Phenotypic and genetic parameters in cattle populations in Ghana

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Summary

This paper reviews phenotypic and genetic parameters in cattle in Ghana. Breeds include the Ghana Shorthorn (GSH), N'Dama, Sokoto Gudali, Sanga (indigenous breeds), Holstein–Friesian (exotic) and crosses between the indigenous breeds and exotics, including Jersey, Red Poll and Santa Gertrudis. A brief history of the dairy industry in Ghana is provided. Traits reviewed for the breeds, maintained in the coastal savannah zone and humid forest zone, include milk production, reproduction, calf growth, carcass parameters and adaptive traits. Even though exotic dairy breeds initially had higher milk production in Ghana than the indigenous breeds, none of the exotic breed programmes could be sustained. Both additive and heterotic effects were important in improving lactation traits in the GSH. Crossbreeding improved reproductive traits. Total heritability figures for birth and weaning weights indicated that selection would be effective in improving the two traits. Carcass parameters showed that crossing Red Poll or Santa Gertrudis with N'Dama improved weight at slaughter and warm carcass weight. Heat tolerance trials and mortality data indicated that while the Sokoto Gudali was the most adapted to heat stress, crossbred animals were better adapted than Holstein–Friesians in the hot humid coastal savannah zone.

Introduction

Ghanaian cattle like other cattle in the tropics are inherently slow maturing and low milk producers. In addition, the levels of nutrition and management to which they are exposed are generally low. Increases in milk and beef production in the country may therefore be achieved through improvement of the environmental conditions as well as the genetic capabilities of the cattle used in the system. The low genetic merit for milk production has been recognised as the major constraint to increased milk production in the country.

In general, efforts to improve the inherent milk producing ability of tropical cattle have involved such policies as breed replacement, selection within the local breeds and crossbreeding with exotic breeds. Some aspects of these strategies have been discussed by Cunningham and Syrstad (1987). The indications are that while breed replacement may be the fastest means of improving the genetic constitution of local tropical cattle, it will be too expensive to be of practical significance. Selection within local breeds, until recently, has also been considered too slow a process for improving milk production. Crossbreeding has been the method of choice for improving the milk or beef producing ability of indigenous cattle. Although the more recent technique of biotechnology (recombinant DNA technique) holds prospects, it has not been successfully integrated on a large-scale into breeding programmes. However, in view of current trends with this method, the future approach to breeding experiments may take an entirely different line.

In Ghana, there have been various breeding experiments involving the major cattle breeds used in the production systems in the country. These are the Ghana Shorthorn (West African Shorthorn), Ghana

Sanga, White Fulani, Sokoto Gudali, N'Dama and Muturu, as well as various crosses among these breeds. In addition, temperate breeds like the Holstein–Friesian, Jersey, Red Poll and Santa Gertrudis have been imported and used either as pure breeds or in crossbreeding with some of the indigenous breeds. While local farmers have generally used the bigger *Bos indicus* breeds as sire breeds for crossing with the smaller indigenous taurine breeds, institutional farms have often used imported temperate taurine breeds either as pure breeds (males and females) or as sire breeds (semen) in crossbreeding with indigenous breeds. The objectives of the various crossbreeding programme for both milk and beef traits have generally been to combine the merits of the breeds involved in the cross. Recently, however, there has been a renewed interest in indigenous breeds because of their adaptability and disease resistance. This has resulted in the adoption of open nucleus breeding schemes for the genetic improvement of indigenous breeds in Ghana.

Information has accumulated over the years on the characteristics and production levels of some breeds and breed crosses in the country. Various subsets of data collected have been analysed to address specific issues pertaining to the breeding programmes. However, the existing body of knowledge on phenotypic and genetic parameters in the cattle breeds and breed crosses has not been fully collated to answer crucial questions relating to the genetic improvement of cattle in different production environments in Ghana. The major performance traits that have been studied in various genotypes and production systems include milk production traits, reproduction traits, calf growth traits and carcass traits. Adaptive characteristics including heat tolerance in some exotic breeds have also been studied. To put this body of knowledge together in order to fully understand the issues and have a sense of direction, this case study seeks to address the following questions.

- What are the levels of performance of indigenous and imported temperate cattle breeds in various production environments in the country?
- How do crossbred animals (exotic × indigenous) compare with indigenous breeds for production traits under prevailing environmental and management conditions?
- What is the optimum level of exotic breeding?
- What are the magnitudes of genetic parameters for beef and dairy traits?
- Given the current emphasis on the importance of indigenous cattle breeds and their improvement in open nucleus breeding schemes, where are the information gaps?

Milk production traits

Indigenous cattle

There is very little information on the milk production of indigenous taurine breeds in Ghana simply because these animals are generally not milked. The history of attempts to establish a dairy industry in Ghana was reviewed by Kabuga (1989). This is summarised in Table 1. The first attempt was in 1941 when a scheme was put forward by the then Ministry of Agriculture to start a dairy farm at Nungua Animal Husbandry Station, using Ghana Shorthorn cattle. Because the milk yield of the breed was too low, the scheme was abandoned. A new scheme was put forward in 1942 to import Bunaji (White Fulani) cattle from Nigeria to start a nucleus dairy herd. Eleven cows and 2 bulls were imported from the Nigerian Ministry of Agriculture and subsequently, in 1943, 100 heifers and cows, and 4 bulls were purchased from Fulani owners in Nigeria. On arrival in Ghana, 32 of the heifers were found to have brucellosis. Then in 1944, CBPP (contagious bovine pleuropneumonia) nearly wiped out the herd. The dairy farm idea was abandoned but the herd was maintained to provide bulls for crossing with Ghana Shorthorn. The resulting crossbred animals were called Sanga. Today the Sanga is the commonest milking animal in Ghanaian herds. Other attempts included the use of Holstein–Friesian and Brown

Swiss as purebreds. In general, the various programmes could not be sustained in the long term. The milk yields obtained in indigenous cattle breeds used in various experiments are shown in Table 2.

Table 1. History of the dairy industry in Ghana.

Year	Location	Breed	Activity	Outcome
1941	Nungua Farm	Ghana Shorthorn (GSH)	Establishment of dairy farm by MoA*.	Scheme abandoned due to low level of milk production.
1942 1943	Nungua Farm	Bunaji (White Fulani)	117 Bunaji cattle imported by MoA from Nigeria to start nucleus dairy herd.	Brucellosis was a problem, CBPP (contagious bovine pleuropneumonia) nearly wiped out herd.
1958	University of Ghana Agricultural Research Station (ARS)	Jersey x local breeds (i.e. GSH, N'Dama and Sokoto Gudali)	One Jersey bull was imported from UK for crossbreeding work.	Programme continued with subsequent importations of Jersey and Friesian Semen. Programme was suspended as a result of heavy culling due to tuberculosis from 1978 to 1981, and theft.
1964	Adidome (Volta Region)	Russian Black-and-White	Establishment of dairy farm from 30 animals by State Farms Corporation.	–
1967	Amrahia Dairy Farm	[1]Holstein–Friesian	100 in-calf and 20 bulls imported from UK by MoA.	Programme continued with subsequent importation of 400 Friesian cattle from the Netherlands, 200 each in 1974 and 1976. Programme could not be sustained.
1974	University of Science and Technology, Kumasi	[1]Holstein–Friesian	35 cows and 5 bulls imported from Canada.	Programme 'succeeded' for a while but was later found unsustainable.

Year	Location	Breed	Activity	Outcome
1977	Accra Plains	Brown Swiss	37 animals imported by a private entrepreneur from Austria to set up a dairy farm.	Programme could not be sustained.
1978	Mim (Brong Ahafo Region)	Jersey crosses	Jersey crosses purchased from ARS to start dairy farm.	–

*MoA = Ministry of Agriculture, now known as Ministry of Food and Agriculture.

Adapted from Kabuga (1989).

Table 2. Milk yield, lactation length and milk fat (%) (mean ± std. error) of indigenous cattle on the Accra Plains.

Breed	Mean total milk yield (kg)	Lactation length (days)	Average daily milk yield (kg)	Milk fat (%)	Milking system	Production environment	Source
Bunaji	619.2 ± 29.9 (109)	–	–	–	DM[2]	On station	Kabuga (1989)
	677 ± 33.0 (68)	–	–	–	DM	On station	”
	571 ± 45.8 (52)	–	–	–	DM	On station	”
Ghana Shorthorn	383.5 ± 30.4 (6)	182	–	–	WSW[4]	On station	Montsma (1960)
	584.1 (6)	182	–	–	WSW	On station	Montsma (1963)
	1002.3 ± 27.39 (6)	252	2.9	–	WSW	On station	Montsma (1962)
	774.0 ± 26.99 (14)	295	0.9–9.00	1.3	WSW	On station	Ngere et al. (1975)
	656.9 ± 183.6 (20)	261 ± 11.85 (20)	2.5	1.3 ± 0.4 (9)	WSW	On station	Rege et al. (1994a)
	44.0 ± 20.77 (10)	–	1.1 ± 0.63 (10)	3.3 ± 0.28 (9)	DM	On station	Akah (1992)
	44.0 ± 212 (10)	29 ± 27.4 (10*)	–	4.1 ± 0.32 (10)	DM	On station	Rege at al. (1994b)
Sokoto Gudali	1145 ± 226 (9)	167 ± 30.4 (9)	5.3 ± 0.69 (9)	4.6 ± 0.30 (8)	DM	On station	Akah (1992)
	893	182	–	–	WSW	On station	Montsma (1963)
	1069 ± 223.5 (9)	198 ± 28.9 (9)	–	5.1 ± 0.34 (9)	DM	On station	Rege at al. (1994b)

Breed	Mean total milk yield (kg)	Lactation length (days)	Average daily milk yield (kg)	Milk fat (%)	Milking system	Production environment	Source
	1532.7 ± 65.69 (9)	252	4.8	–	WSW	On station	Montsma (1962)
	1365 (4)	252	–	5.6	DM	On station	Ngere (1971)
Sanga			0.87 ± 0.01[5] (9)	4.11 ± 1.11 (10)	DM	Smallholder	Okantah (1991)
N'Dama	593.0	182	–	–	WSW	On station	Montsma (1963)
	426 (4)	150	–	–	DM	On station	Ngere (1971)
	944.5 ± 38.2 (6)	252	3.1	–	WSW	On station	Montsma (1962)

1. DM refers to direct milking.
2. Figures in parentheses indicate number of observations.
3. WSW refers to weigh–suckle–weigh.
4. Figure obtained from partial milking.

Among the indigenous breeds, the highest mean total milk yield of 1532 kg in a lactation length of 252 days was obtained for the Sokoto Gudali under WSW (weigh–suckle–weigh). This is not surprising as the Sokoto Gudali, together with Bunaji, Shuwa Arab and Kuri are regarded as good milk producers under traditional husbandry (FAO 1979). The lower yields, ranging from 571 to 677 kg, reported for the Bunaji at the Animal Husbandry Station could be due to the fact that the animals that were imported were of low genetic merit and were not particularly healthy. Ghana Shorthorn (GSH) gave the lowest milk yield of 44 kg in 29 days when the cows were directly milked on station. In general, GSH cows do not let down milk in the absence of the calves. The calves were thus used to initiate milk let down by having them suck momentarily. The milking potential in the GSH is, however, far higher than this low yield would seem to indicate. Using the weigh–suckle–weigh method, milk yields reported by Montsma (1960, 1962) and Ngere et al. (1975) ranged from 383 to 1002 kg over lactation periods ranging from 182 to 295 days on station. The highest yield was obtained when, in addition to 24-h access to grazing, cows were fed on a concentrate mixture composed of 60% maize or maize bran, 40% groundnut cake and minerals at a rate of 1.8 kg/head per day. It is also worthy of note that, in the experiment reported by Montsma (1962), a large part of the lactation occurred in the rainy season. The 383 kg yield reported by Montsma (1960) was obtained when cows lactated mostly during the dry season, but were given small quantities of silage and concentrates. It is evident that GSH will respond to higher levels of nutrition. Even though the maximum genetic potential of the GSH is not really known, Rege et al. 1994b reported a variation in lactation performance of GSH cows ranging from a lactation milk yield of 5 kg over a lactation period of 9 days to a figure of 3059 kg produced over 454 days. There is thus potential for genetic improvement.

The experiment reported by Ngere et al. (1975) showed that maximum daily yield, ranging from 4 to 9 kg, could be attained between 3 and 7 weeks after calving in the GSH. Cows in this experiment were between six and nine years old and started their lactation in the wet season but continued to lactate well into the dry season when they were given some silage in addition to grazing. No concentrates were offered. It is interesting that despite this, they had longer lactation lengths than those reported by Montsma (1960, 1962). Peak daily yield was found to be correlated significantly to total yield (r = 0.77, P<0.01). All cows continued to give at least 0.9 kg of milk/day up to the tenth month of lactation. It was also found that the total second month yield was better than the total for the first or third month for prediction of total lactation yield. Total solids, protein and ash contents of the milk were 10.6, 3.2 and 0.75%, respectively. Comparable figures from the other indigenous breeds were not available.

Across indigenous breeds, fat content of milk showed a wide variation, ranging from 1.3% in the GSH to 5.1% in the Sokoto Gudali. The fat content of 4.11% that was reported by Okantah (1991) for Sanga cattle on smallholder farms is comparable to the 4.1% reported by Rege et al. (1994b) for the GSH.

Exotic cattle

Ghana has experimented with the idea of importing exotic dairy cattle to be used as purebreds or in crossbreeding with indigenous cattle as a means of increasing domestic milk production (Table 1). In 1964, the State Farms Corporation imported 30 Black-and-White cattle from Russia to set up a dairy farm at Adidome in Volta Region. Milk production figures from these animals are not available. Also around 1964, increasing demand for fresh clean milk prompted the Ministry of Agriculture to consider setting up a large-scale dairy farm on the Accra Plains. The Amrahia Dairy Farm was thus founded and equipped for 800 animals. This farm was situated on the Accra-Dodowa road about 26 km north-east of Accra. In this area, the maximum mean monthly temperature is about 32.4°C and minimum is 20°C. Annual rainfall for the area is between 703 and 1123 mm.

The Holstein–Friesian breed was chosen because of its high milk production, and in 1967, the first 100 in-calf Friesian heifers and 20 bulls were imported from the UK. This was followed in 1974 and 1976 by the arrival of 400 Friesians, 200 in each of the years, from The Netherlands. The feeding and management of these animals have been reported by Nartey (1990).

A similar importation of Holstein–Friesian cattle took place in 1974 at the University of Science and Technology farm located in the humid forest zone of Ghana. Thirty-five Holstein–Friesian heifers and 5 bulls were brought in from Canada through the assistance of the Canadian International Development Agency (CIDA). The location and climate of the farm were as reported by Alhassan and Owusu (1980). The housing of the cattle and disease control measures were described by Buadu (1977).

For the first two weeks of arrival, the cattle were completely confined in a cattle barn. They were then sent to the paddock for day and night grazing. It was soon observed that this was detrimental to their health and survival. They were disturbed by several types of dipterous flies, their appetite retrogressed to a low level and daily feed intake became reduced. For these reasons the cattle were confined in the barn during the day but were allowed to graze during the night. Many disease problems were encountered and after seven of them died, the cattle were completely confined in the fly-proofed barn. After a year or so, they were confined during the day and sent to an exercising yard during the night. The animals were given Berenil (Hoeschst, Germany) as prophylaxis against trypanosomiasis. Two weeks later, they were vaccinated against anthrax and black quarter. Later they were vaccinated against rinderpest. To control ticks, spraying was carried out weekly.

Milk production traits in the Holstein–Friesian cattle kept at Amrahia and the University of Science and Technology (UST) farms are presented in Table 3. Clearly, the performance of this breed at the UST farm in the humid forest zone was much better than the breed's performance at the Amrahia farm in the coastal savannah zone. The imported animals had a higher lactation yield than the homebred cows (2603 vs. 1886 kg). The figure 1106 kg reported by Nartey (1990) was rather low compared with the earlier values in the same herd. There may be several reasons for the decline in yield in the Amrahia herd. The cows grazed natural pasture, which is known to be inadequate for feeding in the dry season. Species of plants grazed included *Centrocema pubescens, Panicum maximum* and *Andropogon gayanus.* At milking time, they were fed only small quantities of concentrates consisting of maize, wheat bran and palm kernel meal. Feeding according to production was not practised. Thus feeding was a constraint to higher milk production. This assertion is supported by the fact that at the UST farm where animals were fed according to milk production (at a rate of 1 kg concentrate to 2 or 4 kg milk yield), the mean total milk yield was about 4225 kg, a performance that was better than in most tropical areas (Kabuga and Agyemang 1984). In the early phase of the UST programme, Gyawu and Agyemang (1977) reported even higher yields of about 4867 kg; some animals were giving as much as 5550 kg in 305 days. In the Amrahia herd, it is also highly likely that some amount of inbreeding was practised over the years since breeding bulls were always generated from within the herd and for a long time, identification was a big problem (Bosompem 1977; Nartey 1990). Inbreeding is known to have an adverse effect on milk production.

Table 3. Milk production (mean ± std. error) of Holstein–Friesian cattle in the coastal savannah and humid forest zones of Ghana.

Trait	Coastal savannah[1]		Range	Forest zone[2]	
	Origin	Mean		Origin	Mean
Total lactation milk yield (kg)	Imported[3]	2602.9 ± 95.2 (39)*	–	Imported	4225 ± 160.6 (103)
					4867 ± 971.0 (22)
	Homebred[3]	1885.7 ± 186.7 (18)	–	–	–
	–	1106.2 ± 472.1 (50)	58.8–2305.9	–	–
Actual 305-day yield	–	1509.1 ± 382.0 (12)	–	–	4451 ± 102.7 (103)
					4496 ± 126.4 (20)
Total yield per day (kg)	–	4.3 ± 1.4 (50)	0.4–16.1	–	13.0 ± 0.40 (103)
					14.7 ± 2.1 (20)
Lactation length (days)	Imported[3]	290.7 ± 8.1 (39)	–	–	332.1 ± 14.5 (103)
					358 ± 13.4 (22)
	Homebred[3]	239.1 ± 18.6 (18)	–	–	–
	–	255.8 ± 54.0 (50)	42–339	–	–
Days dry	–	86.9 ± 47.1 (22)	14–185	–	95.9 ± 5.8 (103)
Days open	–	–	–	–	176.5 ± 13.4 (103)
Persistency index	–	–	–	–	73.5 ± 1.0 (103)

*Figures in brackets are number of records.

Adapted from:

1. Nartey (1990).
2. Gyawu and Agyemang (1977); Kabuga and Agyemang (1984).
3. Kabuga (1989).

In general, production traits in the UST herd were better than in the Amrahia herd. In the UST data, age at calving, year of calving and concentrate intake were significant (P<0.05) sources of variation in 300-day yield, peak yield, persistency index and 305-day yield. Lactation number and season of calving generally did not have any significant effect on the milk yield traits. Literature values for the milk yields of Friesian cows abound and are generally higher than yields in the Amrahia herd. Trail and Marples (1968) reported an average yield of 6507 kg in Uganda, while Adeneye and Adebajo (1978) reported an average yield of 2012 kg in Nigeria. The daily yields of 13–14.7 kg reported were lower than the 16.3 kg reported by Chagunda et al. (1995) for Holstein–Friesians in Malawi.

Ambient temperature is known to be negatively correlated with milk production and European type cattle are reported to achieve optimum production when daily temperatures lie within the range of 10 to 21.1°C (Findley 1950). Ambient temperatures above 21°C increase rectal temperature which leads to subsequent depression of milk production. Mean monthly temperature at Amrahia is generally above 25°C. It is not surprising, therefore, that the milk yields were depressed.

Exotic × indigenous crosses

Crossbreeding, the mating of animals from different established breeds or lines (Lasley 1972), is known to increase heterozygosity, thereby increasing genetic variation. By the concept of genetic homeostasis, heterozygotes are likely to be better buffered than homozygotes against environmental variation. Consequently, crossbreeding brings gains. It has been suggested (Dickerson 1973) that these gains are due to complementarity and heterosis. For exotic × tropical breed crosses, complementarity would involve the additive combination of adaptation of the tropical breed with the productivity of the improved exotic breed. Heterotic effects, on the other hand, are accounted for by dominance and epistatic gene effects. These genetic effects are non-additive. The gains from crossbreeding are: exploitation of heterosis in crossbreeding systems; introduction into an established breed a proportion of genes from another breed or breeds, with a view to improvement of the first breed upgrading to the status of the superior breed or developing new breeds or types from crossbred foundations (Turton 1980).

Crossbreeding work in Ghana for the improvement of local breeds (viz. the GSH, Sokoto Gudali and N'Dama) with the Jersey started as far back as 1958 at the University of Ghana Agricultural Research Station (ARS) of Legon. In 1968, the N'Dama herd was transferred to a sister Research Station, the ARS at Kpong, to serve as a basis for beef crossbreeding in which Santa Gertrudis (SG) and Red Poll (RP) constituted the exotic breed components. In 1976, Friesians were introduced through artificial insemination (AI) on GSH and Sokoto Gudali cows.

From these two crossbreeding experiments, several genotypes were produced and a few studies analysing subsets of the data have been published (e.g. Ahunu et al. 1994; Rege et al. 1994b). Some of the crossbreeding results for milk production are shown in Table 4. Reports on mean total milk production in Jersey × GSH F_1 ranged from 1120–1835 kg in lactation lengths ranging from 250 to 305 days. In the Jersey × GSH backcross to exotic mean total milk yield ranged from 1398 to 1679 kg in lactation lengths ranging from 269 to about 285 days. As expected, milk yields in Gudali crosses were higher. Mean total milk yield ranged from 1555 to 2051 kg in the Jersey × Gudali F_1, while total yield in Jersey × Gudali backcrosses ranged from 1749 to 1880 kg. Lactation lengths were also longer in the Gudali crosses. The mean total milk yields reported for Jersey × N'Dama F_1 fall within the range obtained in Jersey × GSH F_1. This is not surprising. Like the GSH, the N'Dama has been described as a poor milk producer (Starkey 1974). In fact the poor milk production of the N'Dama was the main cause of its removal from the dairy crossbreeding programme at ARS, Legon.

Table 4. Milk production (mean ± std. error) in crossbred cattle in Ghana

Genotype*	Source	Mean total milk yield (kg)	Mean lactation length (days)	Milk fat (%)
Jersey crosses:				
J × GSH (F_1)	1	1459 ± 46.6	254 ± 6.0[1]	5.0 ± 0.07
		(208)	(208)	(208)
	2	1835 ± 21	305	–
		(356)		
	3	1568.4 ± 25.5	–	–
		(218)		
	4	1621	280	5.1
		(10)	(10)	
	5	1120.0 ± 104.2	250.9 ± 16.7	–
J × (J × GSH)		(27)	(27)	
		1587 ± 69.9	269 ± 9.0[1]	
	1	(92)	(93)	4.7 ± 0.10
		1679 ± 39	–	(91)
	2	(138)		–
		1398.1 ± 230.5	284.7 ± 13.1	
J × Sokoto Gudali (F_1)	5	(20)	(20)	–
		1563 ± 90.4	238 ± 11.7	
		(55)	(55)	
	1	2051 ± 42	305	4.8 ± 0.13
		(86)		(51)
	2	1819.5 ± 43.6	–	–
		(84)		
	3	1555.2 ± 23.5	294.6 ± 14.7	–
J× (J × Sokoto Gudali)		(8)	(8)	
	5	1848 ± 134	277	–
		(24)		
		1747 ± 136.9	291 ± 17.7	–
	2	(24)	(24)	
		1879.7 ± 246.7	323.3 ± 17.6	5.2 ± 0.2
J × N'Dama (F_1)	1	(4)		(23)
	5	1514.0 ± 38.9	–	–
	3	(88)		–
	4	1333	298	5.3

Genotype*	Source	Mean total milk yield (kg)	Mean lactation length (days)	Milk fat (%)
Friesian crosses:				
Fr × GSH (F_1)	2	1893 ± 60 (61)	305	–
	3	1854.9 ± 55.6 (65)	–	–
Fr × Sokoto Gudali (F_1)				
	2, 5	3047 (6)	268–387	–

Figures in parentheses indicate number of observations.

*J = Jersey; GSH = Ghana Shorthorn; Fr = Friesian.

Adapted from:

1. Rege at al.(1994b).
2. Ahunu et al. (1994).
3. Danbaro (1990).
4. Ngere (1971).
5. Ahunu and Acquaah (1987).

Compared with the milk production in the indigenous breeds shown in Table 2, milk yields increased dramatically in the F_1 crosses with the taurine breeds. Beyond the F_1, however, the increases, if any, were not appreciable. Kabuga (1989) reported results from a crossbreeding programme that was initiated in the UST herd by mating N'Dama heifers and cows to Friesian bulls. Milk yields and lactation lengths for a few crosses that completed lactations were 249 kg and 77 days, 1771 kg and 369 days, and 368 kg and 107 days, respectively, for ½, ¾ and $^7/_8$ Friesian crosses. The failure of higher-grade crossbreds to significantly out yield the F_1s is often attributed to lack of adaptation and reduction in heterozygosity. The Friesian × Gudali F_1 cattle had higher milk yields than the Jersey × Gudali F_1s. This is in agreement with other reports (Meyn and Wilkins 1974; Syrstad 1988) in which Friesian crossbreds were found to be superior to Jersey crossbreds in terms of milk production in the tropics.

Reproductive performance traits

Reproduction rate and/or fertility are generally understood to be complex phenomena involving the interplay of genetic and environmental factors. Genetic factors include both single gene and polygenic effects as well as effects due to breed and system of breeding, such as crossbreeding, and inbreeding (McDowell 1971). Environmental factors consist of management (detection of oestrus, bull to cow ratio and animal age), nutrition, diseases and parasites, and season of the year. For cattle, some of the standard measures of reproductive function are age at first calving, calving interval, length of service period, days open, services per conception, non-return rate and calving rate or calf crop.

Indigenous cattle

Reproductive performance of some indigenous cattle breeds measured on station in the coastal savannah and humid forest zones are shown in Tables 5a and 5b. Mean age at first calving ranged from 32.1 months in N'Dama cattle in the humid forest zone to 49.3 months in inbred GSH cattle in the coastal savannah zone. Age at first calving in both N'Dama and GSH appeared to be lower in the humid forest zone than in the coastal savannah. The 32.1 months obtained in the N'Dama was better than expected. It has long been observed (Mahadevan 1966) that irrespective of whether cattle were Indian, African, European or crossbred in origin, their mean age at first calving under a given tropical environment was essentially the same, i.e. at between three and four years old. The level of feeding at various stages of the reproductive cycle has an important influence on reproductive performance. As pointed out by Osei and Effah-Baah (1989), there were relatively abundant feed supplies in the humid forest zone. Within the Gudali breed, age at first calving was lower in non-inbred cows than in the inbred animals (43.4 vs. 46.3 months).

Table 5a. Reproductive parameters (mean ± std. error) in indigenous breeds in coastal and humid forest zones of Ghana.

Trait	Breed	Coastal savannah		Humid forest zone	
		Mean	Range	Mean	Range
Age at first calving (months)	Ghana Shorthorn	34.8 ± 0.25[3] (24)[1]	23–48[3]	35.93 ± 10.21[10] (6)	
		48.1 ± 1.07[6] (93)		–	
		42.4 ± 6.5[5] (57)		–	
		49.3 ± 2.13[4] (16)	32.7–61.7[4]	–	
		47.9 ± 2.14[4] (33)	29.3–80.5[4]	–	
	N'Dama	39.2 ± 1.56[3] (24)	26–51[3]	33.9 ± 0.82[8] (79)	
				37.41 ± 8.6[10] (17)	
				–	20.3–51.3[7]
				32.07 ± 0.92 (67)	
	Sokoto Gudali	46.7 ± 1.4[6] (51)		–	
		38.6 ± 0.25[3] (23)	28–49[3]	–	
		46.3 ± 12.8[3] (6)	35.5–61.6[3]	–	
		43.4 ± 1.61[4] (24)	28.4–59.1[4]	–	

Trait	Breed	Coastal savannah		Humid forest zone	
		Mean	Range	Mean	Range
Calving Interval (days)	Ghana Shorthorn	444.1 ± 1.36[3]	280–923[3]	557 ± 12.9[10]	
		(99)		(16)	
		549 ± 10.9[6]		462.8 ± 12.78[7]	314–695[7]
		(343)		(67)	
		534 ± 14.71[6]			
		(26)		–	
		501 ± 5.63[4]			
		(82)		–	
	N'Dama	457.3 ± 1.13[3]	307–983[3]	522.0 ± 1.69[8]	
		(111)		(382)	
				501 ± 12.62[7]	310–859[7]
				(76)	
				559.5 ± 9.3[10]	
				(32)	
				511.6 ± 166.6[9]	
	Sokoto Gudali	472 ± 15.4[6]			
		(160)		–	
		552 ± 38.90[4]			
		(11)		–	
		459 ± 8.20[4]			
		(105)		–	
		465.2 ± 11.5[3]	223–790[3]		
		(60)		–	
		474[2]			

1. Figures in parentheses, where indicated, are number of observations:
a) Figure obtained for inbred cows

b) Figure obtained for non-inbred cows

Adapted from:

2. Montsma (1963); 3. Sada (1968); 4. Millar (1979); 5. Rege et al. (1994a); 6. Rege et al. (1994b); 7. Tuah and Danso (1985); 8. Gyawu and Owusu (1988); 9. Karikari et al. (1989); 10. Osei and Effah-Baah (1989).

Table 5b. Reproductive parameters (means ± standard errors) in indigenous cattle breeds in Ghana.

Trait	Breed	Coastal savannah	Humid forest zone
		Mean	Mean
Gestation length (days)	Ghana Shorthorn	285.3 ± 1.67[1] (29)	–
	N'Dama	288.5 ± 0.61[1] (57)	291 ± 0.5[2]
	Sokoto Gudali	290.5 ± 1.84[1] (17)	–
Service period (days)	Ghana Shorthorn	168.1 ± 33.19[1] (98)	117.0 ± 64.3[3] (7)
	N'Dama	184.2 ± 13.02[1] (20)	210.8 ± 127.4[3] (31)
	Sokoto Gudali	100.4 ± 18.2[1] (11)	–
Number of services per conception	Ghana Shorthorn	1.28 ± 0.07[4] (119)	–
	Sokoto Gudali	1.29 ± 0.11[4] (48)	–
Calving rate	Ghana Shorthorn	71.0[5]	66.0 ± 6.8[5]

Figures in parentheses are number of observations.

Adapted from:

1. Sada (1968).
2. Karikari et al. (1989).
3. Gyawu et al. (1989).
4. Osei and Effah-Baah (1989); Rege et al. (1994b).
5. Rege et al. (1994a).

Mean calving intervals in the breeds ranged from 444.1 days in GSH in the coastal savannah to 559.5 days in N'Dama in the humid forest zone. These calving intervals are long compared with those generally considered acceptable (365–420 days). Reproductive efficiency in cattle may be adversely affected by long *post-partum* anoestrus periods, which result in long calving intervals. The service periods in the indigenous breeds (Table 5b) ranged from 100.4 days in the Sokoto Gudali to 168.1 days in the GSH. Sada (1968) suggested that these calving intervals were unsatisfactory. The duration of the 'days open' period is influenced by nutrition, season, milk yield, parity, suckling and uterine involution. Any, or a combination, of these factors could partly be responsible for the long service periods obtained in the indigenous breeds.

Gestation length in the indigenous breeds ranged from 285.3 days in the N'Dama to 290.5 days in the Sokoto Gudali. This agrees with the suggestion (Mukasa-Mugerwa 1989) that gestation tends to be longer in animals with a high proportion of zebu breeding. Rege et al. (1994b) did not find any significant differences between GSH and Sokoto Gudali for the number of services per conception which were 1.28 ± 0.07 and 1.29 ± 0.11, respectively.

Exotic cattle

Reproductive parameters in Holstein–Friesian cattle maintained in the humid forest zone and coastal savannah are shown in Table 6. A mean age at first calving of 30.75 months, with a range of 26.75–35.75 months, was obtained for 27 heifers. This value is lower than some values reported for Friesians in tropical and subtropical environments. Trail and Marples (1968) reported a value of 40.37 months in Uganda. The value is higher than the average of 27.7 months reported for the Holstein–Friesian in Canada and 25 months for the Holstein–Friesian in The Netherlands (Gyawu and Agyemang 1977). The differences in age at first calving between Kumasi and Canada were attributed to late age at breeding at Kumasi. The mean age of the heifers on arrival in Kumasi from Canada was 15 months. In order to give them enough time to adjust to their environment, mating of heifers did not start until about 3 months later. Heifers were thus served when they were about 18 months old. The late age at first service, together with repeat services, increased the mean age at first calving. Trail and Marples (1968) reported that Friesians bred under Ugandan conditions calved at the earlier age of 27.48 months compared with 40.75 months for dams imported into Uganda. It is clear, therefore, that original imported stock needs time to adjust to environmental stress before becoming pregnant, thus in the case of 15-month old imports, prolonging the age at first calving.

Table 6. Reproductive parameters in Holstein–Friesian cattle in Ghana.

Trait	Zone/origin	Mean (± se)	N	Source
Age at first calving (months)	Humid forest zone imported	30.75 ± 0.54	27	Gyawu and Agyemang 1977
		Range: 26.75–35.75	NA	Gyawu and Agyemang 1977
Calving interval (days)	Coastal savannah zone Imported	514.5 ± 21.20	39	Kabuga 1989
	Ghana born	517.3 ± 32.81	18	Kabuga 1989
		368.6 ± 12.13	28	Nartey 1990
Number of services per conception	Humid forest zone imported	3.4 (2.7)	NA	Kabuga 1989
	Ghana born	1.7 (12.3)	NA	Kabuga 1989

NA = Not available; Figures in bracket are standard deviations.

Mean calving intervals in Friesian cattle in the coastal savannah ranged from 368.6 to 517.3 days. The 368.6 days reported by Nartey (1990) is very close to the recommended yearly calving interval for dairy cattle. Interestingly, in the humid forest zone, the number of services per conception was better in the homebred cows than in the imported animals.

Exotic × indigenous crosses

Table 7 shows reproductive performance of crossbred cattle maintained in the coastal savannah zone. Within the Jersey × GSH crosses, age at first calving ranged from 37 to 42.3 months for F_1s and 36 to 38 months for back cross cows. Thus, age at first calving decreased as the level of exotic breeding increased in the crossbreds. The same is true for the Jersey × Gudali crosses. Red Poll × GSH F_1 and Santa Gertrudis × GSH F_1 heifers calved for the first time at about 36 months of age (Ngere 1971), a performance that is better than that of the indigenous breeds (Table 5a). Rege et al. (1994b) found cow genotype and year of calving to be highly significant ($P<0.01$) sources of variation in age at first calving of GSH, Sokoto Gudali and their Jersey F_1 and backcrosses.

Table 7. Reproductive performance (means ± standard errors) of crossbred cattle in the coastal savannah zone in Ghana.

Genotype	Age at first calving (months)	Calving interval (days)	No. of services per conception	Length of dry period (days)
Jersey crosses:				
J × GSH (F_1)	37.0[1]	–	–	–
	42.3 ± 1.38[2] (54)	429 ± 14.8[2] (16)	1.47 ± 0.06[2] (168)	–
	40.6 ± 1.24[3]	414 ± 14.5[3]	1.53 ± 0.06[3]	154 ± 9.2
	38.1 ± 12.5[4] (49)	447 ± 81[4] (100)	–	–
J × (J × GSH) (BC)	36.0 ± 2.3[2] (15)	470 ± 22[2] (70)	1.35 ± 0.80[2] (92)	–
	34.5 ± 2.5[5] (20)	–	–	–
	38.0 ± 2.33[3]	468 ± 24.1[3]	1.48 ± 0.08[3]	1.77 ± 13.7[3]
J × Sokoto Gudali (F_1)	38.8 ± 4.5[5] (8)	–	–	–
	44.7 ± 11.6[4] (11)	468 ± 72[4] (27)	–	–
	40.8 ± 2.45[3]	439 ± 28.5[3]	1.47 ± 0.1[3]	186 ± 16.9[3]
	42.5 ± 2.49[2] (16)	453 ± 27.0[2] (44)	1.46 ± 0.1[2] (56)	–

J × J × Sokoto Gudali (BC)	37.0 ± 2.1 (2) 40.4 ± 3.5[2] (6) 40.6 ± 3.7[3]	– 417 ± 42.2[2] (18) 404 ± 45.3[3]	– 1.20 ± 0.19[2] (15) 1.35 ± 0.19[3]	– – 128 ± 24.6[3]
Santa Gertrudis crosses: SG × GSH (F_1)	36.0[6]	–	–	–
Red Poll crosses: RP × GSH (F_1)	36.0[6]	–	–	–

Figures in brackets indicate number of observations.

J = Jersey; GSH = Ghana Shorthorn; SG = Santa Gertrudis; RP = Red Poll; BC = back cross to exotic.

Adapted from:

1. Ahunu et al. (1994).
2. Akah (1992).
3. Rege et al. (1994b).
4. Millar (1979).
5. Ahunu and Acquaah (1987).
6. Ngere (1971).

Calving interval was shorter in the Jersey × GSH F_1 (414–447 days) than in the Jersey × GSH backcrosses (468–470 days). However, in the Gudali crosses with Jersey, calving interval was better in the backcrosses (404–417 days) than in the F_1s (439–468 days). Cunningham and Syrstad (1987) noted that back crosses to exotics have often been poor in reproductive performance compared with the F_1s, an observation that is true of the crosses involving the GSH and Jersey. Cow genotype, year of calving and parity have been found to have significant effects on calving interval (Rege et al. 1994b).

Calf growth traits

Calf growth traits in the GSH, N'Dama and Sokoto Gudali (indigenous breeds), the Friesian, and various genotypes involving crosses between exotic and indigenous breeds are presented in Tables 8, 9 and 10, respectively. Birth weights in the indigenous breeds ranged from 14.7 kg in N'Dama cattle to nearly 23 kg in Sokoto Gudali. As expected birth weight was higher in the Holstein–Friesian breed. The Friesian crosses (Table 10) also compared favourably with Jersey, Red Poll and Santa Gertrudis crosses for birth weight. It is rather surprising that birth weights reported for crosses between the indigenous breeds were low compared with those for the purebreds.

Table 8. Least-squares means and standard errors for calf growth traits in indigenous cattle in Ghana.

Genotype	Eco-zone	Birth weight (kg)			Weaning weight (kg)			Average daily gain (g/day)		
		Source*	Mean	N	Source*	Mean	N	Source*	Mean	N
Ghana Shorthorn	Coastal savannah	1	18.8 ± 0.16	233	1	90 ± 1.7	–	1	294 ± 11.8	–
		2	19.2 ± 0.3	125	2	108.5 ± 6.2	50	2	432 ± 30	50
		3	16.1 ± 0.3	97	3	94.6 ± 3.3	66	–	–	–235
		4	19.8 ± 0.21	280	4	80.5 ± 2.6	75	4	276 ± 19.4	69
		5	19.1 ± 0.2	173	5	112.1 ± 3.8	69	5	410 ± 20	
	Humid forest zone	6	17.39	60	–	–	–		–	–
		7	17.4 ± 0.23	46	7	64.2 ± 2.7	31	–	–	–
N'Dama	Coastal savannah	2	19.0 ± 0.3	150	2	80.6 ± 1.5	–	1	3 4 2 ± 8	–
		3	16.3 ± 0.1	649	3	90.5 ± 1.6	374	–		–
		8	14.7	26	8	109	21	7		9
									–	
									359	
	Humid forest zone	9	17.8 ± 1.38	383	–	–	–	–	–	–
		6	18.1	324	–	–	–	–	–	–
		7	17.3 ± 0.23	128	7	75.2 ± 2.3		–	–	–
		10	15.9	36	–	–	6 3	–	–	–
							–			
Sokoto Gudali	Coastal savannah	5	22.98 ± 0.6	22 156	5	162.1±13.5	3	4	710 ± 70	3
		1	22.2 ± 0.22		1	122 ± 2.6	–	1	397 ± 18	–
					–		–		–	–

*Source: Adapted from:

1. Rege et al. (1994b).
2. Ahunu et al. (1994).
3. Ahunu et al. (1997).
4. Akah (1992).
5. Danbaro (1990).
6. Tuah and Danso (1985) (unadjusted mean).
7. Osei and Effah-Baah (1989) (unadjusted mean).
8. Ngere and Cameron (1972) (unadjusted mean).

9. Gyawu and Owusu (1988) (mean and standard deviation).
10. Alhassan (1971) (unadjusted mean)

Table 9. Calf growth traits (mean ± s.e.) in Friesian cattle in Ghana.

Eco-zone	Birth weight (kg)	Weaning weight (kg)	Preweaning average daily gain (g/day)	Source
Coastal savannah	31.0	84.2	620	Hagan (1977)
Humid forest zone	37.1 ± 1.04 (27) Range: 27.3–47.7	– –	570 ± 50.0(std. dev)	Gyawu and Agyemang (1977)

Figures in parenthesis are number of observations.

Table 10. Least-squares means and standard errors for calf growth traits in crossbred cattle in Ghana.

	Birth weight (kg)		Weaning weight (kg)		Average daily gain (g/day)	
Genotype*	N	Mean ± se.	N	Mean ± se	N	Mean ± se.
Indigenous breed crosses:						
GSH × N'Dama	5	14.5[2]	4	109.5[2]	4	455[2]
	17	16.9 ± 0.7[3]	8	91.6 ± 8.0[3]	–	–
N'Dama × GSH	33	16.6 ± 0.5[3]	20	77.1 ± 5.4[3]	–	–
N'Dama × (GSH × N'Dama)	12	15.6 ± 0.8[3]	9	83.4 ± 7.5[3]	–	–
Jersey crosses:						
J × GSH F_1	173	20.4 ± 0.2[4]	–	109.2 ± 4.6[4]	–	130 ± 22[4]
	105	20.2 ± 0.24[5]	–	100.0 ± 2.9[5]	–	345 ± 20.2[5]
J × GSH BC	111	21.2 ± 0.25[5]	–	110 ± 2.9[5]	–	380 ±19.8[5]
	129	21.9 ± 0. 3[4]	–	109.8 ± 3.8[4]	–	428 ± 18.0[4]
J75 Plus	100	22.5 ± 0.3[4]	33	95.1 ± 5.0[4]	110	354 ± 24[4]
J × N'Dama (F_1)	53	20.0 ± 0.37[6]	46	110.1 ± 3.9[6]	46	400 ± 20[6]
J × N'Dama (BC)	42	22.1 ± 0.47[6]	27	115.3 ± 31[6]	27	410 ± 20[6]
J × Sokoto Gudali (F_1)	41	23.5 ± 0.42[6]	25	126.2 ± 4.8[6]	25	460 ± 20[6]
	22	23.3 ± 0.40[5]	–	130 ± 4.0[5]	–	477 ± 27.8[5]
J × Sokoto Gudali (BC)	51	24.1 ± 0.36[6]	29	117.8 ± 4.3[6]	29	430 ± 20.0[6]
	16	24.1 ± 0.48[5]	–	118 ± 5.5[5]	–	396 ± 38.3[4]
Friesian crosses:						
Fr × GSH (F_1)	42	22.6 ± 0.41[6]	9	101.1 ± 7.9[6]	9	354 ± 40[6]
Fr × GSH (BC)	20	25.1 ± 0.6[6]	10	103.5 ± 7.7[6]	10	370 ± 40[6]
Fr × Sokoto Gudali (F_1)	32	24.9 ± 0.47[6]	11	118.7 ± 6.9[6]	11	430 ± 30[6]
Fr (J × GSH)	105	24.2 ± 0.27[6]	40	111.3 ± 4.4[6]	40	400 ± 20[6]
Fr (J × GSH)	35	24.2 ± 0.45[6]	14	114.7 ± 6.4[6]	14	430 ± 30[6]
Fr (J × Sokoto Gudali)	17	24.5 ± 0.64[6]	8	112.4 ± 8.4[6]	8	420 ± 40[6]
Red Poll crosses:						
RP × GSH (F_1)	–	22.3[7]	–	–	–	–
	14	22.5[2]	8	110[2]	8	391[2]
RP × N'Dama (F_1)	50	17.7 ± 0.5[3]	28	89.6 ± 4.7[3]	–	–
N'Dama × (RP × N'Dama)	26	21.5 ± 0.8[4]	–	99.5 ± 4.7[4]	–	433 ± 25[4]
	28	16.4 ± 0.6[3]	8	112.7 ± 8.0[3]	–	–
Santa Gertrudis crosses:						
SG × GSH (F_1)	–	23.6[7]	–	–	–19	–

	25	23.8[2]	18	116[2]	–	445[2]
SG × N’Dama (F_1)	21	23.0 ± 0.7[3]	15	98.6 ± 6.2[3]	–	–
N’Dama (SG × N’Dama)	49	21.7 ± 0.5[4]	–	97.3 ± 3.1[4]	–	419 ± 16[4]
	48	16.3	–	–		–

*Genotype: GSH = Ghana Shorthorn; J = Jersey; Fr = Friesian; RP = Red Poll; SG = Santa Gertrudis; BC = back cross to exotic; J75 Plus = >75% Jersey.

N = number of observations.

Source (indicated in superscript): Adapted from:

1. Ngere and Cameron (1972) (unadjusted mean).
2. Ahunu et al. (1997).
3. Ahunu et al. (1994).
4. Rege et al. (1994b).
5. Danbaro (1990).
6. Ngere (1971).

Weaning weights varied widely for both indigenous breeds and crosses. This could partly be explained by the different ages at which calves were weaned, depending on their genotypes. In addition, other factors, such as age of dam, weaning season, and sex of calf, which are known to influence calf weaning weights, could have been responsible for the observed wide variations.

Carcass characteristics in indigenous and crossbred cattle

Table 11 shows measurements of carcass traits obtained on station in some indigenous breeds and their crosses with exotic breeds. In the study reported by Ahunu et al. (1994), all the animals, i.e. the N’Dama and its crosses with Red Poll (RP) or Santa Gertrudis (SG), were raised on natural grassland with occasional supplementation with rice husk during the dry season. Weight at slaughter, warm carcass weight and longissimus muscle area were found to be significantly higher ($P<0.05$) in the crosses than in the purebred N’Dama. A comparison of Jersey × GSH or N’Dama crosses by Osman (1983) showed no significant differences between the crosses even though GSH crosses had higher live weights at slaughter, possibly because they were also slaughtered at older ages. As expected, the RP or SG × N’Dama crosses had higher weights at slaughter (273 kg) compared with the Jersey × N’Dama crosses (237.1 kg), even though the crosses from the heavier beef breeds were slaughtered at younger ages. In the study reported by Ngere (1971), GSH and its crosses with RP or SG were compared at a constant slaughter weight of about 295 kg. The crosses grew faster and attained this weight by 30 to 36 months. The corresponding age at slaughter weight for the GSH was 48–54 months. Thus, the already good beef qualities of the local animals appeared to be enhanced by cross breeding. The dressing percentage obtained in all genotypes ranged from about 44% in the Sanga to about 50% in the N’Dama.

Table 11. Carcass characteristics (means ± se) of some cattle breeds and breed crosses.

Genotype*	*N***	Age at slaughter (months)	Weight at slaughter (kg)	Warm carcass weight (kg)	Weight of forequarters (kg)	Weight of hind quarters (kg)	Longissimus muscle area (cm^2)	Dressing percentage
N'Dama[1]	41	44–47	223	113	NA	NA	67.5	50.4
RP or SG x N'Dama[1]	39	44–47	273	136	NA	NA	79.2	49.9
J × GSH crosses[2]	28	55.3	250.6 ± 17.95	113.7 ± 8.64	59.4 ± 4.72	53.1 ± 4.16	NA	42.5 ± 5.7
J × N'Dama crosses[2]	10	54.3	237.1 ± 28.14	107.5 ± 14.14	56.3 ± 7.59	51.3 ± 6.64	NA	46.3 ± 8.9
GSH[3]	NA	48–54	295.4	NA	NA	NA	NA	46.0
SG × GSH (F_1)[3]	NA	30–36	295.4	NA	NA	NA	NA	47.0
RP × GSH (F_1)[3]	NA	30–36	295.4	NA	NA	NA	NA	48.0
Sanga[4]	60	39	249.3 ± 1.8	110.5 ± 1.5	52.1 ± 1.2	58.4 ± 1.1	NA	44.3 ± 0.5

*Genotype: RP = Red Poll; SG = Santa Gertrudis; J = Jersey; GSH = Ghana Shorthorn.

**N = Number of observations.
NA = Not available.

Adapted from:

1. Ahunu et al. (1994).
2. Osman (1983)/
3. Ngere (1971).
4. AbdulKarim (1999).

Genetic parameters

Genetic parameters are needed for planning breeding strategies under specific production environments and for prediction of response to selection. In Ghana, although many studies have been done on phenotypic parameters in cattle, there are very few studies on genetic parameters. In one study (Rege et al. 1994b), the data involved six genotypes, namely GSH, Sokoto Gudali (GUD) and their Jersey F_1s and backcrosses collected over a 16-year period at the Agricultural Research Station at Legon. Least squares analyses of variance for cow production, reproduction and calf growth traits were carried out to investigate various fixed effects on these traits. Additive and heterotic effects were subsequently estimated. Results for pre-weaning growth traits are shown in Table 12.

Table 12. Estimates of crossbreeding parameters for calf traits.

Parameter	Birth weight (mean ± *s.e.)*	Weaning weight	Pre-weaning average daily gain
Deviations due to additive direct effects (A)+[1]: (least squares mean ± *s.e.)*			
A_{JER}	23.5 ± 0.58	89.2 ± 7.52	366 ± 45.7
A^*_{GSH}	4.6 ± 0.59	23.1 ± 6.75	72 ± 46.7
A^*_{GUD}	1.2 ± 0.61	–8.5 ± 7.0	–31 ± 48.4
[1]Individual Heterosis from crossing with Jersey: (mean ± *s.e.)*			
H_{GSH}	–1.2 ± 0.46	–0.5 ± 5.3	24 ± 36.7
H_{GUD}	0.8 ± 0.52	10.4 ± 5.4	85 ± 37.2
[2]Variance–covariance components and estimates for heritability:	Birth weight	Weaning weight	Pre-weaning average daily gain
Additive direct variance	3.7	198.1	
Additive maternal variance	–	167.2	–
Direct maternal covariance	–	–150.6	
Error variance	4.6	309.4	

Parameter	Birth weight (mean ± *s.e.)*	Weaning weight	Pre-weaning average daily gain
Phenotypic correlation[a]	0.24		
Genetic correlation[a]	0.48		
Direct heritability (h^2A)	0.45 ± 0.08	0.38 ± 0.18	
Maternal heritability (h^2_M)	–	0.32 ± 0.15	–
Direct-maternal genetic correlation (r_{AM})	–	–0.29 ± 0.16	
Total heritability[b]	0.45	0.39	

+ $A_{JER} = A^I_J$; $A*_{GSH} = A^I_J – A^I_{GSH}$; $A*_{GUD} = A^I_{J} – A^I_{GUD.}$

*Values expressed as deviations from that of Jersey (JER).

a..Between birth and weaning weights

b. Total heritability ($h^2_T = h^2_A + ½\, h^2_M + {}^3/_2\, r_{AM}\, h_A h_M$)

c. GSH = Ghana Shorthorn; GUD = Sokoto Gudali

Source:

1. Rege et al. (1994b).

2. Ahunu et al. (1997).

In another study (Ahunu et al. 1997) data generated over a 30-year period at the Agricultural Research Station, Kpong, involved the West African Shorthorn (hereafter called Ghana Shorthorn, GSH), N'Dama (N'd) and crosses involving Red Poll (RP) and Santa Gertrudis (SG). The specific crosses were: N'd × GSH; GSH × N'd; RP × N'd; RP × GSH; SG × N'd; SG × GSH; N'd × (GSH × N'd); N'd × (RP × N'd); and N'd × (SG × N'd). Subsets of records from a total of 1374 animals were analysed. Least squares analyses were carried out to investigate the effects of sex, period (1965–74, 1975–84 and 1985–95), season of birth and breed on birth and weaning weights. Subsequently, variance and covariance components were estimated using a derivative-free restricted maximum likelihood (DF-REML) procedure operated using a front-end program. All known pedigree information was included in the analyses to increase the accuracy of the estimation by inclusion of additional information on relationships between animals. Results from this study are also shown in Table 12.

The results obtained in the GSH and GUD crosses indicate that while improvement in calf growth traits in the two breed crosses were due to both additive and heterotic effects, higher levels of heterosis were obtained in GUD crosses, confirming the expectation of high levels of heterosis for *B. taurus* × *B. indicus* crosses.

The results obtained by Ahunu et al. (1997) for variance–covariance and heritability estimates indicated that birth and weaning weights were moderately heritable. Maternal heritability (0.32 ± 0.15) was lower than direct heritability (0.38 ± 0.18) for weaning weight and was unimportant for birth weight. As pointed out by Ahunu et al. (1997), the implication is that together with a moderate to high coefficient of variation, considerable opportunity exists for the improvement of the two traits by selection. Phenotypic and additive direct genetic correlation coefficients between birth and weaning weights were 0.24 and 0.48, respectively. Even though the phenotypic correlation coefficient was slightly lower than those from other studies, the genetic correlation coefficient was found to be similar to literature values. The unweighted and weighted means obtained from a review by Koots et al. (1994) of all published studies on correlations between birth and weaning weights were 0.36 and 0.46 for phenotypic correlations and 0.47 and 0.55 for genetic correlations. The moderate genetic correlation between birth and weaning weights indicates that selection for one trait will result in a moderate positive correlated response in the other trait.

A negative genetic correlation (r_{AM} = –0.29 ± 0.16) was obtained between direct and maternal effects. This was found to be lower than that reported by Tawah et al. (1993) for Gudali cattle in Cameroon. Selection for both direct and maternal components of pre-weaning traits was therefore advised. According to Tawah et al. (1993) a possible explanation for the negative r_{AM} estimate could be the harsh tropical environment, as was the case in the study reported by Ahunu et al. (1997). It was suggested that females that are genetically small as calves grow up to become small dams which are better able to meet the requirements for their maintenance and growth of their calves in the suboptimal environment than females which are genetically large under similar conditions. Consequently, calves of large dams tend to be smaller at weaning than those of small dams. Total heritability (h^2_T) was 0.45 for birth weight and 0.39 for weaning weight. These moderate values indicate that selection for either birth weight or weaning weight is expected to be effective inspite of the antagonistic association between direct and maternal effects for weaning weight.

Estimates of additive direct and heterotic effects for cow production and reproductive traits reported by Rege et al. (1994b) are presented in Table 13. Additive direct effect for the Jersey were significant (P<0.01) for all traits. As expected, deviations of additive direct effects of GSH from the Jersey (i.e. A^*_{GSH}) were positive and significant (P<0.01) for all cow production traits. Similarly estimates for age at first calving and length of dry period were negative and significant (P<0.05). Additive direct effects for number of services per conception and calving interval were not significant, while the estimate for annualised milk production was positive and significant (P<0.01).

Table 13. Genetic parameters (and s.e.) for cow production and reproductive traits for crosses of Jersey (JER) with Ghana Shorthorn (GSH) and Sokoto Gudali (GUD) cattle in Ghana.

Trait	Deviations due to additive direct effects (A)[1]			Individual heterosis (H)[2] from crossing with Jersey	
	A_{JER}	A^*_{GSH}	A^*_{GUD}	H_{GSH}	H_{GUD}
Cow production traits:					
Lactation length (days)	314 ± 20.9	285 ± 34.5	117 ± 35.7	76 ± 20.3	–12 ± 21.5
Lactation milk yield (kg)	1823 ± 161.9	1779 ± 266.3	754 ± 276.0	504 ± 157.3	139 ± 166.3
Lactation fat yield (kg)	89 ± 8.8	87 ± 14.7	30 ± 15.3	29 ± 8.6	9 ± 9.2

Butterfat content (%)	5.00 ± 0.23	0.97 ± 0.39	–0.06 ± 0.41	0.36 ± 0.23	–0.3 ± 0.25
Cow reproductive traits:					
Age at first calving (months)	37.9 ± 4.6	–10.2 ± 4.6	–8.8 ± 4.7	–2.9 ± 3.2	–1.0 ± 3.6
No. of services per conception	1.33 ± 0.21	0.05 ± 0.22	0.04 ± 0.24	0.25 ± 0.16	0.14 ± 0.15
Length of dry period (days)	135 ± 30.1	–173 ± 86.3	–78 ± 59.9	–55 ± 45.3	–1 ± 34.6
Calving interval (days)	446 ± 53.8	–104 ± 54.9	–26 ± 55.9	–68 ± 38.3	–35 ± 40.4
Annualised milk production (kg)	1696 ± 168.8	1673 ± 283.3	678 ± 283.3	534 ± 166.0	184 ± 172.7

1 $A_{JER} = A^I_J$; $A^*_{GSH} = A^I_J – A^I_{GSH}$; $A^*_{GUD} = A^I_J – A^I_{GUD}$.

2 Individual heterosis (i.e. H^I).

Source: Rege et al. (1994b).

Jersey additive direct effects were significantly higher than corresponding Gudali effects for lactation length (P<0.01), lactation milk yield (P<0.01), lactation fat yield (P<0.05) and annualised milk production (P<0.05).

Among cow traits, crossbreeding of the Jersey with the shorthorn resulted in desirable and significant (P<0.01) heterosis for lactation length, lactation milk yield, lactation fat yield and annualised milk production. The heterosis estimate for calving interval was not significant. Crossbreeding the Jersey with the Gudali produced no significant heterosis for cow traits. In the Gudali crosses therefore, improvements in lactation milk yield, lactation length and annualised milk production were largely due to additive effects. Results for cow production traits that showed higher heterosis estimates for exotic *B. taurus* × indigenous *B. taurus* crosses were contradictory to expectation.

Adaptive traits

It is well known that the major components of environmental stress on cattle in Ghana are poor nutrition, high parasitic burden (both internal and external) and hot humid climatic conditions. On the Accra Plains, for instance, high ambient temperatures, sometimes coupled with high relative humidities, are usually the primary cause of heat stress. According to Turner (1984), the expression of a low rectal temperature in a hot environment appear to be a good index of heat tolerance, where the latter is defined as insensitivity of productive functions to heat exposure.

Aggrey (1985) studied rectal temperatures in Ghana Shorthorn, Sokoto Gudali, Jersey × GSH crosses and Friesian cattle on the Accra Plains. Measurements were taken during the cool morning hours (between 06.00 and 07.00 h) when ambient temperatures averaged 22.95 ± 0.23°C and during the hot afternoons (between 13.00 and 1400 h) when ambient temperatures averaged 32.7 ± 0.50°C. Average relative humidities in the morning and afternoon were 75 ± 0.83 and 52.0 ± 1.04%, respectively. Results obtained from this study are presented in Table 14. The average morning rectal temperatures did not vary significantly between breeds and were all closely similar to the normal body temperature of cattle (38.3°C). Thus, in the mornings, none of the breeds were under heat stress and they were all very comfortable. In the hot afternoons, however, the rectal temperatures were higher in all the breeds. The highest rectal temperatures were recorded in the Friesians. Differences between breeds were highly significant (*P*<0.01). Mean daily changes in rectal temperature in the breeds indicated that under the environmental conditions prevailing on the Accra Plains, the Sokoto Gudali was the most adapted or heat tolerant, followed by the Ghana Shorthorn and Jersey × GSH crosses. The Friesian was the least adapted.

Table 14. *Mean (± s.e.) rectal temperature of some cattle breed and breed crosses on the Accra Plains*.*

Parameter	Sex	Ghana Shorthorn (GSH)	Sokoto Gudali	Jersey x GSH crosses	Holstein–Friesian
Mean morning rectal temperature (°C)	Male	38.14 ± 0.08 (5)	38.25 ± 0.07 (5)	–	38.72 ± 0.03 (5)
	Female	38.31 ± 0.08 (5)	38.43 ± 0.08 (5)	38.38 ± 0.05 (10)	38.73 ± 0.04 (5)
Mean afternoon rectal temperature (°C)	Male	39.29 ± 0.10 (5)	39.18 ± 0.04 (5)	–	42.02 ± 0.06 (5)
	Female	39.28 ± 0.11 (5)	39.37 ± 0.08 (5)	39.45 ± 0.07 (10)	41.79 ± 0.09 (5)
Mean daily change in rectal temperature (°C)	Male	1.14 ± 0.11 (5)	0.87 ± 0.03 (5)	–	3.31 ± 0.04 (5)
	Female	0.97 ± 0.12 (5)	0.91 ± 0.05 (5)	1.07 ± 0.08 (10)	3.08 ± 0.07 (5)

Source: Aggrey (1985).

Agbemawle (1989) studied reasons for disposal of 433 Friesian cows that left the Amrahia herd between 1972 and 1988. The results indicated that 30.9% of the cows died. In addition, 22.9% were culled because of various diseases including heart water. By comparison, Aboagye and Agbemawle (1995) reported that death accounted for only 6.9% of total cow disposals amongst 189 Jersey or Friesian crosses with indigenous breeds between 1966 and 1985 at the University of Ghana's Agricultural Research Station at Legon. Skin disease and other disease conditions together accounted for 14.8% of total disposals. The crosses were clearly better adapted than the purebred Friesians.

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