COMPARISON OF AFRIKANER- AND BRAHMAN- CROSS CATTLE IN PAPUA NEW GUINEA

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Summary

After the virtual eradication of cattle during World War II, Papua New Guinea herds were rebuilt with Shorthorn and Aberdeen Angus cattle from Australia. These, and Red Sindhi and Sahiwal, imported in 1952, were considered unsuitable breeds. In 1954, Department of Agriculture, Stock and Fisheries imported three Brahman bulls and three heifers from Texas and in 1960 began importations of Afrikaner from Queensland. In Central Province, Brahmans were crossed with Angus and at Erap (Morobe) the hottest place in Papua New Guinea, Shorthorns were crossed with Afrikaners. In 1965, Brahman and Brahman-cross were sent to Erap. Records of breeding and growth rates were collected for use in upgrading in cattle on the basis of performance, not pedigree. The data are not ideal for genetic analysis, since no control groups were maintained. Birth weights (BWT), weaning weights (WWT) and calving intervals (CI) were analysed for the period 1969-1978. After exclusion of unsatisfactory data, 2,514 calf records were used, including both breeds from 1969 to 1973, but only Brahman-cross subsequently.

Breed mean BWT ranged only from 30.6 to 33.8 kg. As Brahman content increased, BWT decreased and WWT increased; within a genotype, there was a negative maternal effect of high Brahman content on BWT and a positive effect on WWT which ranged from 138 to 174 kg. Afrikaner calves had heavier BWT but lighter WWT. As expected, bulls were heaviest, heifers lightest and mature cows bore and reared heavier calves. Calving interval (405 days, equivalent to 90% calving) was unaffected by breed but 4-year old cows averaged 423 days.

Breed differences in BWT and WWT are consistent with the body of literature on performance of Brahmans and Afrikaners. Since cattle tick are not present and internal parasites are insignificant at Erap, the superiority of Brahmans indicates that they were better at utilising the mediocre quality grazing of the Markham Valley or were more heat tolerant. Performance selection over ten years resulted in the virtual elimination of Afrikaners, with the final genotype approximately 9/16 Brahman, 3/8 Shorthorn and 1/16 Afrikaner.

(**Key Words**: Brahman, Afrikaner, Papua New Guinea, Weaning Weight, Reproduction)

Introduction

Cattle have been introduced to Papua New Guinea (PNG) since the 1880's from both Australia and South East Asia, but during World War II, the cattle population was almost eradicated. The Shorthorn and Aberdeen Angus cattle subsequently imported from Australia were obviously unsuited to the humid tropical lowlands. Red Sindhi and Sahiwal imported from Pakistan in 1952 were not considered to be the optimal breed for PNG and have made only a small contribution to the local cattle herd (Anderson, 1972). In 1954, the Department of Agriculture, Stock and Fisheries imported three Brahman bulls and three heifers from Texas and in 1960 began importing Afrikaner cattle from CSIRO, Rockhampton, Qld, Australia. Brahmans were crossed with Aberdeen Angus at Moitaka, near Port Moresby, while Afrikaners were crossed with Shorthorns (AX) at Erap, near Lae, on the north coast (Anderson, 1961a). A series of trials rapidly established the superiority of both crossbreds over the pure-bred temperate breeds (Anderson, 1966),

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despite the occasional occurrence of lactational anoestrus in the Brahman cattle (Anderson, 1961b). In 1965, direct comparisons began of Brahman- and Afrikaner- Shorthorn crosses (BX and AX) at Erap.

Reproductive and growth data were recorded for all cattle at Erap, utilising the Australian National Beef Recording Scheme (NBRS) to calculate calving intervals (CI) and standardised pre- and post weaning growth rates. These data were used, together with assessment of temperament, to select herd replacements in a breeding program designed to produce superior adapted cattle for distribution to livestock owners; the data have many deficiencies for genetic analysis. However, these data from 1969 to 1978 allow estimation of the effects on calves' birth weight (BWT) and weaning weight (WWT) of the age of dam, sex of calf and several levels of crossbreeding with three breeds, in an equatorial lowlands environment for which no data are available. The BX and AX cattle of northern Australia originate from the same narrow genetic base as the P. N. G. cattle, permitting comparisons between the equatorial P. N. G. environment and the drier tropical regions of Australia.

Materials and Methods

Environment

The Pastoral Research Centre, 'Erap', comprised 2000 ha of the alluvial outwash of the Erap River, at 100 m altitude, in the Markham Valley, 55 km west of LAE. The climate is uniformly hot, with two wet seasons separated by short dry seasons (table I). The soils range from free-draining sandy and gravelly loams in the north to silty loams overlying a shallow water table in the south. On lighter soils *Sida* spp. and in some areas *Dichanthium annulatum* rapidly replaced the original *Themeda australis* when grazing commenced in the 1950's. *Imperata cylindrica* occurs on heavier soils and *Saccharum* species and sago palms in the wetter areas. Approximately 500 ha were fully improved, with *Cenchrus ciliaris* (Biloela and Nunbank Buffel grass) on lighter soils, *Panicum maximum* (Hamil grass) and small areas of *Brachiaria decumbens* and *B. mutica* on heavy soils. Due to the high pH of soil and water, of the introduced legumes only *Leucaena leucacephala* flourished, although *Calopogonium mucinodies, Macroptilium atropurpureus* and *Stylosanthes guianensis* occurred sporadically in all pastures. Set-stocking was practised, with cattle moved to drier areas in wet seasons and vice versa, so that some green feed was available to most cattle most of the time. For most of the study period, stock numbers were about 1700 cattle, 70 horses, 140 water buffalo and up to 500 sheep. When set-stocked all year round steers grew 0.65 kg/day at 2/ha on Buffel grass, but only 0.25 kg/day at 1/ha, on native pastures.

TABLE 1. CLIMATIC DATA FOR ERAP FOR 1948-1985

	Rainfall/ month (mm)	Chance of effective rain* (%)	Mean maximum temperature (℃)	Mean minimum temperature (℃)	Relative humidity index (%)
January	144	89	33.8	22.1	74
February	149	90	33.9	22.4	74
March	165	92	34.0	22.5	77
April	103	89	33.6	21.7	76
May	60	54	32.3	23.3	80
June	71	66	32.0	20.9	80
July	90	79	30.9	20.4	82
August	90	74	30.9	20.5	81
September	77	63	31.7	20.7	81
October	80	59	32.3	21.1	79
November	82	68	34.0	22.0	75
December	136	86	33.9	22.5	74

* Effective rain: at least 50 mm in 10 days.

P.N.G. is devoid of the major cattle diseases such as FMD, Rinderpest, Pleuropneumonia, Brucellosis, Tuberculosis and Vibriosis. Cattle tick was not present in this district. The only mineral deficiency known at Erap is sodium; salt is provided.

Herd Management and Breeding Program

Since Erap has two wet seasons, and no significantly better time for calving (Schottler and Williams, 1977), year round mating was practiced. Pregnant cows of all breeds ran together until about six weeks after they calved when they were re-allocated to mating groups with one or more bulls. Cows of different breeds were separated only for the mating period until diagnosed pregnant. All calves and their dams were yarded within one day of birth; they were treated to prevent myiasis (Chrysomia bezziana infestation), calves were weighed and ear tagged and dams' identities were recorded. WWT was recorded after overnight fasting. Until 1972, most male calves were castrated at six weeks of age. From 1973, the Station produced bulls for distribution to small-holders and male calves were not castrated before weaning. Most males were sold soon after weaning, while heifers entered grazing trials, so few post-weaning data were recorded.

NBRS analysis of WWT, post-weaning growth and subjective assessment of temperament were the basis for selection of heifers and bulls, while cows were culled on the basis of NBRS records for calf WWT, failure to breed, poor temperament or poor condition. The reason for culling individuals was not usually recorded. From 1965, Droughtmaster (approximately 1/2 Brahman, 1/2 Shorthorn) and other Brahman cross (BX), Brahman and AX bulls were mated to BX and AX cows, producing cattle with varying levels of Brahman, Afrikaner and Shorthorn content. Generally AX cows were mated to AX bulls. The calves in this study were third to fifth generation crossbreds.

Statistical Analysis

Since genotypes were somewhat confounded within year, the data was split into two subsets for analysis of genotype comparisons, Set (I): records from 1969 to 1972 on BX and AX heifer, steer and bull calves, Set (II): from 1973 to 1978, only BX heifer and bull calves. Sire, dam and calf genotypes and the number of records used are shown in table 2. Many records were rejected as unsatisfactory for analysis: e.g. the genotype of many cows was not known with sufficient accuracy and in some cases changes in management had led to incomplete recording. About 2,500 preweaning records were analysed from about twice that number of calves born.

Data were analysed by least-squares procedures using the following fixed effects model:

$$Y_{ijklm} = u + g_i + s_j + y_k + b_l + a_m + e_{ijklm}$$

where Y_{ijklm} is the liveweight or liveweight gain of an individual animal,

u is the population mean,

g_i is the ith genotype of the calf where $i = 1_{1-6}$ for genotypes listed in Table 2,

s_j is the jth sex with $j = 1$, 2 and 3 for males, females and steers, respectively,

y_k is the yth year of birth of the calf,

b_l is the lth season of birth with $l = 1, \cdots 4$ for January-March, April-June, July-September and October-December, respectively,

a_m is the mth age of dam with $m = 1, \cdots 4$ for 3, 4, 5-9 and > 9 years old, respectively and

e_{ijklm} is a random error on the observation.

All first-order interactions were fitted, but were removed from the model if not significant at the $p < .05$ level. Traits analysed were BWT, WWT (adjusted by linear regression to an average age of 200 days) and post-weaning average daily gain (ADG). Only a few post-weaning records were available in Set II so ADG was not included in this analysis.

Calving interval (CI) was also analysed as a trait of the cow using a model similar to that for calf growth except that effects for cow genotype and sire genotype replaced the effects of calf genotype. All records of calving intervals greater than 620 days were excluded from the analysis to avoid bias in the estimation of calving interval in normal breeding cows. We considered that cows not calving within 620 days either had missing records or had permanently impaired fertility. Since cows were constantly being culled for reproductive performance, there were few in this latter category. As some of the culling was on the basis of pregnancy testing, cows were removed from the herd before the calving which would have resulted in recording of a long CI. Fertility is thus indicated by the ability of cows

TABLE 2. SIRE AND DAM GENOTYPE COMBINATION USED TO PRODUCE CALVES FROM 1969-1972 AND 1974-1978

	Sire genotype		Dam genotype	Calf genotype	Number of pre-weaning records
1969-1972					
Analysis 1	1B[a]	×	1/2B	3/4B	102
	3/4B	×	1/2B	5/8B	161
	3/4B	×	1/4B	$1/2B_1$[b]	202
	1/2B	×	1/2B	$1/2B_2$	744
	1/2A	×	3/4A	5/8A	92
	1/2A	×	1/2A	1/2A	394
1974-1978					
Analysis 2	1B	×	1B	1B	168
	1B	×	3/4B	7/8B	41
	1B	×	1/2B	$3/4B_1$	166
	1/2B	×	1B	$3/4B_2$	6
	1/2B	×	3/4B	5/8B	51
	1/2B	×	1/2B	1/2B	387

[a] Only the proportion of "tropical breed" (Afrikaner, A, or Brahman, B) content is shown.
[b] Subscripts identify calf genotypes with the same zebu content but differences in genotypes of their parents.

to remain in the herd under this culling regime, rather than by the CI recorded. As calving rate was high and cow mortality was extremely low, many fertile young cows were sold to local small-holders before they yielded useful data on CI. As a result, for 1973-1978, too few records were available to analyse CI.

Results

Genotype effects on all calf growth traits were large and significant (table 3). Generally, as Brahman content of the genotype increased, BWT decreased and ADG and WWT increased. In analysis 1, Brahman cross calves were non-significantly lighter at birth than Afrikaner cross calves, but at weaning were heavier ($p < 0.001$). In Analysis 2, as the proportion of Brahman genotype increased from 50% to 100%, weaning weight increased by 15.9 kg. Calves with similar Brahman content (1/2 Brahman in analysis 1, 3/4 Brahman in Analysis 2) but with dams lower in Brahman content grew slightly faster but their weaning weights were not significantly greater. This indicated that any negative maternal effect of higher Brahman content on BWT and any positive effect on WWT were quite slight. Both Afrikaner cross (AX) genotypes tended to be heavier at birth but grew more slowly before and after weaning. Overall, bull calves had greater BWT, WWT and postweaning ADG than heifers, with steers intermediate (table 4). Older cows produced calves with significantly greater BWT and WWT (table 5) but post-weaning ADG was unaffected by age of dams. CI was significantly affected by age of the cows; four year-old cows had significantly longer CI and the oldest cows slightly shorter CI (table 6). There was no consistent pattern in any performance characteristic between seasons or years. There were no sire genotype, dam genotype or other fixed effects on CI so no data for individual groups are presented. The mean CI of 405 days is equivalent to an annual calving rate of 90%. By 1978, the breed composition of the Erap herd had altered from 1/2 Shorthorn, 1/2 Afrikaner or Brahman to 9/16 Brahman, 6/16 Shorthorn and only 1/16 Afrikaner, due to selection on growth and fertility.

Discussion

Average BW of all genotypes lay between 30.6 (pure Brahman) and 33.8 kg (half Brahman,

TABLE 3. LEAST-SQUARES MEANS (μ) AND GENOTYPE EFFECTS ON CALF GROWTH TRAITS IN ANALYSES 1 AND 2

	Birth wt (kg)	200 day weaning wt	Post weaning ADG
Analysis 1			
$\mu \pm$ s.e.	32.6 ± 0.4	151.8 ± 1.5	0.288 ± 0.010
3/4B	− 0.1	+ 7.6[a]	+ 0.047[a]
5/8B	− 0.5	+ 4.2[ab]	+ 0.007[b]
1/2B_1	− 0.3	+ 2.8[b]	+ 0.043[a]
1/2B_2	− 0.1	+ 4.0[ab]	+ 0.019[ab]
5/8A	+ 0.1	− 12.5[d]	+ 0.080[d]
1/2A	+ 0.9	− 6.1[c]	− 0.036[c]
Significance	n.s.	***	***
Analysis 2			
$\mu \pm$ s.e.	32.3 ± 0.5	166.1 ± 2.6	−
1B	− 1.7[a]	+ 7.8[a]	
7/8B	+ 0.2[ab]	− 0.4[ab]	
3/4B_t	+ 1.5[b]	+ 0.7[ab]	
3/4B	− 1.3[a]	+ 4.2[a]	
5/8B	− 0.6[a]	− 4.2[b]	
1/2B	+ 1.5[b]	− 8.1[b]	
Significance	**	*	−

n.s.: Not significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
[a,b,c,d] Means within a column with different superscripts are significantly different.

TABLE 4. LEAST-SQUARES CONSTANTS FOR SEX AFFECTS ON BIRTH WEIGHTS (BWT), WEANING WEIGHT (WWT) AND POST-WEANING AVERAGE DAILY GAIN (ADG) IN ANALYSES 1 AND 2

Trait	$\mu \pm$ s.e.	Sex effect			Significance
		Bulls	Steers	Heifers	
Analysis 1					
BWT (kg)	32.6 + 0.4	+2.2[a]	−0.5[b]	−1.7[c]	***
WWT (kg)	151.8 ± 1.5	+16.1[a]	−5.4[b]	−10.7[b]	***
ADG (kg/day)	0.288 ± 0.10	+.053[a]	−.009[b]	−.044[c]	
Analysis 2					
BWT (kg)	32.3 ± 0.5	+0.7[a]	−	−1.7[b]	*
WWT (kg)	166.1 ± 2.6	+4.5[a]	−	−4.5[b]	**

* $p < 0.05$.
** $p < 0.01$
*** $p < 0.001$.
[a,b,c] Means in a row with different superscripts are significantly different.

Set. II); these BW are not small enough to present a problem with survival of undersized calves or large enough to cause dystocia. From 1973 to 1979, dystocia occurred in less than 1% of 2500 births among all genotypes. Cows with calving problems were culled. The greater BWT of Afri-

TABLE 5. LEAST-SQUARES CONSTANTS FOR DAM AGE EFFECTS ON BIRTH WEIGHT (BWT) AND WEANING WEIGHT (WWT) IN ANALYSES 1 AND 2

	Trait	$\mu \pm$ s.e.	Dam age effect (kg)				Significance
			3	4	5-9	10+	
Analysis 1							
	BWT	32.6 ± 0.4	-0.9^{a}	-0.2^{b}	$+0.1^{b}$	$+1.0^{c}$	**
	WWT	151.8 ± 1.5	6.5^{a}	-0.1^{b}	$+5.1^{c}$	$+1.5^{bc}$	***
Analysis 2							
	BWT	32.3 ± 0.5	1.7^{a}	0.0^{b}	$+0.9^{b}$	$+0.8^{b}$	***
	WWT	166.1 ± 2.6	-7.0^{a}	0.0^{ab}	$+1.1^{b}$	+5.9	n.s.

n.s.: not significant.
** $p < 0.01$
*** $p < 0.001$.
a,b,c Means in a row with different superscripts are statistically significantly different.

TABLE 6. LEAST-SQUARES CONSTANTS FOR DAM AGE EFFECTS ON CALVING INTERVAL ANALYSIS 1

	$\mu \pm$ s.e.	Dam age effect (kg)				Significance
		3	4	5-9	10+	
Calving interval	405.4 ± 6.6	-4.5^{a}	$+18.2^{b}$	4.2^{a}	-9.5^{a}	**

kaner-cross calves and the progressive reduction of BWT with increasing Brahman content, found after several generations of cross-breeding, are consistent with previous reports (Holmes, Takken and Seifert, 1968; Hetzel, 1985). In Australia, several authors recorded that Brahman-sired F1 calves were larger at birth than many F1 *Bos taurus* crossbreds and F1 Afrikaner- Shorthorns, and caused more dystocia (Copland, 1985). This problem was resolved by further cross-breeding and selection; F1 Brahman cows bore the smallest calves with the least difficulty (Obst and Morgan, 1985).

Increases in WWT with Brahman content are consistent with the higher milk production of BX than AX in central Qld (Holmes, Takken and Seifert, 1968) and may also reflect superior adaptation of Brahmans to this constantly hot environment. Carrick and Pratchett (1985) found that F2 Brahman-Shorthorn calves weighed 155 kg, 14 kg more than Afrikaner- Shorthorn calves, at weaning in the seasonally extremely hot Kimberley area of Western Australia. Among the genotypes studied in P.N.G., the pure-bred Brahman was superior in growth and may be the optimum genotype. When equivalent genotypes are compared between the early and later sets of data, growth rate had increased by about 0.030 kg/day. This may represent the result of selection on performance, but it is completely confounded with increases in stocking rate, increase in area of improved pasture and presumably an improvement in indefinable aspects of management during the period of the study.

Maternal influence on BWT of calves of similar genotype, 1/2 B, with dams of different genotype, 1/4 B or 1/2 B, was non-existent, but between 3/4 B calves from 1/2 B or B cows, there was a reduction of 2.8 kg due to high grade dams. Whether under extremes of heat and poor nutrition as in P.N.G. or cool conditions with good nutrition in southern Australia, Brahman cross cows bear light calves; the nature of this maternal effect is unknown, but it may be related to poorer visceral blood supply and enhanced peripheral blood supply which facilitates heat dissipation. Maternal influences on WWT between calves of similar genotype but different dam genotype were small, in favour of calves whose dams were higher grade Brahmans, presumably with higher milk production and generally better adaptation.

Post-weaning growth rates were not high, since weaners were merely being held until distribution to small holders, rather than being grown for beef production. When stocked for production, steers could be grown at 0.7 kg/day (Holmes, 1985). ADG increased with Brahman content, as with pre-weaning data.

The obvious inferiority in growth of the AX partly explains their rapid disappearance as a major contributor to the genetic composition of the herd. The reasons for the better performance of BX are not clear: there were no cattle tick (Boophilus microplus) at Erap; drenching for internal parasites gave little benefit (Glasgow, 1966); kerato-conjunctivitis occurred but responded rapidly to treatment; the growth rates indicate moderate levels of nutrition. Systematic measurements of these and other factors may have revealed consistent, if small, differences in favour of BX, as shown by Lemerle and Holmes (1986) regarding the high-grade Brahman's relative insensitivity to sodium deficiency at Erap.

Direct heat stress may be responsible for the breed differences; Erap is consistently the hottest weather- recording station in P.N.G. During the heat of the day it was often noted that white Brahman cattle rested in the sun, while the coloured cattle, with less Brahman content, sought shade. It is not known if lowgrade Brahmans were able to alleviate heat stress completely without reducing grazing time. Brahmans and Afrikaners maintain similar body temperatures, well below British breeds, when heat-stressed (Hetzel, 1985); however, even within these supposedly heat-tolerant breeds, heat stress can depress growth rate significantly.

The effects of sex of calf on BWT and WWT are consistent with the data of the Australian NBRS. The 2.7 kg superiority in BWT of bulls over steers is merely an indication that small size was a major criterion for castration. The effects of dam age on BWT and WWT are also consistent with the patterns reported by NBRS, the high weights recorded from very old cows indicating that selection on performance has retained only the best cows to this age.

The management of reproduction, as described, prevented the expression of differences between genotypes in CI, since cows were culled after pregnancy testing, before they could express differences. The disappearance of AX cattle from the herd would have been partly due to poor results at pregnancy testing and the consequent anticipated long CI. The CI of 405 days with year-round mating, equivalent to a calving rate of 90% per annum, is perhaps the consequence of the selection program employed, but indicates the high fertility of the selected population of both breeds at Erap. At Rockhampton, at 22.5 S, F2 and F3 AX cows had 16% higher calving rate than BX (77% vs 61%, Hetzel, 1985); in the Kimberleys, at 16 S, limited data indicated 24% higher rates in AX (71% vs 47%, Carrick and Pratchett, 1985). But at latitude 20 S in Queensland, Entwistle and Goddard (1985) found that F2 BX had pregnancy rates 11% higher than AX, 57% vs 46%. The combination of the PNG environment and this management system is superior for reproduction to any of the Northern Australian environments where closely related cattle of both breeds have been compared.

The selection program at Erap, based on these data as they accumulated, eliminated the Afrikaner as a major component of the cattle herd in less than ten years. There are areas in Central Queensland where the Afrikaner can make a contribution to an adapted beef genotype, as in the Belmont Red breed, but growth rates of Afrikaner crosses were poorer than Brahman crosses in northern Queensland, northern W. A. and P. N. G. while reproduction was no better than Brahmans except in the limited data from W. A. In P. N. G., with F2 and F3 cattle, the poor performance of AX cattle is not likely to be due to inbreeding. As parasitism and nutritional problems were mild, the superior performance of the Brahman may have been due mainly to direct heat tolerance.

Literature Cited

Anderson, J. L. 1961a. A project in the development of cattle adapted to a tropical environment. Papua New Guinea J. Agric. 14:113-123.

Anderson, J. L. 1961b. Breeding problems in cattle in Papua and New Guinea. Aust. Vet. Jour. 37: 162.

Anderson, J. L. 1966. The effect of the environment in Papua and New Guinea on the growth and reproduction of cattle. M. V. Sc. thesis, University of Queensland, pp. 122.

Anderson, J. L. 1972. The importation of cattle from Pakistan to Australia in 1952. Aust. Vet. Jour. 48:87-93.

Carrick, M. J. and D. Pratchett. 1985. Progress in the evaluation of cattle genotypes for Northwestern Australia. in Evaluation of Large Ruminants for the Tropics ACIAR proc. No. 5 Edit. J. W. Copland. pp. 134-137.

Copland, J. W 1985. Editor: Evaluation of Large Ruminants for the Tropics. ACIAR Proc. No. 5, Proceedings of an international workshop held at CSIRO, Rockhampton, *Queensland, Australia*, 19-23 March, 1984.

Entwistle, K. W. and M. E. Goddard. 1985. Productivity of some Bos indicus cross genotypes in sub-coastal northern Queensland. in Evaluation of Large Ruminants for the Tropics. ACIAR proc. No. 5 edit J. W.Copland. pp. 156-160.

Glasgow, J. D. 1966 Papua New Guinea Agricultural Journal 18:17-19

Hetzel, D. J. S. 1985. Understanding genotype/environment interactions: the Rockhampton experience. in Evaluation of Large Ruminants for the Tropics. ACIAR Proc No. 5, edit J. W. Copland. pp 126-133.

Holmes, J. H. G. 1985. Beef breeds for the humid tropics: a review of PNG experiences in Evaluation of Large Ruminants *for the* Tropics ACIAR Proc. No. 5, edit J. W. Copland, pp. 61-67.

Holmes, J. H. G., A. Takken *and* G. W. *Seifert*. 1968. Milk production and calf growth rate in *Hereford*, Afrikaner Shorthorn and Brahman Shorthorn cattle in Queensland. Proc. Aust. Soc. Anim. Prod. 7:163-171.

Lemerle, C. and J. H. G. Holmes. 1986 Sodium deficiency of grazing cattle in Papua New Guinea. Trop. Anim. Hlth. Prod. 18:166-170.

Obst, J. M. and J. H. L. Morgan. 1985. Breed evaluation of large ruminants in Southern Australia ACIAR Proc No. 5. edit J. W. Copland, pp. 113-119.

Schottler, J. H. and W. T. Williams. 1977. Aust. J. Exper. Agric. 15:456