14–92%) over the 2-year observation. Annual changes in weight and relative net worth were calculated for all breeding and non-breeding cohorts. Reasons for outcomes are discussed.

Compared with SLIM herds, both weaning weights and annual growth were ≥30 kg higher, enabling 86–100% of HIM steers to exceed 500 kg at 2.5 years of age. Very few contemporary SLIM steers reached this target. HIM was most profitably applied to steers. Where HIM was able to achieve high pregnancy rates in yearlings, its application was recommended in females. Well managed, appropriate HIM systems increased profits by around $15/adult equivalent at prevailing beef and supplement prices. However, a 20% supplement price rise without a commensurate increase in values for young slaughter steers would generally eliminate this advantage.

This study demonstrated the complexity of profitable application of research outcomes to commercial business, even when component research suggests that specific strategies may increase growth and reproductive efficiency and/or be more profitable. Because of the higher level of management required, higher costs and returns, and higher susceptibility to market changes and disease, HIM systems should only be applied after SLIM systems are well developed. To increase profitability, any strategy must ultimately either increase steer growth and sale values and/or enable a shift to high pregnancy rates in yearling heifers.

Introduction

Concurrent with the development of infrastructure over the past 30 years, the northern Australian beef industry has developed strategic low-input management (SLIM) systems that have substantially improved beef production efficiency. However, weaning rates and weaner weights remain relatively low and variable in many situations, as a function of low and variable rainfall (Bortolussi *et al*. 2005*a*, 2005*b*). Slaughter-weight steer sale ages are high for the same reason (Bortolussi *et al.* 2005*b*). To achieve steer slaughter weights by 2.5 years of age and meet high-value market specifications requires three primary strategies:

(1) Productive genotype. Breeding objectives should include growth.
(2) Reproductive management enabling concentrated early conceptions and heavy calves at the first weaning.
(3) Pasture management and supplementation to achieve high growth rates.

 10.1071/EA07225 1836-0939/09/030177

Many component studies have been conducted on the effects of energy supplementation and growth promotants on growth and fertility of animals in the seasonally dry tropics (e.g. Fordyce *et al.* 1988, 1996*a*, 1996*b*, 1997; Lindsay *et al.* 1996; Hunter *et al.* 2000). Desktop systems studies suggested that in Queensland, where annual molasses production is ~0.5 million t, there was an opportunity to further increase the efficiency of grazing beef production. Emerging market needs could be met by high-input management (HIM) systems for most breeding-age and immature females and for steer progeny.

HIM systems would be expected to consistently achieve steer liveweights of 500 kg by 2.5 years of age when fewer than 25% of steers have more than two permanent incisors, thereby increasing cash surplus, reducing risk, and potentially improving time efficiency (lifestyle). A demonstrated increase in cash surplus and a reduction in risk would facilitate adoption of alternative management systems by the grazing industry. In this paper, production and financial benefits were evaluated and compared for SLIM and HIM systems in regions of low animal growth. HIM systems utilised a high level of fortified molasses, whereas SLIM systems relied mostly on dry lick supplements.

Methods

Site description

Three north-eastern Queensland sites (Table 1) were used. All properties were in the seasonally dry tropics. During the study, 70–90% of total rainfall occurred during the wet season, which peaks between January and March. At Charters Towers, which is central to the sites, average minimum and maximum temperatures are 20 and 33°C for September to April, and 13 and 26°C from May to August, respectively.

Animals and management

Five breeding herds were established (Table 1) each comprising ~300–400 females plus their steer progeny. Animals were allocated to these herds on the basis of age and stage of pregnancy to represent expected status in an ongoing system. Prior mating management and fortified molasses supplementation facilitated establishment of the study in the face of extremely poor seasonal conditions (late 2003 and early 2004). All herds and age groups within herds were segregated except the Thalanga SLIM herd, which comprised individually identified animals (about one-third) within much larger groups of females.

SLIM mating lasted 5–7 months from mid-to-late January (Table 2). HIM mating lasted 3 months from mid-to-late December. First mating of SLIM heifers was at 2 years of age, and first mating of HIM heifers was at 1 year of age. All HIM calves were weaned from April to May. SLIM calves >100 kg at this time were weaned, with the balance weaned from August to September. Cattle moved to their next age management group from April to May. Females joined the cow herds after weaning their first calf. Sufficient heifers to achieve replacement breeder needs were selected, primarily on high postweaning growth,

Table 1. Herds established and description of study sites

HIM, high-input management system; SLIM, strategic low-input management system

	Thalanga	Swan's Lagoon	St Margaret's Creek
Location	145.8°E, 20.3°S	147.2°E, 20.2°S	147.1°E, 19.4°S
Soils	Yellow earths that are mostly acutely phosphorus deficient	Duplex soils that are mostly phosphorus deficient	Duplex soils that are mostly phosphorus deficient
Vegetation	Open eucalypt savannah woodland (ironbark and wattles mainly) with a native pasture predominated by Golden beard, wire and black spear grasses	Open eucalypt savannah woodland with a native pasture predominated by black spear, Indian couch, and Golden beard grasses	Mostly cleared with sown tropical pasture predominated by *Brachiaria* spp.
Cattle	Brahman cows with Brahman and Senepol × Red Angus bulls	Composite, primarily of Brahman and Shorthorn (objective selection for growth, fertility, temperament, adaptation, conformation and milk yield)	Brahman
Herd	HIM and SLIM herds	HIM and SLIM herds	HIM herd

Table 2. Basic management and supplements for cattle in the study

Cattle were fed fortified molasses in shaded periods; outside these periods they received loose dry licks formulated for either wet or dry seasons. HIM, high-input management system; SLIM, strategic low-input management system; S, start mating; E, end mating; W, wean calves

		Dry season May	June	July	Aug.	Sept.	Oct.	Nov.	Wet season Dec.	Jan.	Feb.	Mar.	Apr.
HIM	Female: >1 year	W							S			E	
	Female: <1 year; steers												
SLIM	Female: >2 years	W >100 kg			E, W					S			
	Female: <2 years and >150 kg												
	Female: <2 years and <150 kg												

ability to hold body condition in the dry season and good temperament. Non-pregnant cows and cows with defects were culled each year. The oldest cows were culled to match herd size to available pasture as determined by available photo standards and feed budgeting (Aisthorpe *et al*. 2004). If numbers were still insufficient, non-pregnant first-lactation cows were retained.

At Swan's Lagoon and Thalanga, weaner steers were selected from those available in the 2004 and 2005 cohorts (year of weaning) by stratified randomisation on liveweight and allocated to three growth pathways:

(i) SLIM: weaned from the SLIM herd, postweaning SLIM management; $n = 30$.
(ii) SLIM-HIM: weaned from the SLIM herd, postweaning HIM management; $n = 40$.
(iii) HIM: weaned from the HIM herd, postweaning HIM management; $n = 40$.

All SLIM-HIM and HIM steers were managed together. The St Margaret's Creek HIM steers were managed as one group. All steers received a 6-monthly Compudose 200 implant (Elanco Animal Health, Macquarie Park, NSW), or an annual Compudose 400 implant, which commenced at weaning.

Pasture management as recommended by GLM Edge (Chilcott *et al*. 2005) was implemented. All of the cattle grazed paddocks that were part of programs to achieve either short (~2 months) annual wet season spelling or full wet season spelling (each ~3 years). Short spelling allowed pastures to seed before grazing recommenced. The typical stocking rate at Swan's Lagoon and Thalanga was 5 and 6 ha/adult equivalent (AE), respectively. Stocking rate averaged 1 AE/3 ha on the tropical sown pastures at St Margaret's Creek.

Molasses with 8% urea (M8U) and molasses with added protein meal and urea (MUP) were the primary fortified molasses mixes fed (Table 3) and these were usually available *ad libitum.* MUP was fed to all HIM and SLIM-HIM weaners and steers for the dry season (Table 2). At St Margaret's Creek, MUP was continually available to HIM steers. MUP was fed to SLIM weaners until they reached 150 kg. All HIM females over 18 months were fed M8U from August until the onset of the wet season. For short periods at various times, the level of urea and protein meal in molasses mixes was varied to meet intake objectives, which were 0.5 and 1.0% of liveweight daily for M8U and MUP, respectively.

When not fed fortified molasses, all HIM and SLIM cattle were offered dry licks *ad libitum*, with different formulations for the wet and dry seasons (Table 3).

Measurements and analyses

All female cattle were mustered between April and May for weaning when their weight, body condition (5-point scale; Graham 2003) and lactation status were measured and stage of pregnancy estimated by rectal palpation. All measurements were repeated at the second weaning muster. Mating outcomes were determined by transforming this data into estimated date of conception (from fetal ageing), success/failure to wean a calf and date of weaning. Unmated juvenile females were also assessed at the end of the dry season. The 2004 and 2005 steer cohorts were assessed approximately every 2 months until they reached 2.5 and 1.5 years of age, respectively.

An AE value was calculated for each animal in each year as the average AE at the April–May muster in consecutive years. Using current regional standards (Meat and Livestock Australia 2003), AE was calculated for non-breeding animals as liveweight corrected for pregnancy divided by 454; for cows rearing a calf, a value of 0.3 was added.

Average daily intakes of supplements were calculated for animals in each management group. Costs of supplements, which included associated capital costs, were calculated to represent an average over the functional life of the infrastructure, rather than the development costs involved in starting a supplementation program. Supplementation costs included:

(i) Supplements including freight and handling to the property.
(ii) Storage and mixing costs. This included the cost of purchasing and maintaining sheds and molasses mixers. Usual practices and amounts stored for 6–24 months were included.
(iii) Feeding costs, including troughs and purchase and maintenance of vehicles and equipment for distribution, were calculated. Distances and times for feeding each group were included.
(iv) Labour was costed at $20/h.

The key differences between the HIM and SLIM systems are cost of supplementation, cattle handling costs, cattle sales and asset values. These were included in calculations of gross margins

Table 3. Constituents of dry lick and fortified molasses supplements used in the study
MUP, molasses with added protein meal and urea; M8U, molasses with 8% urea

	Dry licks			Fortified molasses	
Ingredient (kg)	Dry season	Wet season	Ingredient (kg)	MUP	M8U
Urea	30%	21%	Molasses[A]	1000	1000
Ammonium sulfate	6%	4%	Urea	30	80
Calcium phosphate	12%	75%	Protein meal[B]	100	–
Protein meal[B]	5%	–	Di-calcium phosphate	10	10
Salt	47%	–	Flossy fine salt	10	10
			Rumensin 100[C]	0.5	0.5

[A]Comprising ~75% dry matter (DM) and ~10.5 MJ of metabolisable energy (ME)/kg of DM (Bortolussi and O'Neill 2006).
[B]Comprising ~90% DM; ~12.5 MJ of ME/kg DM; either palm kernel extract (15–20% crude protein) or copra meal (20–25% crude protein).
[C]The active ingredient is monensin at 100 g/kg, Elanco Animal Health, Macquarie Park, News South Wales, Australia.

(GM) for each age group within each herd. Other than for St Margaret's Creek steers, which were sold at 2 years of age, no price premiums were included in these analyses. After consultation with the cattle owners and managers, it was determined that weaning management costs per weaner were consistent between HIM and SLIM systems. The primary comparison between systems was made on an AE basis.

Mustering costs, which included helicopter hire ($300/h), station labour (on a contract basis, which included horses and associated equipment), motorbikes and vehicles, were calculated to be ~$5/animal per muster. For commercial (non-study) situations, it was considered that SLIM cattle <18 months and SLIM breeding cattle were mustered twice annually, and all other cattle mustered once each year.

The net value (value minus potential selling costs) of each animal in the study was determined in April–May of each year using the following strategy:

(1) Weight of pregnant cows was corrected for the products of conception using the method of O'Rourke *et al*. (1991).
(2) Market values were calculated on value per kg of liveweight. Base value was $1.71/kg liveweight, which was a typical average value over the study period for condition score 4 steers at the Charters Towers saleyards. Values were adjusted for: (*a*) body condition: add [(condition score –4) × $0.10] per kg; and (*b*) class: heifers less $0.10 and cows less $0.25/kg in comparison to steers.
(3) The value of a weaned calf (average of male + female) was added to the cow's value after calculation from estimates of calf age (using estimated conception date plus average gestation length) and average preweaning growth rates of 0.9 kg/day.
(4) If a cow weaned a calf in August–September in the previous year, its value included the increase in value of the previous year's calf between April and May and August and September using a growth rate of 0.5 kg/day at Thalanga and 0.65 kg/day at Swan's Lagoon.
(5) Selling costs included a 5% commission and transport costs ($1.50/deck.km). The proportion of the deck taken by each animal was calculated as: $1/(48 - 0.047 \times \text{weight})$. The distance to sale for Thalanga, Swan's Lagoon and St Margaret's Creek was 60, 200 and 150 km, respectively.

The 2004 steer cohort at St Margaret's Creek was slaughtered within the trial period. Actual values less transport costs were analysed in comparison to costs calculated as above.

Economic analyses of whole herd performance were conducted using the Breedcow Plus component of BREEDCOW (Holmes 2006). Whole herd representations were developed using branding and death rates, growth rates (as expressed in sale weights and AE ratings), breeding female selection decisions, sales decisions and variable costs. Comparisons between strategies within herds were made by calculating GM per AE. Input data were derived from herds in the study, with interpolation required for assessing the expected average for a range of years based on data for 2 years. Some interpolation was also required for assessing alternate strategies.

Management across sites was generally consistent. One variation in the strategies analysed was that yearling heifers were not mated: at any time at Thalanga; in the SLIM system at Swan's Lagoon; and for the alternate strategy of SLIM systems to 2.5 years for HIM heifer progeny. Yearlings were otherwise mated.

Selling strategies used in economic analyses were based as closely as possible to normal industry practice:

(1) Thalanga analyses had HIM steer sales at 2.5 years and SLIM steers 2 months later; cows losing calves sold in May each year; and cows culled for non-pregnancy and other reasons sold 10 months after removal from the breeding herd when they reach fat-cow values. Surplus heifers were sold in August after first mating.
(2) Swan's Lagoon analyses had steer sales 2 months after reaching 2.5 years (July), and all surplus heifers sold in May at 2.5 years of age when all surplus cows were also sold.
(3) St Margaret's Creek analyses had steer sales 7 months after reaching 1.5 years of age (November), cows that lost their calves sold in April each year, cows culled for non-pregnancy and other reasons sold 4 months after pregnancy diagnoses at fat-cow values. Surplus heifers were sold in July after reaching 2.5 years of age.

Alternate strategies for HIM and SLIM herd progeny were with and without HIM systems for heifers and for yearling steers. Prices used in all analyses were as for comparative accounting analyses, except for premiums of $0.10 and $0.20/kg of liveweight for 2.5-year-old steers ex. HIM management in their first and second years postweaning, respectively. These premiums were typical of those reported in similar cattle in local live and slaughter market reports during the study period.

Sensitivity analyses were conducted by varying the price of 2.5-year-old steers, and incrementing supplement costs for all animals by the levels indicated in the analyses.

The differences in operational time involved with both systems were calculated as for business comparisons, i.e. aspects where differences occurred. However, this occurred only for supplementation and mustering of cows.

Results

Seasons

The study commenced with the late arrival of wet season rain after 3 years of below-average rainfall. Wet season rainfall over the study period (Table 4) continued to be below average and the onset of the wet season was 1–2 months later than average in 2004–05, with relief from this in 2005–06 at Thalanga only.

Cattle selected and survival

Herd structure was stable over the 2-year study period. HIM herds comprised 266–326 females after culling each year; SLIM herds comprised 365–383 females. Mortality rates in all classes of cattle were generally <1% except for: 4–7% in breeding cows at Thalanga and 3–6% in Swan's Lagoon HIM cows in 2004–05; and 10% of first-pregnancy HIM heifers at both Swan's Lagoon and Thalanga in 2005–06 (Table 5).

Young HIM cattle had a higher AE value than SLIM cattle of a similar age, but at maturity HIM and SLIM cattle had similar AE values (Table 6).

Table 4. Average and seasonal rainfall summary for each study site

	Thalanga	Swan's Lagoon	St Margaret's Creek
	Long-term average rainfall and timing of wet season		
Total rainfall (mm)	672 (107 years)	839 (40 years)	1500 (estimate)
Wet season onset[A]	Early December	18 November	November (estimate)
Wet season[B] (mm)	589	744	1300 (estimate)
	Rainfall and timing of wet season for 2004–05		
Total rainfall (mm)	566	575	1222
Wet season onset	08 December 2004	09 January 2005	10 December 2004
Wet season (mm)	526	439	1089
	Rainfall and timing of wet season for 2005–06		
Total rainfall (mm)	742	732	1595
Wet season onset	03 December 2005	09 January 2006	09 January 2006
Wet season (mm)	627	530	1390

[A]The start of the growing season – usually denoted by at least 50 mm of rainfall, with a further 50 mm within 1 month.
[B]Wet season onset to May inclusive.

Supplementation

During dry seasons, average daily MUP intake was close to 1% of bodyweight. When provided *ad libitum*, average daily M8U intake was 0.5% of bodyweight (Table 7). Feeding of M8U to cows occurred over a much longer period at Swan's Lagoon than at Thalanga. At both sites, intakes were relatively low, especially at Swan's Lagoon during the severe dry season of 2005. Low intakes during feeding at Thalanga may have been related to early rain. At Swan's Lagoon, insufficient M8U was provided to achieve *ad libitum* intakes.

In the SLIM herd at Swan's Lagoon, fortified molasses was only fed to weaners. At both Swan's Lagoon and Thalanga, very poor seasonal conditions in late 2004 resulted in all SLIM weaners being fed fortified molasses (Table 7). Yearling and 2-year-old SLIM heifers were fed M8U in the late dry seasons at Thalanga as part of usual SLIM systems (to reach fertility targets), and were fed for a longer period in 2004 because of the poor seasonal conditions (Table 7).

MUP was offered to yearling steers at St Margaret's Creek in the wet season where intake between the wet season onset and

Table 5. Mating outcomes: pregnancies, reproductive wastage and calves weaned for each female class at each site in each year
HIM, high-input management system; SLIM, strategic low-input management system

Herd	Mating class	Mating 2003–04 for 2005 calves			Mating 2004–05 for 2006 calves					Mating 2005–06 for 2007 calves	
		Allocated[A]	Calf loss[B]	Cow death	Mated	Pregnant	Calf loss[B]	Cow death	Weaned	Mated	Pregnant
					Thalanga site						
HIM	Cow	88	6%	6%	83	99%	6%	0%	92%	108	74%
HIM	First lactation				57	82%	2%	0%	74%	44	61%
HIM	2 years maiden	61	7%	7%	50	94%	6%	10%	84%	72	89%
HIM	1 year maiden				73	16%	17%	1%	14%	63	38%
SLIM	Cow	167	10%	4%	151	57%	12%	0%	50%	118	70%
SLIM	First lactation				43	86%	5%	0%	81%	47	96%
SLIM	2 years maiden	50	14%	4%	60	78%	9%	0%	72%	101	71%
					Swan's Lagoon site						
HIM	Cows	126	9%	3%	156	81%	10%	0%	72%	166	92%
HIM	2 years	36	11%	6%	36	64%	0%	0%	64%	37	89%
HIM	1 year	38	29%	5%	73	56%	24%	10%	42%	74	69%
SLIM	Cows	117	8%	0%	163	87%	7%	0%	78%	162	59%
SLIM	3 years	46	7%	0%	54	98%	9%	2%	90%	53	72%
SLIM	2 years	55	9%	2%	58	97%	7%	0%	89%	60	88%
					St Margaret's Creek site						
HIM	4–14 years	60	12%	0%	93	89%	5%	0%	84%	107	89%
HIM	3 years	33	3%	0%	34	88%	0%	0%	88%	48	90%
HIM	2 years	34	9%	0%	54	91%	8%	0%	83%	83	73%
HIM	1 year	52	15%	0%	85	18%[C]	8%	1%	14%	84	79%

[A]Pregnant. [B]Pregnancy to weaning.
[C]Group was 69% postpubertal at end of mating; infertile bull used; pregnancies at end of mating by 'trespassing' bull.

Table 6. Average 'adult equivalent' per gender, herd and year group at each site
HIM, high-input management system; SLIM, strategic low-input management system

	2004–05			2005–06		
	Thalanga	Swan's Lagoon	St Margaret's Creek	Thalanga	Swan's Lagoon	St Margaret's Creek
HIM females[A]						
1997–2001	1.21	1.28	1.30	1.27	1.28	1.33
2002	1.07	1.06	1.17	1.16	1.02	1.24
2003	0.69	0.93	1.07	1.15	1.06	1.19
2004	0.45	0.52	0.57	0.80	1.07	0.89
2005	–	–	–	0.53	0.57	0.56
SLIM females[A]						
1997–2001	1.20	1.31	–	1.29	1.33	–
2002	1.06	1.13	–	1.15	1.21	–
2003	0.60	0.73	–	1.03	1.17	–
2004	0.35	0.41	–	0.61	0.72	–
2005	–	–	–	0.49	0.46	–
2004 steers						
HIM	0.55	0.59	0.75	0.96	1.00	0.47
SLIM-HIM	0.44	0.46	–	0.82	0.88	–
SLIM	0.39	0.43	–	0.73	0.78	–
2005 steers						
HIM	–	–	–	0.60	0.63	0.72
SLIM-HIM	–	–	–	0.48	0.55	–
SLIM	–	–	–	0.44	0.51	–

[A]Values include suckling calves.

April averaged 1.3 kg/day (Table 7). From May to October, MUP intake averaged 2.8 kg/day, compared with at least 4 kg/day recorded at Swan's Lagoon and Thalanga.

Target dry licks intakes of ~1 kg/week in the dry season and ~0.35 kg/week in the wet season were achieved.

The full cost of M8U as fed was \$0.17/kg at Thalanga, \$0.14/kg at Swan's Lagoon and \$0.12/kg at St Margaret's Creek. MUP costs were \$0.01/kg higher. M8U and MUP costs were primarily affected by molasses costs which varied with distance from a sugar mill. Molasses cost ~\$100, \$80 and \$65/t landed at Thalanga, Swan's Lagoon and St Margaret's Creek, respectively. The monthly costs per animal of dry season and wet season dry lick supplements were \$2.25 and \$0.75 at Thalanga, \$2.80 and \$0.85 at Swan's Lagoon, and \$4.60 and \$1.30 at St Margaret's Creek, respectively. Labour at \$20/h constituted an average of 4–5% of the total cost of feeding either fortified molasses or dry licks.

Fertility

Thalanga

Pregnancy rates in maiden 2-year-old heifers were 16–18% lower in the SLIM herd than in the HIM herd (Table 5). There was no evidence of dystocia in the small number within the 2004 HIM heifer cohort that conceived as yearlings.

The Thalanga HIM herd average calving date was 1.3 months earlier (mid November *v.* late December), and the calving period reduced from 6 to 4 months for 95% of calves in comparison to the SLIM herd.

Swan's Lagoon

Previous observations suggested that SLIM cows grazed a paddock with generally better nutrition than the HIM cows; e.g. average soil phosphorus levels were estimated at 6.5 and 5.2 mg/kg, respectively. Following restricted supplementation with M8U in 2004, HIM cows were in poorer body condition and had lower pregnancy rates than SLIM cows in 2005 (Table 5). In 2006, HIM pregnancy rates were high, including those in lactating 2-year-old cows. SLIM pregnancy rates were lower in the first 3 months of mating (Table 5). Calf wastage was within the normal reported range (Holroyd 1987) for all groups except for heifers conceiving as yearlings where losses of 20–30% were recorded (Table 5). This included a 5–10% loss associated with cow deaths because of dystocia.

Average calving date was 1.6 and 1.1 months earlier in the HIM herd than the SLIM herd for the 2005 and 2006 calves, respectively. Average calving date was early November in the HIM herd and mid December in the SLIM herd. About 90% of calves were born over a 3-month period in the HIM herd in comparison to 5 months in the SLIM herd.

St Margaret's Creek

Pregnancy rate in lactating cows consistently exceeded 90%, with 90% of cows calving within a 3-month period (Table 5). Almost 80% of yearlings conceived in 2006. Single-sire mating to a bull, that was subsequently confirmed to be infertile, resulted in no pregnancies during mating of yearlings in 2005; however, a straying bull did impregnate 14% of these heifers at the end of mating. Calf wastage generally remained within reported normal range (Holroyd 1987), although it was slightly higher in first-lactation, 2-year-old cows bearing the 2005 calves (Table 5).

Table 7. Fortified molasses supplement intakes for each animal class at each site
HIM, high-input management system; SLIM, strategic low-input management system; MUP, molasses with added protein meal and urea; M8U, molasses with 8% urea

Class and site	Supplement	2004 dry season		2005 dry season	
		Days	Average intake (kg/day)	Days	Average intake (kg/day)
HIM: Thalanga[A]					
Weaners	MUP	227	1.6	207	1.6
Yearling heifers	M8U	80	1.9	88	1.8
Yearling heifers	MUP	–	–	119	4.0
Yearling steers	MUP	–	–	207	4.0
Cows	M8U	93	1.7	24	1.5
SLIM: Thalanga					
Big weaners	M8U	80	0.9	47	0.8
R1 small weaners[B]	MUP	227	1.2	207	1.6
R2 small weaners[B]	MUP	176	1.3	95	1.5
Yearling heifers	M8U	100	1.3	71	1.8
2-year-old heifers	M8U	80	1.5	40	1.4
HIM: Swan's Lagoon[A]					
Weaner steers	MUP	146	2.8	253	2.6
Weaner steers	M8U	85	2.7	–	–
Weaner heifers	MUP	220	1.8	253	1.7
Yearling heifers	M8U	55	2.4	64	2.2
Yearling heifers	MUP	90	3.3	84	1.9
Yearling steers	MUP	–	–	197	4.1
Cows	M8U	146	1.6	169	1.1
SLIM: Swan's Lagoon					
Big weaner steers	M8U	47	0.3	35	2.5
R1 small weaner steers	MUP	146	2.4	253	2.1
R2 small weaner steers	MUP	84	3.1	126	2.3
Small weaner heifers	MUP	142	1.6	35	0.5
HIM: St Margaret's Creek					
Weaner heifers	MUP	241	2.6	280	1.9
Weaner steers	MUP	241	2.4	280	1.8
Weaner steers (wet season)	MUP	135	1.2	80	1.8
Yearling heifers	M8U	107	3.1	–	–
Yearling heifers	MUP	–	–	117	2.3
Yearling steers	MUP	–	–	191	2.8
Cows	M8U	92	3.1	112	3.3

[A]Includes SLIM-HIM for weaners and steers.
[B]R1, April–May; R2, August–September.

Changes in weight and value

Thalanga

HIM weaners were ~30 kg heavier than SLIM weaners. In heifers, this advantage increased to ~70 kg at 18 months of age (average weight of 320 ± 44 kg), but declined to ~50 kg at 2.5 years (Table 8). Variation in weight of HIM heifers at 1.5 years was high (Fig. 1). Females generally remained in condition scores 3–4, except for SLIM heifers at the end of the dry season as yearlings and in their first pregnancy, when condition scores averaged 2–3.

In the year after weaning, HIM and SLIM-HIM steers gained 170–180 kg, which was 45–50 kg more than SLIM steers. In 2005–06, the 2004 cohort of SLIM steers gained 200 kg, as they grazed a paddock in which growth is usually highest for the station and experienced an early onset of the wet season. The growth of these SLIM steers matched that of contemporary HIM steers (Table 8). Overall, 86% of HIM, 34% of SLIM-HIM and 8% of SLIM steers reached 500 kg by 2.5 years of age. At this age, 18, 75 and 7% of steers had 0, 2 and 4 permanent incisors, respectively.

The GM/AE for breeding-age females within herd was generally higher in the HIM system than in the SLIM system (Table 8). Value increase of yearling heifers that did not conceive was less in the HIM than in the SLIM systems. This was also the obvious outcome in SLIM steers over 18 months of age with favourable pasture conditions enabling similar weight gain as heavily supplemented HIM steers. GM for first-lactation females tended to be lower than for other classes, mainly because of a shift from prime to average condition.

Swan's Lagoon

HIM weaners were 30 kg (or more) heavier than SLIM weaners. In heifers, this advantage increased to around 70 kg

Table 8. Liveweight change and relative change in net worth of each high-input management system (HIM) and strategic low-input management system (SLIM) age × gender group at Thalanga

Mustering costs for calculation of gross margins (GM) are given in the text

	Liveweight (kg)			2004–05				2005–06			
	May 2004	May 2005	May 2006	Value in	Supplement	Value add[A]	GM/AE[B]	Value in	Supplement	Value add[A]	GM/AE[B]
HIM females											
1994–2001	408	434	464	$535	$43	$331	$234	$589	$24	$306	$218
2002	362	359	422	$545	$44	$224	$163	$465	$23	$326	$257
2003	244	380	403	$331	$37	$247	$298	$578	$26	$242	$183
2004	138	280	405	$209	$69	$201	$279	$416	$117	$227	$131
2005	–	–	320	–	–	–	–	$245	$65	$227	$295
SLIM females											
1994–2001	410	434	471	$528	$21	$217	$154	$571	$19	$265	$183
2002	357	370	409	$541	$36	$241	$184	$471	$22	$249	$189
2003	214	333	353	$290	$32	$211	$280	$499	$26	$234	$192
2004	114	205	347	$173	$48	$105	$135	$282	$32	$244	$332
2005	–	–	252	–	–	–	–	$198	$27	$168	$266
2004 steers											
HIM	165	331	537	$265	$69	$248	$317	$521	$152	$341	$191
SLIM-HIM	129	269	471	$207	$62	$209	$320	$422	$152	$343	$227
SLIM	122	227	428	$196	$43	$136	$209	$336	$14	$339	$434
2005 steers											
HIM	–	179	357	–	–	–	–	$289	$66	$265	$324
SLIM-HIM	–	148	316	–	–	–	–	$237	$50	$260	$424
SLIM	–	149	279	–	–	–	–	$239	$38	$189	$316

[A]Value added for surviving cattle.
[B]GM per adult equivalent.

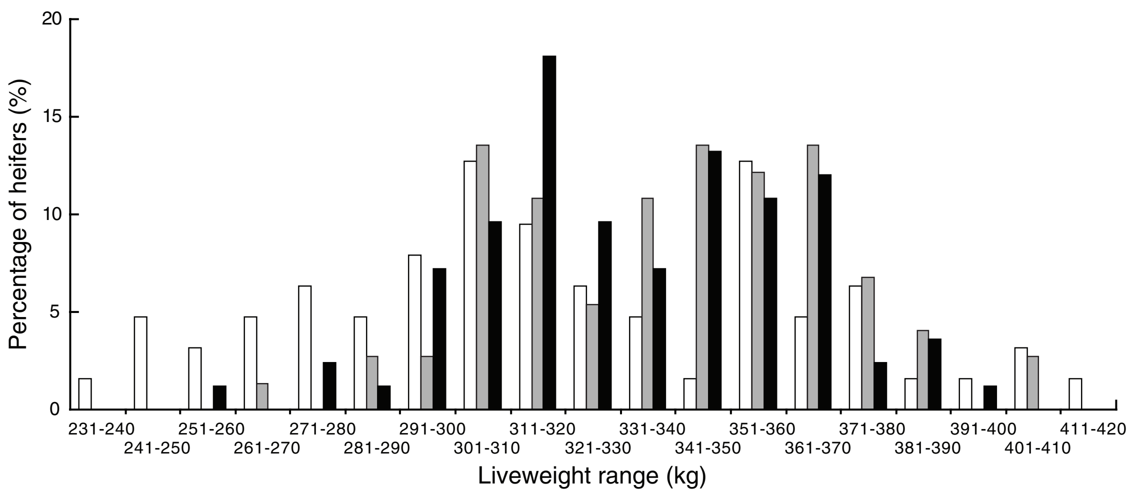

Fig. 1. Distribution of 2005 cohort HIM heifer after mating weights at each site. Thalanga: open bars, *n* = 63; Swan's Lagoon: shaded bars, *n* = 74; St Margaret's Creek: black bars *n* = 83.

at 18 months of age (HIM heifers averaged 340 kg), but this declined to ~25 kg at 2.5 years, reducing further after that (Table 9). In 2004, when M8U was restricted for HIM cows that were also grazing what was considered poorer-quality pasture, these cows dropped a unit of condition score lower than SLIM cows (2.5 *v.* 3.2). At other assessment times, cattle had condition scores of 3–4 except yearling SLIM heifers that were in condition score 2 at the end of the dry season.

HIM and SLIM-HIM steers gained 160–180 kg and 205–210 kg in consecutive years after weaning. This was 25–45 kg more each year compared with SLIM steers (Table 9). In the 2004 cohort at 2.5 years of age, 96, 61 and 0% of the of HIM, SLIM-HIM and SLIM steers were over 500 kg, with average weights of 554 ± 45, 502 ± 50 and 435 ± 51 kg, respectively. In April 2005, the 2004 steer cohort was transferred to new paddocks in which a toxic weed, *Lantana camara* was

Table 9. Liveweight change and relative change in net worth of each high-input management system (HIM) and strategic low-input management system (SLIM) age × gender group at Swan's Lagoon

Mustering costs for calculation of gross margins (GM) are given in the text

	Liveweight (kg)			2004–05				2005–06			
	May 2004	May 2005	May 2006	Value in	Supplement	Value add[A]	GM/AE[B]	Value in	Supplement	Value add[A]	GM/AE[B]
HIM females											
1997–2001	463	451	469	$619	$44	$213	$127	$557	$38	$329	$223
2002	360	360	438	$538	$44	$175	$118	$430	$40	$306	$258
2003	298	356	431	$444	$34	$205	$178	$489	$38	$270	$215
2004	159	320	416	$236	$63	$218	$287	$460	$60	$323	$241
2005	–	–	340	–	–	–	–	$266	$67	$238	$291
SLIM females											
1997–2001	443	496	469	$576	$24	$285	$191	$640	$28	$235	$148
2002	361	417	433	$542	$24	$225	$169	$519	$29	$280	$198
2003	275	407	398	$392	$18	$218	$261	$612	$28	$140	$86
2004	116	257	390	$170	$35	$190	$355	$361	$21	$210	$247
2005	–	–	266	–	–	–	–	$227	$19	$161	$286
2004 steers											
HIM	181	349	554	$286	$95	$266	$281	$552	$137	$303	$159
SLIM-HIM	123	292	501	$192	$88	$254	$349	$452	$135	$331	$217
SLIM	123	267	435	$192	$37	$213	$380	$419	$21	$269	$305
2005 steers											
HIM	–	206	381	–	–	–	–	$308	$100	$265	$252
SLIM-HIM	–	170	332	–	–	–	–	$262	$95	$241	$258
SLIM	–	170	301	–	–	–	–	$264	$32	$197	$301

[A]Value added for surviving cattle.
[B]GM per adult equivalent.

growing. Three HIM steers died and nine others were temporarily affected. HIM and SLIM-HIM steers were exposed to more lantana and were more severely affected, which may have reduced the growth differences between the groups as the surviving affected steers were not excluded from the study.

Annual GM/AE of gender × age groups within the HIM system were lower than in the SLIM system for most classes of cattle in 2004 (Table 9). This was the year in which M8U supplementation was restricted. The opposite occurred in 2005 in female cattle. HIM systems still did not match GM in either weaner or yearling steers in 2005. The depressive effect of first lactation on value increase was the same effect observed at Thalanga.

St Margaret's Creek

An average annual postweaning liveweight gain of 161 kg was achieved by heifers (Table 10). Gain from 1.5 to 2.5 years of age was 81 kg in the 2004 heifer cohort, most of which did not rear a calf after mating to an infertile bull. In females rearing calves, annual weight gain from 18 months of age was ~30 kg. The

Table 10. Liveweight change and relative change in net worth of each high-input management system (HIM) age × gender group at St Margaret's Creek

Mustering costs for calculation of gross margins (GM) are given in the text

	Liveweight (kg)			2004–05				2005–06			
	May 2004	May 2005	May 2006	Value in	Supplement	Value add[A]	GM/AE[B]	Value in	Supplement	Value add[A]	GM/AE[B]
HIM females											
1994–2001	458	472	480	$607	$62	$276	$161	$611	$73	$294	$162
2002	394	423	433	$572	$62	$216	$128	$528	$73	$297	$176
2003	365	393	436	$551	$59	$228	$154	$557	$73	$252	$146
2004	181	344	425	$271	$78	$235	$267	$506	$53	$152	$105
2005	–	174	332	–	–	–	–	$260	$66	$230	$284
HIM steers											
2004	203	473	539	$324	$92	$421	$434	$751	$70	$241	$357
2005	–	192	459	–	–	–	–	$306	$83	$418	$456

[A]Value added for surviving cattle.
[B]GM per adult equivalent.

St Margaret's Creek cattle maintained a body condition score of 3–4.

The 2004 and 2005 steer cohorts gained 270 and 267 kg (0.66 kg/day), respectively, in the year after weaning (Table 10). The 2004 steer cohort reached 539 kg liveweight at 2 years of age and a carcass weight of 304 kg. Seventy-five percent of the 2004 steer cohort had no permanent incisors at slaughter. Rump fat depth was 11 ± 4 mm.

The business strategy at St Margaret's Creek was to sell steers at ~2 years of age with a carcass weight of 300 kg. Selling time is near the end of the dry season. The value of the 2004 steer cohort at slaughter was $135 higher than expected at mid-year saleyard prices and equivalent to a premium of $0.25/kg liveweight.

Time input

The HIM system required 5–7 times as much labour for supplementation as the SLIM system (Table 11). The inputs at Thalanga were much lower because of the better seasons experienced during the study, and were relatively high at St Margaret's Creek because of the relatively small size of the herd on which the calculations were based. The extra handling required by SLIM herds did not outweigh the labour required to conduct HIM systems. At Thalanga, under good seasonal conditions, the overall labour inputs for the two systems were similar.

Table 11. Labour input (hours/1000 cows aged 2+ years) for supplementation and cattle handling within high-input management (HIM) and strategic low-input management (SLIM) systems at each site

Site	Period	Supplementation		Mustering	
		HIM	SLIM	HIM	SLIM
Thalanga	2004–05	160	35	120	219
	2005–06	170	33	120	219
Swan's Lagoon	2004–05	584	106	115	187
	2005–06	736	107	125	187
St Margaret's Creek	2004–05	1101		134	
	2005–06	1147		134	

Whole herd economic analyses

Thalanga

When all data were combined into GM analyses of several business options where all sales were at 2.5 years of age or older and premiums were paid for heavier steers at 2.5 years of age (Table 12), several outcomes were noted:

(1) A full HIM system was more profitable than a full SLIM system. When no price premiums were applied for 2.5-year-old steers, overall profitability for the two systems was similar.
(2) A HIM system has 12% fewer cattle than a SLIM system at the same total herd AE value.
(3) With the premiums applied to 2.5-year-old sale steers, there is generally a small overall advantage in using the HIM system in both years after weaning in steers, rather than just in the postweaning year.
(4) When a breeding herd is managed using a HIM system, and mating of heifers is delayed to 2 years, it is more profitable to minimise supplementation of heifer progeny until they are pregnant.

A price sensitivity analysis for Thalanga that compared a full SLIM system to SLIM with HIM for steers to 18 months (Fig. 2), which was the most profitable option at that site, showed that:

(1) A small increase in price for steers is required to break even if supplement prices rise more than 20% above the level they were during the study.
(2) At a price premium of $0.10/kg liveweight for 2.5-year-old steers, breakeven is experienced when supplement costs rise by 40%.

Table 12. Inputs and estimated gross margins (GM) for management options at Thalanga

Herd size of 2700 adult equivalents (AE), and annual mortality rate of 3%. HIM, high-input management system; SLIM, strategic low-input management system

Cow management:	SLIM	SLIM	SLIM	HIM	HIM	HIM	HIM
Heifer management:	SLIM	SLIM	SLIM	HIM	HIM	SLIM[A]	SLIM[A]
Steer management:	SLIM	HIM	HIM 1[B]	HIM	HIM 1	HIM 1	HIM
Total cattle	3454	3265	3307	3026	3055	3166	3144
Mated females kept	1140	1078	1092	1011	1021	1058	1051
Calves weaned	1026	970	983	940	949	984	977
Females sold	454	429	435	419	423	438	435
Steers sold	493	466	472	452	456	472	469
Average female price	$608	$608	$608	$640	$640	$624	$624
Average steer price	$683	$952	$837	$1007	$863	$865	$1007
Herd capital value	$1 519 130	$1 493 464	$1 506 537	$1 508 842	$1 523 125	$1 525 581	$1 515 177
Net cattle sales	$612 288	$703 935	$659 237	$723 067	$664 269	$681 680	$744 061
Direct costs	$158 878	$219 845	$164 911	$253 952	$200 538	$195 534	$251 655
Herd GM	$453 411	$484 091	$494 325	$469 115	$463 732	$486 146	$492 407
GM/AE	$168	$179	$183	$174	$172	$180	$182

[A]Heifers excluded from HIM system until 2.5 years.

[B]HIM system for steers only to 18 months.

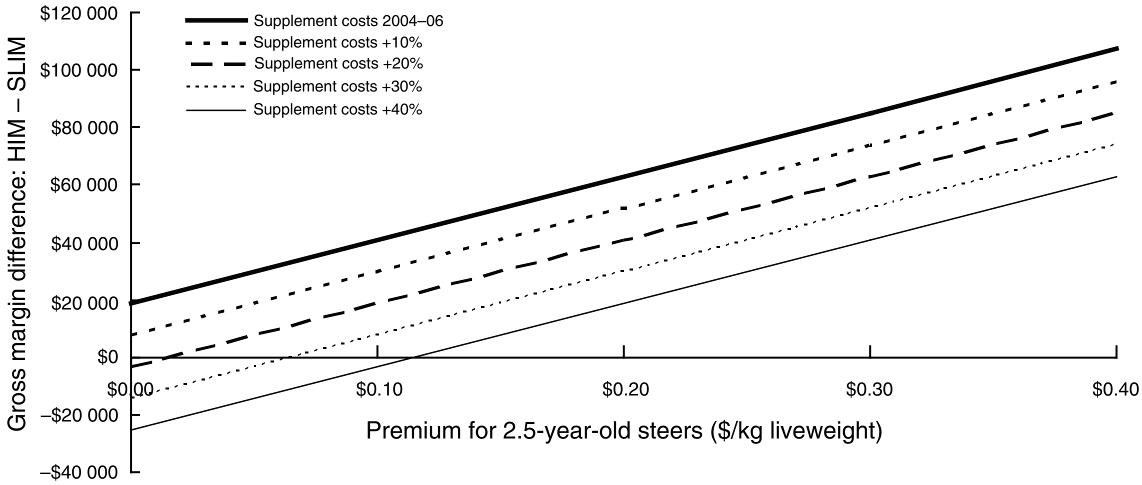

Fig. 2. Thalanga: gross margin advantage (AU$) of using a HIM system for steers to 18 months within a SLIM system for females as supplement costs and steer premiums increase.

A price sensitivity analysis for Thalanga compared a full SLIM system to HIM with SLIM for heifers (Fig. 3). This was the second most profitable option at that site and showed that a price premium of $0.20/kg liveweight for 2.5-year-old steers is required to break even if supplement prices rise more than 20% above the level they were during the study.

Swan's Lagoon

When all data were combined into GM analyses of several business options, sales were at 2.5 years of age or older, and higher prices paid for heavier steers at 2.5 years of age (Table 13), several outcomes were noted:

(1) A full HIM system was more profitable than a full SLIM system and was the most profitable option to use given the molasses and beef prices used in the analyses.
(2) A HIM system runs 10% fewer cattle than a SLIM system with the same total herd AE value.
(3) With the higher prices applied, there was a small overall advantage in using the HIM system in both years after weaning in steers, rather than just in the postweaning year.
(4) When a HIM system was used in breeding females, it is more profitable to mate yearlings than to defer mating until 2 years of age.
(5) When first mating was deferred to 2 years of age within either breeder management system, there was little difference in returns between HIM and SLIM systems for breeding females.

A price sensitivity analysis for Swan's Lagoon that compared SLIM to HIM (Fig. 4) showed that:

(1) An increase of $0.07/kg liveweight for steers was required to break even, given the supplement costs during the study.
(2) When supplement costs increase by 20% based on the 2004–06 levels, breakeven occurred with a price premium of $0.25/kg liveweight.

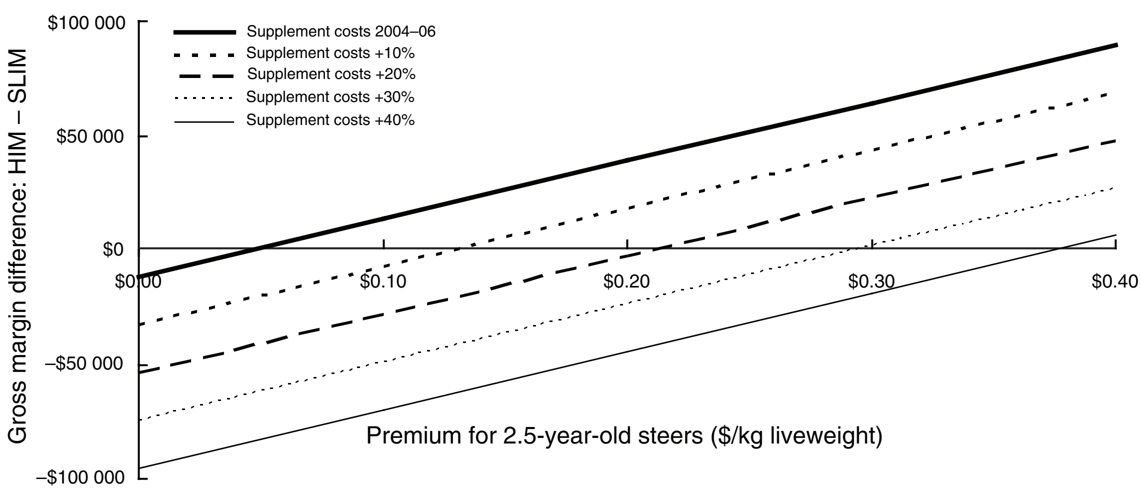

Fig. 3. Thalanga: gross margins advantage (AU$) of HIM with SLIM for juvenile females over a SLIM system as supplement costs and steer premiums increase.

Table 13. Inputs and estimated gross margins (GM) for management options at Swan's Lagoon
Herd size of 3000 adult equivalents (AE), and annual mortality rate of 2%. HIM, high-input management system; SLIM, strategic low-input management system

Cow management:	SLIM	SLIM	SLIM	HIM	HIM	HIM	HIM
Heifer management:	SLIM	SLIM	SLIM	HIM	HIM	SLIM[A]	SLIM[A]
Steer management:	SLIM	HIM	HIM 1[B]	HIM	HIM 1[B]	HIM 1[B]	HIM
Total cattle	3581	3453	3499	3230	3274	3315	3274
Mated females kept	1256	1211	1227	1305	1323	1162	1147
Calves weaned	1155	1114	1129	1153	1169	1069	1055
Females sold	530	511	517	535	543	490	484
Steers sold	545	526	533	544	552	504	498
Average female price	$623	$623	$623	$667	$667	$637	$637
Average steer price	$708	$936	$785	$1067	$922	$922	$1068
Herd capital value	$1 583 952	$1 565 838	$1 583 840	$1 545 211	$1 563 716	$1 581 993	$1 565 012
Net cattle sales	$722 336	$818 295	$747 479	$948 184	$879 563	$785 216	$849 459
Direct costs	$141 413	$229 049	$167 102	$325 182	$262 429	$209 664	$267 857
Herd GM	$580 923	$589 246	$580 377	$623 002	$617 134	$575 553	$581 602
GM/AE	$194	$196	$193	$208	$206	$192	$194

[A]Heifers excluded from HIM system until 2.5 years and then not mated as yearlings.
[B]HIM system for steers only to 18 months.

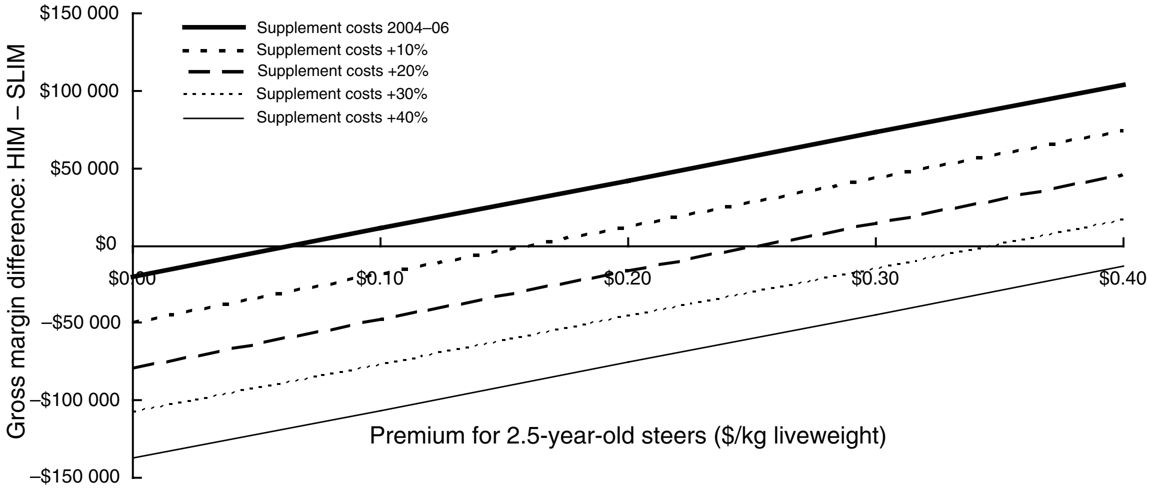

Fig. 4. Swan's Lagoon: gross margin advantage (AU$) of using a HIM system as supplement costs and steer premiums increase.

A price sensitivity analysis that compared a full SLIM system to SLIM with HIM for steers (Fig. 5), which was the second most profitable option at that site, showed that:

(1) An increase of $0.16/kg liveweight for steers was required to break even, given supplement prices during the study.
(2) When supplement costs rise by 20% on the 2004–06 levels, an increase in price greater than $0.30/kg liveweight for steers was required to break even.

St Margaret's Creek

GMs (Table 14) at St Margaret's Creek were high in comparison to Thalanga and Swan's Lagoon.

Discussion

This study has demonstrated that HIM systems can profitably increase steer growth to reach 500 kg by 2.5 years of age in poor-quality-nutrition regions of northern Australia's dry tropics. Steers in HIM systems achieved average annual growth of 160–200 kg, and up to 270 kg at one site. This growth matches the highest levels reported by Bortolussi *et al.* (2005*b*) and Hasker (2000) for northern Australia, whereas growth of SLIM cattle was closer to average for the region. However, the study also demonstrated the complexity of profitable application of component research outcomes to commercial business.

The GM for cows over a year should not be interpreted directly as indicating relative business profit. This study has clearly indicated that while cow management strategies can increase reproductive efficiency such as increasing calf weight weaned per cow retained (du Plessis *et al.* 2006), it is not sufficient evidence to recommend its inclusion within a business. A practice only becomes more profitable when the net return per AE for the herd is increased. The extra value of weaners produced by HIM systems in comparison to SLIM systems must be realised in sales before it

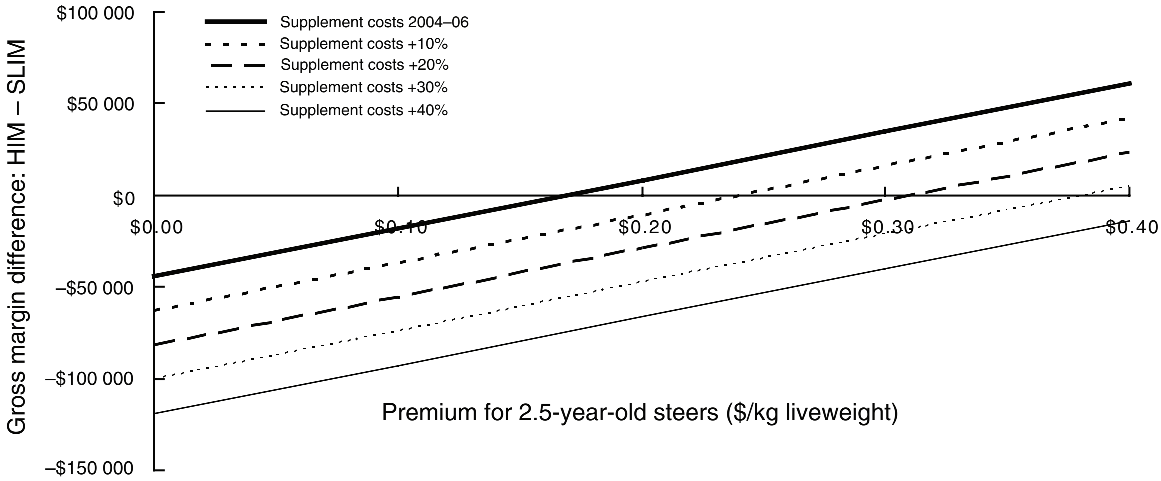

Fig. 5. Swan's Lagoon: gross margins advantage (AU$) of SLIM with HIM for steers over SLIM as supplement costs and steer premiums increase.

Table 14. Inputs and estimated gross margins (GM) at St Margaret's Creek

Adult equivalents	450	Average female price	$725
Total cattle	381	Average steer price	$910
No. of mated females kept	194	Herd capital value	$204 424
No. of calves weaned	179	Net cattle sales	$143 362
Mortality rate	1%	Direct costs	$44 503
No. of females sold	87	GM for herd	$98 859
No. of steers sold	89	GM per adult equivalent	$220

can be deemed more profitable. Extra value of female progeny is generally lost as they approach maturity. To counteract this situation, mature size may be reached at a younger age, with higher sale values of younger surplus females and potentially higher early life productivity. Therefore, it is difficult to recoup the extra value created in female progeny unless yearling mating can be implemented. In contrast, extra value in steer progeny flows through to heavier weights, thus higher values, at sales at a young age, which is the primary basis for success of HIM systems.

HIM systems applied appropriately to steer progeny can improve profitability, irrespective of management systems applied to cows or heifers. However, the success of these systems is dependent on higher prices for steers at turnoff. With sales at 2.5 years, at least 90% of steers still have at most two permanent incisors. These animals attract higher prices at slaughter.

The high GM achieved at St Margaret's Creek is a clear example of the effect of the HIM system on steer sale values, as GM for breeder performance at St Margaret's Creek are less than at the other sites, whereas those for steers are very high. This situation occurs for several reasons: historically, performance under SLIM management at St Margaret's Creek is very low because of very poor soil nutrition despite higher average wet season rainfall than at the other sites; the rainfall received on sown pastures produces high pasture dry matter levels and strongly complements fortified molasses feeding, resulting in only moderate supplement intakes by cattle, thus moderate costs.

HIM systems for breeding cows (Fordyce *et al*. 1996*a*, 1997) result in earlier calves born over a much shorter period and all calves weaned at the optimum time of the year. An extra 30 kg of weaner weight, with all weaning occurring at the first annual muster, achieved a similar benefit to a full dry season of fortified molasses supplementation (after wet season compensation) to weaners. If nutrition is adequate such that 90% of heifers reach 300 kg by 18 months of age, pregnancy rates of yearling Brahman heifers in HIM systems may reach 80%. Despite the 2005 HIM heifer cohort reaching an average weight of 320–340 kg at 1.5 years of age at each site, pregnancy rates at Thalanga were 38% in comparison to 69–79% at the other sites. A significant contributor appeared to be a skewed weight distribution at Thalanga where a third of the group was <300 kg, whereas only 5–10% of Swan's Lagoon and St Margaret's Creek heifers weighed <300 kg. This suggests that fewer heifers may have reached puberty by the end of yearling mating as weight is a major determinant of age at puberty (Fordyce 2006). An additional effect of reproductive disease was not discounted at Thalanga, as only 47% of those females >300 kg conceived, compared with conception rates of 70 and 82%, respectively, at the other sites. Pestivirus was subsequently found to be endemic in the Thalanga herd, which is the case for a majority of large northern Australian herds, whereas the other herds were free of this disease.

Whole herd economic analyses indicated that where heifers are not expected to achieve high pregnancy rates as yearlings, they should not be mated at this age. For example, at Thalanga, heifers should be managed using SLIM systems between weaning and first pregnancy. The reason for this is that high calf output is required to at least match the extra costs required to boost weight for yearling mating. This does not exclude targeted supplementation of heifers within a SLIM system to reach target mating weights at 2 years of age from being profitable. The inability of HIM to achieve yearling pregnancies also resulted in HIM for cows not being significantly more profitable than SLIM. A corollary of this is that, if pasture nutrition is relatively poor, it may be inadvisable to implement HIM systems other than in steers, and the criterion for judging this is whether HIM systems can achieve mating weights in yearling heifers at which 60% or more high could be expected to conceive within 3 months.

The value of yearling mating within HIM systems, where adequate growth is achieved, was clearly shown at the St Margaret's Creek site where the 2004 heifer cohort was inadvertently mated to an infertile bull. Denying these heifers the chance to rear a calf to weaning resulted in them having the lowest increase in value of any class of animal in 2005–06.

The complexities associated with determining whether HIM systems are profitable are such that they should only be implemented after analyses indicate a reasonable probability of increased profitability for each specific business. Primary risk factors are presented in Table 15. If managed well, adopting the most appropriate HIM system (application to weaners, steers, heifers and/or cows) increases GM by ~$15/AE in the herd at the price of molasses as-fed and the premiums expected for high-quality cattle during the study period. This increment will be lower at greater distances from molasses sources. A supplement price rise of only 20% appears to eliminate the potential benefits of HIM systems in many situations, especially in females, unless substantial cattle price increases occur.

HIM system supplementation requires 0.2–1.0 h labour input annually per cow over 2 years of age, depending on the length of the dry season. This labour, which is costed into supplementation, is 5–7 times that required for SLIM systems supplementation. For example, a 3000 AE herd with 1500 cows might require half a full-time person equivalent for annual HIM supplementation, whereas annual supplementation of an equivalent SLIM system herd would take the equivalent of 1 month by one person.

There are several other factors to consider before implementing HIM systems (Table 15). The most apparent is that it is only applicable where infrastructure and management are well developed. Without this, the expensive inputs are not well targeted, thus reducing the potential returns available. In particular, HIM systems are not advised where pastures are heavily grazed as the substitution of pasture for supplement and the relatively low production responses are very unlikely to be cost effective. HIM systems result in younger cattle having a larger body mass, thus higher feed intake, which highlights the attention required to pasture utilisation. If yearling mating is implemented, then our analyses suggest the business should have up to 25% fewer breeding females over 2 years of age, depending on level of implementation, to maintain similar grazing

Table 15. Factors to consider in comparative risk analyses of strategic low-input management (SLIM) and high-input management (HIM) systems in the dry tropics of northern Australia

Factor	Comment
Commitment	HIM systems require much higher labour inputs and this labour must be technically oriented. Business managers must have a sustained commitment to ensuring HIM systems operate effectively
Severe weather fluctuations	A major advantage of HIM systems is their ability to improve and sustain high sale numbers and values
Pasture utilisation	All systems are at risk of lowered profitability if pasture is overutilised. HIM systems are more at risk as pasture utilisation creates substitution feeding, thus creating higher intakes and a higher cost of diets, which erode cost-benefit differences
Infrastructure and skills to segregate, control, manage, and supplement cattle	The base level required for the use of HIM systems is much higher than that required to achieve greater profitability when using SLIM systems
Availability of labour	Labour to implement HIM systems must be assured before commencement of the systems. The opportunity provided by HIM systems to complement part-time labour for other business operations may reduce the risk of accessing labour by creating full-time employment positions
Access to skills for fetal ageing	The efficiency of all systems is similarly improved by access to accurate fetal ageing skills
Control of infectious and non-infectious diseases	HIM systems may be more at risk to disease reducing profitability as diseases have the potential to erode much higher input costs
Access to high-value markets	The ability to access high-value markets for young heavy steers is a critical element in the success of HIM systems
Ability to meet high-value market specifications	Failure of a HIM system to take steers into higher-value markets may render a business at best no more profitable than if SLIM systems were used
Collapse in market values	This has a greater effect on the profitability of HIM systems as input costs/adult equivalent are higher
Capital for supplements	Cow sales to accommodate HIM systems will offset initial capital costs for supplementation infrastructure
Oil and natural gas prices	The costs of both inorganic and organic components of supplements are directly affected by oil and natural gas prices
Availability of molasses	Molasses may be difficult to access outside sugarcane crushing periods unless suitable contracts have been made, or there is sufficient on-farm molasses storage
Cost of molasses	The availability of molasses makes HIM systems viable as it is much cheaper per energy unit than grain in many areas of tropical Australia. Long delivery distances or molasses price increases will substantially reduce the relatively higher profitability of HIM over SLIM systems
Access to products that can enhance growth and the efficiency of feed utilisation	Products such as hormonal growth promotants contribute vital annual growth increments that enable steers to reach high-value markets that accept their use. The efficiency of both SLIM and HIM systems are reduced without access to these products
Ability to continue with late dry season molasses-based supplements in cows	If cows mated to calve early do not have adequate dietary energy in early lactation, mortality risk in cows and calves will increase and reconception may be substantially delayed
Dystocia in calving 2-year-old heifers	Suitable nutritional management will reduce the probability of dystocia to very low levels

pressure. When yearling mating is not practised, then 10% fewer breeding females are recommended.

Supplementation of pregnant HIM-system yearlings at Swan's Lagoon was not maintained at a high level in the first half of pregnancy nor throughout the dry season, and as a consequence, it appears that foeto-pelvic disproportion and dystocia occurred in at least 5% of births; overall calf losses between pregnancy and weaning may be elevated to over 20%. Norman (2006) has outlined strategies to prevent dystocia and the most important one is that pregnant yearlings should be maintained in forward body condition throughout gestation, and particularly during the first and second trimesters, to avoid high calf wastage, calving difficulties and cow deaths.

We conclude that HIM systems using high-level feeding of fortified molasses, growth promotants for steers and short seasonal mating enables most steers to reach 500 kg by 2.5 years of age. HIM can be profitably applied if basic infrastructure and management is well developed and strategies are only applied where there is a reasonable chance of higher net returns per AE for the herd.

Acknowledgements

This study was strongly supported by many sponsors whom we thank sincerely for their generous provision of substantial operating expenses, product and/or time to enable the study to operate effectively. These include: the Department of Primary Industries and Fisheries (Queensland); Meat and Livestock Australia (Project NBP.334); CSR Molasses; BEC Feed Solutions Pty Ltd and KK Animal Nutrition; Elanco Animal Health; Incitec Pivot Fertilisers; and Stocklick Trading Pty Ltd. We also greatly appreciated the strong support provided by the Industry Reference Group including Robert Rea, David Scott, Gerard and Elizabeth Lyons, Tammy Cross, Peter Ramsey, Goscelyn Smith and Dave Collyer. Sincere thanks to Dr Stu McLennan and Tom Mullins for their professional input and advice and to Dr Brian Burns, Kev Shaw and Fred Chudleigh for their critical reviews of this paper.

References

Aisthorpe J, Paton C, Timmers P (2004) 'Stocktake: balancing supply and demand.' (Department of Primary Industries and Fisheries: Brisbane)

Bortolussi G, O'Neill CJ (2006) Variation in molasses composition from eastern Australian sugar mills. *Australian Journal of Experimental Agriculture* **46**, 1455–1463. doi: 10.1071/EA04124

Bortolussi G, McIvor JG, Hodgkinson JJ, Coffey SG, Holmes CR (2005*a*) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Australian Journal of Experimental Agriculture* **45**, 1075–1091. doi: 10.1071/EA03097

Bortolussi G, Hodgkinson JJ, McIvor JG, Coffey SG, Holmes CR (2005*b*) The northern Australian beef industry, a snapshot. 3. Annual liveweight gains from pasture-based systems. *Australian Journal of Experimental Agriculture* **45**, 1093–1108. doi: 10.1071/EA03098

Chilcott CR, Nelson BS, Quirk MF, Paton CJ (2005) 'Burdekin grazing land management workbook.' (Edge Network, Meat and Livestock Australia: Sydney)

du Plessis I, Hoffman LC, Calitz FJ (2006) Influence of reproductive traits and pre-weaning growth rate on herd efficiency of different breed types in an arid sub-tropical environment. *South African Journal of Animal Science* **36**, 89–98.

Fordyce G (2006) Practical strategies to reach target mating weight in north Australian beef heifers. In 'Proceedings of the Australian Association of Cattle Veterinarians conference, 16–19 November 2006, Port Macquarie'. pp. 142–152. (Australian Association of Cattle Veterinarians: Brisbane)

Fordyce G, Holroyd RG, James TA, Reid DJ (1988) The effect of post-weaning growth on the fertility of Brahman cross heifers. *Proceedings of the Australian Society of Animal Production* **17**, 396.

Fordyce G, Cooper NJ, Kendall IE, O'Leary BM, de Faveri J (1996*a*) Creep feeding and pre-partum supplementation effects on growth and fertility of Brahman cross cattle in the dry tropics. *Australian Journal of Experimental Agriculture* **36**, 389–395. doi: 10.1071/EA9960389

Fordyce G, D'Occhio MJ, Cooper NJ, Kendall IE, O'Leary BM (1996*b*) First oestrus in Brahman cross heifers in the dry tropics and the influence of supplementation. In 'Proceedings of reproduction in tropical environments, satellite meeting of the 13th international congress on animal reproduction'. Free communication 7. (Tropical Beef Centre: Rockhampton, Qld)

Fordyce G, Fitzpatrick LA, Mullins TJ, Cooper NJ, Reid DJ, Entwistle KW (1997) Pre-partum supplementation effects on growth and fertility in *Bos indicus* cross cows. *Australian Journal of Experimental Agriculture* **37**, 141–149. doi: 10.1071/EA96015

Graham JF (2003) Condition scoring of beef cattle. Agriculture notes AG0113. Department of Primary Industries, Melbourne, Vic.

Hasker PJS (2000) 'Beef production in northern Australia: a summary of research.' (Department of Primary Industries: Brisbane)

Holmes WE (2006) 'Breedcow and Dynama Herd budgeting software package. Version 5.04 for Windows 95, 98, Me, NT, 2000 and XP. Training series QE99002.' (Queensland Department of Primary Industries and Fisheries: Townsville)

Holroyd RG (1987) Foetal and calf wastage in *Bos indicus* cross beef genotypes. *Australian Veterinary Journal* **64**, 133–137. doi: 10.1111/j.1751-0813.1987.tb09661.x

Hunter RA, Magner T, Allingham PG (2000) Sustained growth promotion, carcass characteristics, and meat quality of steers treated with oestradiol-17β. *Australian Journal of Agricultural Research* **51**, 133–138. doi: 10.1071/AR99048

Lindsay JA, Dyer RM, Gelling BA, Laing AR (1996) Finishing *Bos indicus* crossbred cattle on northern spear grass pastures using molasses or grain based supplements. *Proceedings of the Australian Society of Animal Production* **21**, 82–91.

Meat and Livestock Australia (2003) 'The nutrition edge.' (Meat and Livestock Australia, Sydney)

Norman ST (2006) The management of dystocia in cattle. In 'Proceedings of the Australian Association of Cattle Veterinarians Conference, 16–19 November 2006, Port Macquarie'. pp. 70–81. (Australian Association of Cattle Veterinarians: Brisbane)

O'Rourke PK, Entwistle KW, Arman C, Esdale CR, Burns BM (1991) Fetal development and gestational changes in *Bos taurus* and *Bos indicus* genotypes in the tropics. *Theriogenology* **36**, 839–853. doi: 10.1016/0093-691X(91)90350-M

Manuscript received 30 August 2007, accepted 14 November 2008