Australian Journal of Experimental Agriculture, 1993, **33**, 119–27

The performance of Brahman–Shorthorn and Sahiwal–Shorthorn beef cattle in the dry tropics of northern Queensland
3. Birth weights and growth to weaning

G. Fordyce[A], *T. A. James*[AB], *R. G. Holroyd*[AC], *N. J. Beaman*[A], *R. J. Mayer*[D] *and P. K. O'Rourke*[E]

[A] Queensland Department of Primary Industries, Swan's Lagoon, Millaroo, via Ayr, Qld 4807, Australia.
[B] Current address: Queensland Department of Primary Industries, Brigalow Research Station, MS 586, Theodore, Qld 4719, Australia.
[C] Current address: Queensland Department of Primary Industries, PO Box 46, Brisbane, Qld 4001, Australia.
[D] Queensland Department of Primary Industries, PO Box 1085, Townsville, Qld 4810, Australia.
[E] Queensland Department of Primary Industries, PO Box 46, Brisbane, Qld 4001, Australia.

Summary. The birth weights and weaning weights of *Bos indicus* cross calves from 4 *inter se* mated herd groups in a dry tropical environment were studied. The calving season commenced in late October, about 2 weeks before the start of the pasture-growing season. Second and subsequent generations of 1/2 Brahman and 1/2 Sahiwal crosses and first backcross, and later generations of 3/4 Brahman and 3/4 Sahiwal crosses, were represented. The *Bos taurus* component of the crosses was primarily Beef Shorthorn.

In general, Brahman crosses were heavier at birth and grew faster to weaning than Sahiwal crosses ($P<0.05$), with consequent advantages in weaning weights of 11 and 6 kg in first backcross and late generation crosses, respectively. There was a birth weight advantage ($P<0.05$) of 1/2 crosses over 3/4 crosses, which was eroded by the time of weaning. Superior growth rates of 3/4 crosses were primarily expressed in years with greater nutritional stress and appeared to be due to better adaptation to environmental stresses by the calf. The only difference between filial generations was the growth rate advantage ($P<0.05$) of F_2 1/2 crosses over F_3 1/2 crosses, apparently due to suckling of F_1 and F_2 dams, respectively.

Males exhibited an 8% average advantage ($P<0.05$) over females for all weight and growth traits in late generation calves. Calves with mature dams were 1.8 kg heavier ($P<0.05$) at birth. This, along with their higher ($P<0.05$) preweaning growth rate (19–49 g/day), resulted in calves with mature dams being 4–10 kg heavier ($P<0.05$) at weaning than calves of young cows.

Differences between years in birth weights and preweaning growth rates were ≤25% ($P<0.05$). Birth weight was affected by nutrition of the dam in late pregnancy (early calves were generally about 1 kg lighter than late calves), and growth of calves was higher in years when the pasture growing season commenced earlier.

Introduction

Performance of calves to weaning is an important component of all beef production systems. In the dry tropics of northern Australia, adaptive traits are an important component of beef productivity (Turner 1975). Selection for adaptive traits may be at the expense of production potential (Frisch and Vercoe 1984). Breeds such as *Bos indicus* x *Bos taurus* crosses exhibit the best compromise between these attributes to allow optimum production.

Until recently, the 3 primary zebu beef breeds available in Australia were Brahman, Africander, and Sahiwal. There has been much comparative research of Brahmans and Africanders and their half crosses with British breeds, but little objective productivity data are available for either Sahiwal or 3/4 *Bos indicus* crosses.

At Swan's Lagoon Beef Cattle Research Station, a program of comparative evaluation was initiated to provide data on Brahman and Sahiwal crosses as beef breeds (Holroyd *et al.* 1990*a*). The study compared 1/2 and 3/4 crosses to determine the productivity of these levels of *Bos indicus* and, so, to indicate the most appropriate crosses for the dry tropics of northern Australia. Two previous papers (Holroyd *et al.* 1990*a*, 1990*b*) reported reproductive performance and liveweights of F_1 and F_2 *et seq.* crossbred cows. This paper examines breed and environmental effects on preweaning growth.

Materials and methods

Location

The experiment was conducted at Swan's Lagoon Beef Cattle Research Station (20°05'S., 147°14'E.) in the subcoastal black spear grass region of North Queensland (Weston *et al.* 1981). The climate is dry tropical and characterised by a distinct hot, wet, summer period (wet season) and a warm, dry, winter period followed by a hot, dry period (dry season). Mean maximum and minimum temperatures for January (midsummer) are 31 and 23°C, and for July (midwinter) 26 and 9°C. Amount and distribution of rainfall are highly variable. Rainfall over the experimental period is shown in Table 1. A seasonal break occurred when there was sufficient rainfall to initiate grass growth and a significant increase in cattle growth. This is generally after at least 25–50 mm of rainfall (depending on severity of the dry season), with a minimum of 25 mm of further rainfall within 40 days.

The vegetation is open woodland (primarily *Eucalyptus*) with a native unimproved pasture of predominantly black spear grass (*Heteropogon contortus*), with tropical tall grasses and other medium grasses (e.g. *Eulalia fulva*, *Themeda triandra*, *Bothriochloa petusa*). Soils are generally of low fertility with phosphorus levels about 6–8 µg/g and organic carbon <0.5–1.5% (oven dry weight). A more detailed description of the site is provided by Holroyd *et al.* (1990*a*).

Crosses and their management

The development of the crosses has been described by Holroyd *et al.* (1990*a*). The program was commenced in 1967 to develop 1/2 and 3/4 Brahman cross herds. This was subsequently expanded to include 1/2 and 3/4 Sahiwal cross herds. The *Bos taurus* component of the crosses was predominately Beef Shorthorn.

Data reported in this study were collected from 1972–73 to 1985–86 for calf year groups 1973–86. Calves were second and subsequent generations of 1/2 Brahman and Sahiwal crosses, and first backcross and later generations of 3/4 Brahman and Sahiwal crosses. Calves of F_3 and later generations were pooled and called the F_3 *et seq.* generation. Filial generation of the progeny was taken to be the filial generation of the dam plus 1. First backcross 3/4 crosses were called F_1 3/4 crosses.

All cows were control-mated with bulls of the same breed cross, except for some F_1 1/2 crosses which were mated to pure-bred *Bos indicus* bulls to produce F_1 3/4 crosses. Mating commenced in mid–late January in each year and continued for 86–100 days, except in 1973 and 1974 (120 days) and 1972 (162 days). The calving period generally commenced in late October, with the latest calves born in early February. In 1973, it continued to late April, and in 1974 and 1975, to mid–late March. Mating was timed for the start of calving to be near to the start of the wet (growing) season. This coincided with the peak calving period for typical North Queensland herds (Holroyd *et al.* 1979*a*).

Calving cows were inspected, on average, 3 times weekly. Calves were tagged within 3 days of birth, and records were made of date, birth weight, dam, and sex. Calves were weighed at weaning at 5–7 months of age in late May or early June at the end of the growing season. The exceptions were (i) 1973, when most calves were weaned on 3 July, with calves born in March and April weaned on 21 August; (ii) 1974, when calves were weaned on 24 June; (iii) 1982, when half of the females were weaned on 20 April as part of an observation of weaning age effects on post-weaning coccidiosis (Parker *et al.* 1986); and (iv) 1983, when calves were weaned on 18 April just before the end of a severe drought.

Outside the mating period, all cattle were run together. Calf management between birth and weaning included vaccinations against clostridial diseases at the beginning and end of the mating period, and branding (fire branding, ear marking, and dehorning) at 3–5 months, which was generally at the end of the mating period. Males were not castrated prior to weaning.

Statistical analyses

The following response data were subjected to analyses of variance: birth weight (kg); average daily liveweight gain (ADG) from birth to weaning (g/day); adjusted weaning weight (AWW, kg), adjusted to 180 days of age (birth weight +180 x ADG). Where birth weight was not available for an individual, the average for calves of the same cross and sex in that year was used to estimate AWW and ADG.

Table 1. Seasonal rainfall (mm) and date of seasonal break (start of wet season) for Swan's Lagoon

	Rainfall				Date of seasonal break
	Dry season (July–Oct.)	Wet season (Nov.–Mar.)	Transition (Apr.–June)	Total	
1972–73	1	533	75	619	15.i.73
1973–74	136	1751	63	1941	14.ix.73
1974–75	82	716	53	851	30.viii.74
1975–76	181	1008	6	1195	8.ix.75
1976–77	110	995	185	1290	22.x.76
1977–78	0	696	109	827	24.xi.77
1978–79	79	937	62	1097	14.xi.78
1979–80	50	739	90	840	27.xii.79
1980–81	22	821	153	1001	29.xii.80
1981–82	26	503	38	560	17.xi.81
1982–83	0	287	407	694	16.i.83
1983–84	9	423	0	488	23.xi.83
1984–85	128	415	113	670	7.x.84
1985–86	169	402	50	584	20.x.85
24-year mean	66	698	116	892	14.xi

Analyses were based on the least squares method for unequal subclass numbers (Harvey 1960). Factors included in the models were year, sex, genotype, birth date, and dam age (at calving). Birth date was included as a 2-level factor. Calves born within 309 days of the start of mating were called early calves, and the balance were classed as mid–late calves. There was partial confounding between genotype, year, and dam age; to overcome this, dam age was classed as either 3–4 years or >4 years. Filial generation was partially confounded with year. Initial analyses showed that there were no differences between F_2 and F_3 *et seq.* 3/4 cross calves, and so these were bulked to form an F_2 *et seq.* 3/4 cross class, leaving a total of 8 genotypes to compare. The confounding of year with genotype prevented any statistical comparison of all genotypes in a single analysis. Final analyses were of 4 data sets: (i) F_1 3/4 Brahman and Sahiwal crosses (n = 739) from the 1973–77 year groups; (ii) F_2 1/2 Brahman and Sahiwal crosses (n = 375) from the 1979–84 year groups (the dam age of all calves was >4 years); (iii) F_2 *et seq.* 3/4 *Bos indicus* crosses and F_3 *et seq.* 1/2 *Bos indicus* crosses (n = 1682) from the 1981–86 year groups; (iv) F_2 and F_3 *et seq.* 1/2 Brahman and Sahiwal crosses (n = 379) from the 1981–84 year groups [includes subsets from sets (ii) and (iii)].

Initial analyses included all main effects plus first-order interactions; due to imbalances in the data, not all interactions could be fitted. Interactions were then tested individually and a stepwise procedure was used to eliminate those that were not significant. Pairwise comparisons between levels within significant main effects and interactions were tested using the protected least significant difference procedure (Snedecor and Cochran 1974).

Results

Breed

Brahman crosses were generally heavier and grew faster (P<0.05) than comparable Sahiwal crosses (Tables 2–4), except within F_2 crosses, where ADG was higher (P<0.05) in Sahiwal crosses (Table 3). In some years there was no significant breed difference, resulting in significant (P<0.05) breed x year interactions. There was a wide range of seasonal conditions across the years when significant breed differences did not occur.

Table 2. Least squares means for breed, sex, dam age, and birth date effects, and significant interactions with year, on birth to weaning performance of first-backcross Brahman and Sahiwal calves [data set (i)]

Means within factors or within interactions between factors followed by the same letter are not significantly different at P = 0.05

	Mean ± s.e.	Breed		Sex		Dam age (years)		Birth date	
		Brahman	Sahiwal	Male	Female	3–4	5+	Early	Mid–late
No. of calves	739	453	286	392	347	415	324	351	388
				Birth weight (kg)					
Main effects	30.4 ± 0.21	32.8a	28.1b	32.4a	28.5b	30.4	30.4	30.0a	30.8b
Interactions									
1973		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	28.3ab	29.5abc
1974		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	32.5e	30.5bcd
1975		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	29.8bc	31.6de
1976		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	31.8de	33.1e
1977		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	27.8a	29.4abc
				Average daily gain (g/day)					
Main effects	801 ± 4.0	818a	784b	852a	751b	788a	814b	798	805
Interactions									
1973		827c	728a	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1974		782b	776b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1975		901e	874d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1976		839c	758ab	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1977		743ab	784b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
				Adjusted weaning weight (kg)					
Main effects	175 ± 0.8	180a	169b	186a	164b	172a	177b	174	176
Interactions									
1973		180de	158a	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1974		175cd	169bc	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1975		195f	186e	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1976		186e	167b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1977		165ab	167ab	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 3. Least squares means for breed, sex, dam age, birth date, and year effects, and significant interactions with year, on birth to weaning performance of F_2 half Brahman and Sahiwal cross calves with mature dams [data set (ii)]

Means within factors or within interactions between factors followed by the same letter are not significantly different at $P = 0.05$

	Mean ± s.e.	Breed		Sex		Birth date		Year group					
		Brahman	Sahiwal	Male	Female	Early	Mid–late	1979	1980	1981	1982	1983	1984
No. of calves	375	201	174	190	185	194	181	131	77	35	61	47	24
					Birth weight (kg)								
Main effects	28.3 ± 0.31	29.1a	27.5b	29.1a	27.5b	27.5b	29.1b	30.4d	30.2d	27.2b	29.9cd	24.9a	27.2abc
Interactions													
1979		30.7ef	30.1de	n.s.	n.s.	29.6def	31.1fg						
1980		29.2cde	31.3ef	n.s.	n.s.	27.9bd	32.6g						
1981		28.0bcd	26.5b	n.s.	n.s.	28.2bcde	26.3ab						
1982		32.6f	27.2bc	n.s.	n.s.	29.3def	30.6efg						
1983		26.3b	23.5a	n.s.	n.s.	24.6a	25.1ac						
1984		27.7bcde	26.6bc	n.s.	n.s.	25.3abd	29.0bdef						
					Average daily gain (g/day)								
Main effects	804 ± 6.6	790a	818b	840a	767b	805	803	786b	720a	807bc	870d	800bc	841cd
					Adjusted weaning weight (kg)								
Main effects	173 ± 1.3	171	175	180a	165b	172	173	172b	159a	172b	187c	169b	179bc

Within late generation calves, Brahman crosses had higher (P<0.05) ADG and AWW than Sahiwal crosses if their dams were mature but not when dams were 3–4 years of age (Table 4).

Percentage Bos indicus

Within late generation calves, 1/2 crosses were heavier (P<0.05) at birth than 3/4 crosses. ADG and AWW were higher (P<0.05) over all years in 3/4 crosses (Table 4). However, the only year groups in which 3/4 crosses had a significant (P<0.05) advantage were the 1981 (ADG, AWW) and 1983 (ADG) groups (Table 4). In these years there was a very late start to the wet season.

Filial generation

Preliminary analyses showed no difference in birth to weaning performance between F_2 and F_3 *et seq.* 3/4 *Bos indicus* cross calves. Within 1/2 crosses [data set (iv)], there was no difference in birth weight between F_2 and F_3 *et seq.* 1/2 Brahmans (average 29.4 kg), but within 1/2 Sahiwals, F_3 *et seq.* calves were 1.5 kg heavier (P<0.05) at birth than F_2 crossbreds. F_2 calves grew faster (P<0.05) after birth and were 13 kg heavier (P<0.05) at weaning than F_3 *et seq.* calves. The advantage of F_2 cross calves over F_3 *et seq.* crosses in ADG was higher (P<0.05) in Sahiwal crosses (96 g/day) than in Brahman crosses (48 g/day).

Sex

Males were heavier and grew faster than females (P<0.05), and there were no significant interactions with other factors (Tables 2–4). Over all traits, the average advantage of F_2 and later generation males was 8%. The average advantage of males within F_1 3/4 crosses was 13%.

Dam age

Dam age did not affect birth weight of F_1 3/4 cross calves (Table 2). However, late generation calves with mature dams were 1.8 kg heavier (P<0.05) at birth than calves of the same crosses from young cows (Table 4).

Calves with mature dams grew faster (P<0.05) after birth and were heavier (P<0.05) at weaning than calves with young dams (Tables 2 and 4). Within the F_1 3/4 crosses, the advantage was 26 g/day for ADG and 5 kg for AWW. For late generation Sahiwal cross calves the advantage was 19 g/day for ADG and 4 kg for AWW. In Brahman crosses, there was a greater advantage for calves born to mature dams (ADG, 49 g/day; AWW, 10 kg).

Birth date

There was a significant (P<0.05) interaction between birth date and year in their effects on birth weight of first backcross calves (Table 2). In the very wet year of 1973–74, early calves were 2 kg heavier (P<0.05), but in the 1975 year group, late calves were 1.8 kg heavier (P<0.05). Late calves in the 1973, 1976, and 1977 year groups tended (P>0.05) to be heavier.

A similar interaction occurred in F_2 1/2 cross calves (Table 3). In 1979–80 (1980 year group) when there was a late start to the wet season, late calves were 4.7 kg heavier (P<0.05). A similar, but non-significant, trend occurred in the 1979 and 1982–84 year groups. In 1980–81 there was a late break to the season but some light rainfall in the preceding months, and earlier calves tended (P>0.05) to be heavier.

Table 4. Least squares means for breed, *Bos indicus* content, sex, dam age, and birth date effects, and significant interactions with year or breed, on birth to weaning performance of late generation half and three-quarter Brahman and Sahiwal cross calves [data set (iii)]

Means within factors or within interactions between factors followed by the same letter are not significantly different at $P = 0.05$

	Mean ± s.e.	Breed		*B. indicus* content		Sex		Dam age (years)		Birth date	
		Brahman	Sahiwal	1/2	3/4	Male	Female	3–4	5+	Early	Mid–late
No. of calves	1682	1054	628	748	934	836	846	694	988	757	925
					Birth weight (kg)						
Main effects	27.2 ± 0.12	28.3a	26.1b	27.9a	26.5b	28.3a	26.0b	26.3a	28.1b	26.8a	27.6b
Interactions											
1981		26.3bcd	25.4b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	25.5ab	26.2b
1982		28.8e	26.8bcd	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	27.5c	28.2cde
1983		25.9bc	23.7a	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	25.1a	24.5a
1984		28.7e	26.9cd	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	26.9bc	28.8de
1985		30.1f	26.4bcd	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	27.9cd	28.7de
1986		29.9f	27.1d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	28.0cd	29.1e
Brahman										27.6b	29.0a
Sahiwal										26.1c	26.1c
					Average daily gain (g/day)						
Main effects	778 ± 3.1	788a	768b	767a	789b	805a	751b	761a	794b	784a	772b
Interactions											
1981		n.s.	n.s.	644a	733bc	n.s.	n.s.	n.s.	n.s.	712b	664a
1982		n.s.	n.s.	789de	797de	n.s.	n.s.	n.s.	n.s.	803cd	783c
1983		n.s.	n.s.	711b	739c	n.s.	n.s.	n.s.	n.s.	724b	727b
1984		n.s.	n.s.	787d	785d	n.s.	n.s.	n.s.	n.s.	792cd	780c
1985		n.s.	n.s.	850g	859g	n.s.	n.s.	n.s.	n.s.	847e	862e
1986		n.s.	n.s.	823f	819ef	n.s.	n.s.	n.s.	n.s.	823d	818d
Brahman								763bc	812a		
Sahiwal								759c	778b		
					Adjusted weaning weight (kg)						
Main effects	167 ± 0.6	170a	164b	166a	168b	173a	161b	163a	171b	167	167
Interactions											
1981		n.s.	n.s.	140a	156b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1982		n.s.	n.s.	172cd	170c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1983		n.s.	n.s.	153b	157b	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1984		n.s.	n.s.	170c	168c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1985		n.s.	n.s.	182e	183e	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1986		n.s.	n.s.	177d	176d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Brahman								165bc	175a		
Sahiwal								162c	166b		

In late generation calves (Table 4), the birth weight advantage of late-born calves was only significant (P<0.05) in the 1984 (1.9 kg) and 1986 (1.1 kg) year groups. In these calves, there was no effect of birth date on birth weight in Sahiwal crosses, but late-born Brahman crosses were 1.4 kg heavier (P<0.05) than calves born early. On average, late calves were 1 kg heavier (P<0.05) at birth than early calves (Tables 2–4).

There was a significant (P<0.05) interaction between year and date of birth in their effects on ADG in late generation crossbred calves. This was because ADG of early calves was 48 g/day higher than that of mid–late calves in the 1981 year group, which had the lowest overall ADG. There were no significant main effects of birth date on either ADG or AWW.

Year

Year main effects were significant (P<0.05) in all analyses. Birth weight varied greatly between years. The year with the longest dry period prior to the start of the wet season was 1983, when calves were also the lightest (P<0.05; Tables 3 and 4). Calves in the 1981, 1984, 1982, and 1980 year groups (in order of decreasing season severity and of increasing birth weight) were also born in poor seasons (Tables 3 and 4). The 1976 and 1979 year groups were the heaviest

(P<0.05; Tables 2 and 3) and were born after the best dry seasons, when rainfall was higher and more frequent. The largest difference was 5.5 kg (22%) in the F_2 1/2 *Bos indicus* cross calves [data set (ii)] between the best (1978–79) and poorest (1982–83) seasons.

Year effects for ADG and AWW were very similar. There was considerable variation between years, with a trend to higher growth rates and liveweights occurring for year groups experiencing an earlier start of the wet season (1975, 1982, 1985, 1986; Tables 2–4). Lowest ADG occurred in the 1980, 1981, and 1983 groups, which were born in the years with the latest seasonal breaks (Tables 3 and 4). In 1973–74, growth was also low despite the wet season commencing early (Table 2); however, rainfall was extremely high and frequent in that year, creating a very wet and stressful environment over most of the preweaning period.

Discussion

This study examined pre-weaning calf performance for selection and management of appropriate crosses for northern Australia's dry tropics. Birth weights and growth of calves to weaning are very important for 3 reasons. Firstly, heavier calves at birth probably have a greater chance of survival in this harsh environment (Frisch 1973*b*). Within *Bos indicus* crosses in the dry tropics, the incidence of dystocia is generally very low, even with heavier calves (Holroyd 1987). Secondly, heavier calves are generally easier to manage after weaning at the beginning of the dry season, due to higher survival probability and lower supplement requirements (McCosker *et al.* 1984). Thirdly, for an average calf, weight at weaning generally constitutes at least 25% of growth to slaughter.

The Sahiwal has been reported as a dairy breed with small mature size (Joshi and Phillips 1953). We previously reported that F_2 *et seq.* Brahman cross cows are about 12% heavier when mature than equivalent Sahiwal crosses (Holroyd *et al.* 1990*b*). Therefore, our finding that Brahman cross calves have higher birth weights than Sahiwal cross calves, independent of year, is the expected allometric relationship.

In F_1 half crosses, Winks *et al.* (1978) found no differences between Brahman and Sahiwal crosses in 2 years but found that after correction for body condition at calving in a third year, Sahiwal crosses had higher birth weights than Brahman crosses. This contrast with the differences found in subsequent generations may have been due to greater hybrid vigour with respect to growth in Sahiwal crosses, brought about by the Sahiwal almost certainly being closer to a full-blood *Bos indicus* than the Brahman. Syrstad (1985) reported that increasing distance between parent breeds increases the amount of heterosis.

The potential of the Sahiwal for milk production was not realised in this environment, and the growth rate of their progeny did not match that of Brahman crosses, which also have high milk yields for a beef breed (Stubbs 1962; Holroyd *et al.* 1979*b*). Winks *et al.* (1978) reported no difference in preweaning growth rate between F_1 Brahman and Sahiwal crosses and concluded that the dry tropical environment may limit the mothering potential of Sahiwal crosses.

The 5% weight advantage to late generation 1/2 cross calves over 3/4 crosses at birth was, on average, eroded by weaning. As *Bos taurus* calves are generally heavier than *Bos indicus* calves at birth (Kennedy and Chirchir 1971), it is expected that within late generation crosses, calves with higher *Bos indicus* content would be lighter. The average advantage of 3/4 crosses in preweaning growth could have been due to higher milk yield, greater growth potential, or better adaptation to stress in the calf or cow. While there are several reports that *Bos indicus* crosses have higher milk yields than *Bos taurus* cows in this environment (e.g. Holroyd *et al.* 1979*b*), this cannot be extrapolated to predict differences between 1/2 and 3/4 crosses. In 2 comparisons (G. Fordyce unpublished data) between 1/2 and 3/4 cross cows (20–30 in each group for each comparison) in this herd during the growing season, 1/2 crosses tended (P>0.05) to have higher milk yields than 3/4 crosses (6.9 *v.* 5.9 kg/day within aged cows in 1988; 4.1 *v.* 3.0 kg/day within first-calf cows in 1991). This suggests that the advantage of 3/4 cross calves is not a function of lactation yields of the dams during the growing season. Greater growth potential in 3/4 crosses is also considered unlikely; in favourable environments, crosses with higher *Bos indicus* content show lower growth potential (Frisch and Vercoe 1984). Better adaptation to stress in 3/4 cross cows or calves would explain why the advantage only occurred in relatively poor seasons. The 3/4 crosses may display better utilisation of available milk and pasture or have higher feed intake and milk yields prior to the start of the pasture-growing season.

The F_1 1/2 cross calves are expected to exhibit 100% heterosis for growth. Heterosis for growth in 3/4 crosses and F_2 *et seq.* 1/2 crosses may be up to 50%. As well, F_2 1/2 crosses and F_1 3/4 crosses both suckle F_1 1/2 cross cows, which will express 100% heterosis for milk production; at least 50% of this advantage will be lost in subsequent generations.

Because of the confounding of filial generation with year, the only valid comparisons that could be made were between F_2 and later generation calves. No significant differences occurred between F_3 1/2 crosses or F_2 3/4 crosses and subsequent generations. Within 1/2 crosses, no advantage in birth weight of F_2 crosses over F_3 crosses occurred, and it might be expected that there would be no advantage of F_2 crosses in subsequent growth potential. That there was suggests maternal heterotic effects, that is, F_2 and F_3 calves suckling F_1 and F_2 dams, respectively. There was no obvious explanation for the higher birth weights of F_3 *et seq.* 1/2 crosses than F_2 1/2 crosses within the Sahiwals, as no similar effect was found in the Brahman crosses.

The 3–7% advantage in birth weight and preweaning growth of calves with mature dams over calves with young dams is consistent with previous reports (Seifert 1975; Buvanendran 1990; Burrow *et al.* 1991). Diversion of energy to growth in young cows reduces the amount available for lactation. As well, older cows, being larger, can transfer more nutrients to the fetus and into milk. Holroyd *et al.* (1990*b*) reported that during lactation, mature cows were 22% heavier than first-calf cows and 13% heavier than second-calf cows. Seifert (1975) showed that the effects of dam age on birth weights of 1/2 *Bos indicus* crosses was primarily due to weight of the dam.

The higher birth weight and preweaning growth rates of males than females within late generation Brahman and Sahiwal half crosses agrees with other reports for *Bos indicus* crosses in tropical environments (Kennedy and Chirchir 1971; Seifert 1975; Winks *et al.* 1978; Buvanendran 1990; Burrow *et al.* 1991). The 13% advantage to males that we found for these traits within first-backcross (F_1 3/4 cross) calves is higher than other reports.

The start of the 3-month calving season in our herd was, on average, 2 weeks before the start of the growing season. The trend for late calves to be 1 kg heavier at birth agrees with the report of Winks *et al.* (1978) and suggests that improved nutrition in the last trimester of pregnancy increases fetal growth, even though it may not be fully expressed through body condition of the dam. Winks *et al.* (1978) found a significant correlation (r = 0.22) in only 1 of 3 years between precalving body condition of *Bos indicus* cross cows and calf birth weight.

The only significant reversal to the birth weight advantage of late calves occurred in an extremely wet year (1973–74), when late-calving cows would have experienced greater stress in the precalving period than early calvers. In 2 other years, when a very late break in the season created greater nutritional stress in late calvers, there was a trend for late calves in some calf groups to be lighter at birth (1980–81 for F_2 half crosses; 1982–83 for late generation crosses).

The effect of precalving nutrition on birth weight was far more dramatic between years (22% range in birth weight), with birth weight increasing with the quality of dry season nutrition. Bellows and Short (1978) showed, with Hereford x Angus crosses, that cows fed high levels of energy in the final trimester bore calves 1.9 kg heavier at birth than cows fed a low level of energy. Our results and those of Bellows and Short (1978) contrast with the report by Frisch (1973*a*) in which birth weights of zebu cross calves were unaffected by drought. In that study, however, poor condition cows were supplemented daily during the period of nutritional stress with 2.25 kg of high quality hay. Cows in our study were given a high quality supplement [*ad libitum* molasses with 5% urea (w/w)] only in the severe drought of 1982–83.

There was no overall effect of birth date on preweaning gain. This contrasts with the reports of Winks *et al.* (1978) for F_1 calves in the same environment and Seifert *et al.* (1974) in a similar environment where early calves grew faster than late calves, but is in agreement with a subsequent report by Seifert (1975) for 1/2 *Bos indicus* crosses.

There was a marked variation in growth rate between years, with growth in the best season (1984–85) 24% higher than in the poorest season (1981–82). The trend was for preweaning growth rate to be higher with an earlier start to the growing season. A major component of this was the nutrition available to the dams for milk supply to the calf. Holroyd *et al.* (1979*b*) and Hunter and Magner (1989) reported moderate to high correlations between milk yields and calf growth rates in *Bos indicus* crosses. Siebert (1971) demonstrated that improved pasture increases milk yields in *Bos indicus* crossbred cows. Holroyd *et al.* (1979*b*, 1983) found that improved pasture resulted in higher postweaning growth rates of *Bos indicus* crossbred calves, and that a significant component of the effect may have resulted from pasture intake of calves. Winks *et al.* (1978) found that the growth rates of calves increased with increasing body condition of cows precalving. The profound effects of nutrition on calf growth rates are best seen when comparing wet and dry seasons. Growth rates of 0.38 kg/day were observed for suckling 5/8 *Bos indicus* cross calves <7 months of age during the early dry season (G. Fordyce unpublished data). Lee *et al.* (1985) has shown that protein supplementation of Brahman cross cows fed a low quality forage, dramatically increases milk yield (+2 kg/day) and calf growth rate (+0.4 kg/day).

Conclusions

Despite higher grade *Bos indicus* crosses having smaller, and possibly less robust, calves, a 3/4 cross appears more suitable than a 1/2 cross for producing heavier, and therefore more easily managed, weaners in environments which impose significant nutritional stress in the pre- and postweaning periods. The performance of Sahiwal crosses is slightly lower than Brahman crosses. The Sahiwal does not appear to offer any significant advantages over the Brahman in preweaning performance in the dry tropics. Heterosis for milk production in F_1 1/2 cross dams confers significant preweaning growth advantages in F_2 1/2 cross calves over F_3 *et seq.* crossbreds. No other significant heterotic effects on growth are likely to occur in F_2 or later generation crossbred calves where inbreeding is avoided.

Improving precalving and postcalving nutrition of cows in poor seasons may increase birth weights and growth rates of calves, thereby increasing calf survival and producing heavier weaners that are easier to manage.

In evaluating preweaning performance (birth weight and growth rate) of calves in a selection program, correction factors should be applied for the following: dam age (calves with young dams had, on average, 5% lower birth weights and growth rates than calves with mature dams); birth date (late calves were generally about 1 kg heavier at birth); filial generation of dam (the growth rate for calves suckling F_1 dams was about 8% higher than for calves suckling F_2 *et seq.* dams); management group (extremes in pre- and postcalving nutrition varied birth weights and preweaning growth rates by up to 25%).

Acknowledgments

We thank the many people who assisted in the conduct of this research, especially Russ Tyler, Kathleen Beaman (*nee* Heater), Ian Loxton, Joerg Laetsch, Honor Stephenson and Vivienne Doogan (*nee* Anderson).

We also thank the Australian Meat Research Committee for partial funding of the project (DAQ44).

References

Bellows, R. A., and Short, R. E. (1978). Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility. *Journal of Animal Science* **46**, 1522–8.

Burrow, H. M., Seifert, G. W., and Hetzel, D. J. S. (1991). Consequences of selection for weaning weight in Zebu, *Bos taurus* and Zebu x *Bos taurus* cattle in the dry tropics. *Australian Journal of Agricultural Research* **42**, 295–307.

Buvanendran, V. (1990). Adjustment factors for weaning weights of Mashona cattle in Zimbabwe. *Journal of Agricultural Science, Cambridge* **114**, 35–40.

Frisch, J. E. (1973*a*). Comparative drought resistance of *Bos indicus* and *Bos taurus* crossbred herds in central Queensland. 2. Relative mortality rates, calf birth weights, and weights and weight changes of breeding cows. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13**, 117–26.

Frisch, J. E. (1973*b*). Comparative drought resistance of *Bos indicus* and *Bos taurus* cattle in central Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13**, 127–33.

Frisch, J. E., and Vercoe, J. E. (1984). An analysis of growth of different cattle genotypes reared in different environments. *Journal of Agricultural Science, Cambridge* **103**, 137–53.

Harvey, W. R. (1960). Least squares analysis of data with unequal subclass numbers. United States Department of Agriculture, Agricultural Research Service. No. ARS-20-8.

Holroyd, R. G. (1987). Foetal and calf wastage in *Bos indicus* cross beef genotypes. *Australian Veterinary Journal* **64**, 133–7.

Holroyd, R. G., Arthur, B. A., and Mayer, B. G. (1979*a*). Reproductive performance of beef cattle in north-western Queensland. *Australian Veterinary Journal* **55**, 257–62.

Holroyd, R. G., James, T. A., Doogan, V. J., Fordyce, G., and O'Rourke, P. K. (1990*a*). The performance of Brahman–Shorthorn and Sahiwal–Shorthorn beef cattle in the dry tropics of northern Queensland. 1. Reproductive rates and liveweights of F_1 and backcross females. *Australian Journal of Experimental Agriculture* **30**, 717–25.

Holroyd, R. G., James, T. A., Doogan, V. J., Fordyce, G., Tyler, R., and O'Rourke, P. K. (1990*b*). The performance of Brahman–Shorthorn and Sahiwal–Shorthorn beef cattle in the dry tropics of northern Queensland. 2. Reproductive rates and liveweights of F_2 *et seq.* females. *Australian Journal of Experimental Agriculture* **30**, 727–33.

Holroyd, R. G., O'Rourke, P. K., and Allan, P. J. (1979*b*). Effect of pasture type and supplementary feeding on the milk yield of Shorthorn and Brahman cross cows and the growth rate of their progeny in the dry tropics of north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **19**, 389–94.

Holroyd, R. G., O'Rourke, P. K., Clarke, M. R., and Loxton, I. D. (1983). Influence of pasture type and supplement on fertility and liveweight of cows, and progeny growth rate in the dry tropics of north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **23**, 4–13.

Hunter, R. A., and Magner, T. (1989). The effect of supplements of formaldehyde-treated casein on the partitioning of nutrients between cow and calf in lactating *Bos indicus* x *Bos taurus* heifers fed a roughage diet. *Australian Journal of Experimental Agriculture* **29**, 389–94.

Joshi, N. R., and Phillips, R. W. (1953). Zebu cattle of India and Pakistan. F.A.O. Agricultural Studies. No. 19.

Kennedy, J. F., and Chirchir, G. I. K. (1971). A study of the growth rate of F_2 and F_3 Africander cross, Brahman cross and British cross cattle from birth to 18 months in a tropical environment. *Australian Journal of Agricultural Research* **11**, 593–8.

Lee, G. J., Hennessy, D. W., Williamson, P. J., Nolan, J. V., Kempton, T. J., and Leng, R. A. (1985). Responses to protein meal supplements by lactating beef cattle given a low-quality pasture hay. *Australian Journal of Agricultural Research* **36**, 729–41.

McCosker, T. H., Eggington, A. R., and Doyle, F. W. (1984). Observations on post-weaning performance of Brahman cross animals in the Darwin district of the Northern Territory. *Proceedings of the Australian Society of Animal Production* **15**, 452–5.

Parker, R. J., Jones, G. W., Ellis, K. J., Heater, K. M., Schroter, K. L., Tyler, R., and Holroyd, R. G. (1986). Post-weaning coccidiosis in beef calves in the dry tropics: experimental control with continuous monensin supplementation via intra-ruminal devices and concurrent epidemiological observations. *Tropical Animal Health and Production* **18**, 198–208.

Seifert, G. W. (1975). Effectiveness of selection for growth rate in Zebu x British crossbred cattle. I. Pre-weaning growth. *Australian Journal of Agricultural Research* **26**, 393–406.

Seifert, G. W., Rudder, T. H., and Lapworth, J. W. (1974). Factors affecting weaning weight of beef cattle in a tropical environment. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**, 277–80.

Siebert, B. D. (1971). Growth and water metabolism of cows and progeny on fertilized and unfertilized tropical pastures. *Australian Journal of Agricultural Research* **22**, 415–28.

Snedecor, G. W., and Cochran, W. G. (1974). 'Statistical Methods.' 6th Edn. (Iowa State University Press: Ames , IA, U.S.A.)

Stubbs, W. C. (1962). Brahman cross tops beef cow milk yield. *Queensland Agricultural Journal* **88**, 362.

Syrstad, O. (1985). Heterosis in *Bos taurus* x *Bos indicus* crosses. *Livestock Production Science* **12**, 299–307.

Turner, H. G. (1975). Breeding of beef cattle for tropical Australia. AMRC Review No. 24. pp. 1–30.

Weston, E. J., Harbison, J., Leslie, J. K., Rosenthal, K. M., and Mayer, R. J. (1981). Assessment of the agricultural and pastoral potential of Queensland. Queensland Department of Primary Industries. Agriculture Branch Technical Report No. 27.

Winks, L., O'Rourke, P. K., Venamore, P. C., and Tyler, R. (1978). Factors affecting birth weight and performance to weaning of beef calves in the dry tropics of north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **18**, 494–9.

Received 9 December 1991, accepted 17 August 1992