

**CROSSBREEDING, ADDITIVE AND HETEROTIC EFFECTS
ON PRODUCTION TRAITS IN JERSEY CROSSBRED CATTLE
AT AGRICULTURAL RESEARCH STATION , LEGON.**

A THESIS

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by
Seth M.K. Akah

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DEDICATION

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ABSTRACT

Relative performance of breed groups, additive and heterotic effects on milk production, reproduction and calf growth traits in Jersey x West African Shorthorn (WAS) and Jersey x Sokoto Gudali (GUD) crossbred cattle were studied using sixteen years field records kept at the Agricultural Research Station, Legon.

The genotypes consisted of WAS; 1/2 Jersey, 1/2 WAS (WAS F_1); 3/4 Jersey, 1/4 WAS (WAS Bc); GUD; 1/2 Jersey, 1/2 GUD (GUD F_1); 3/4 Jersey, 1/4 GUD (GUD Bc).

Milk production traits analysed were first lactation milk yield, average lactation milk yield, average daily milk yield, annualized milk yield, lactation fat yield, fat percentage and lactation length. Analysis of reproduction traits included age at first calving, number of services per conception and calving interval. The calf growth traits examined were birthweight average daily gain to weaning and weaning weight.

All traits were analysed by least squares fixed model procedures using the GLM methods in SAS (1987) to generate genotypic least squares means. Additive and heterotic effects on crossbreds were estimated using the additive-dominance model.

With regard to the milk production traits and calf growth traits, the performance of GUD was significantly ($P < .01$) better than WAS. WAS and GUD were similar for the reproductive traits except for calving interval where GUD had a significantly ($P < .01$) shorter calving interval than

WAS (475 days as against 551 days). WAS F_1 and GUD F_1 crossbreds were significantly ($P < .05$) better than their corresponding purebreds for all the traits examined except for birth weight where both F_1 's were similar to their respective purebreeds. This indicated that crossbreeding with Jersey would lead to significant increases in the production level of the local breeds. GUD Bc and GUD F_1 cows were similar for the milk production traits whereas WAS Bc cows were superior to WAS F_1 cows. WAS Bc calved significantly ($P < .05$) earlier for the first time (36 months) than WAS F_1 (42.3 months). There was no difference between WAS Bc and GUD Bc when compared to their corresponding F_1 's for the other reproductive traits. WAS Bc and GUD Bc calves weighed significantly ($P < .01$) more at birth (21.7kg and 24.6kg respectively) than their respective F_1 's (20.1 kg and 23.1 kg respectively).

The performance of WAS Bc and WAS F_1 were similar for pre-weaning average daily gain (ADG) and weaning weight. GUD Bc declined significantly ($P < .05$) in growth rate when compared to GUD F_1 .

Additive genetic breed effects and heterosis contributed significantly to the improvement in milk production traits and calf growth traits in the WAS crossbred group. Additive effects however, made greater contribution to the improvement than heterotic effects. Of the reproductive traits in WAS crossbred group, only the additive effect for

age at first calving (-10.2 ± 2.5 months) and the heterotic effect for calving interval (-102 ± 31.8 days) were significant ($P < .05$) and desirable. These results showed that additive and heterotic effects could be exploited in crossbreeding to improve growth and milk production in WAS.

Only average lactation milk yield and lactation length were significantly ($P < .05$) improved by additive effect among the milk production traits in the GUD crossbred group. Additive and heterotic effects were not significant for any of the reproductive traits in GUD crossbreds. Additive and heterotic effects however, significantly ($P < .05$) influenced calf growth traits in GUD crossbreds.

DECLARATION

I hereby declare that this thesis has been written by me and that it is the record of my own research work. It has not been submitted to any University for the award of a higher degree.

SETH M.K. AKAH

.....
Candidate's Name

The above declaration affirmed.

..... J Saloague 16/9/93.
Senior Supervisor

..... [Signature] 16/9/93
Supervisor

..... [Signature] 16/9/93
Head of Department

.....
External Examiner

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CHAPTER ONE

INTRODUCTION

Expansion in world population is now in exponential growth form (Keating, 1980). As a result of this, attention has been focused on how to feed the increasing population occurring mainly in the tropics. Currently, food production especially protein foods, is inadequate in the tropics. For example, of the recommended minimum level of 0.75 g/kg body weight of protein intake per day, only 0.4-0.5 g/kg body weight intake pertains in the developing countries (F.A.O./W.H.O./U.N.U., 1985). Among the protein foods, milk and eggs are of higher quality protein (F.A.O., 1985). The role of dairy products in human nutrition cannot therefore be over emphasised.

The bovine is more generally used throughout the world than any other milch animal for milk production (F.A.O., 1982). There are however, constraints to its use in milk production in the tropics. The constraints are both environmental and genetic in nature. Tropical cattle are inherently low milk producers. In addition to this, the levels of nutrition and management to which they are exposed in the tropics are low (F.A.O., 1982). Increases in milk production in the tropics therefore may be achieved through improvement of the environmental conditions as well as the genetic capabilities of the cattle used in the system. Hence establishment of systematic genetic improvement programmes are necessary in order to generate sustainable increases in cattle milk production.

Various methods are available for improving the genetic potential for milk production of herds of indigenous cattle. For example:-

1. The improvement of indigenous breeds by selection.
2. The introduction of more productive exotic breeds partly to replace the indigenous breeds.
3. Crossbreeding of the indigenous cattle with exotic dairy cattle; and
4. Biotechnology (recombinant D.N.A. technique).

The first and second methods have not been entirely successful in most instances. In the case of the first method, a long period of time is required to effect sufficient desirable genetic change. Furthermore, in the indigenous breeds variance within breeds is small so that the improvement expected from selection will also be small and slow (McDowell, 1972).

In the case of the second method, though it would appear to be the fastest method of improving dairy production, there is the problem of adaptation to the environment in addition to other constraints like huge costs of importation.

The third method is the key approach. The objective here is to combine the merits of the two different populations; namely the productivity of exotic cattle with the adaptation of indigenous cattle, and to take advantage of existing large cow populations in the tropics.

To exploit fully the advantages offered by crossbreeding, it is necessary to determine the magnitudes

of additive and heterotic effects on the traits of interest. These describe to some extent the genetic and environmental complex affecting the traits. The magnitudes of both the additive and heterotic effects also form the basis in deciding what the appropriate breeding strategy should be. For instance depending on the absolute and relative values of additive and heterotic effects, the best strategy may be any of the following:- breed replacement, some form of rotational crossing and grading up to half or three quarter exotic (Cunningham and Syrstad, 1987).

A more recent technique is biotechnology. This method holds prospects but has not been successfully integrated on a large scale into breeding programmes. However, approach to breeding experiments may take an entirely different line in view of current trends with this method.

Indeed, it has increasingly been the practice in the past decade or so for workers to decipher the exact base sequence of a particular gene and amend it to alter the gene (Brem, 1990). This is likely to circumvent the fairly lengthy process of conventional methods of improving the genetic potential in higher organisms. Much success in biotechnology has been achieved in lower organisms, such as bacteria and viruses. Infact, in some higher organisms, advantage has been taken to alter the genes through biotechnology to effect growth and quality of animal products. For example, by manipulating genes in the growth hormone regulatory system, attempts have been made to alter the growth performance and carcass composition of farm

animals (Smith et al, 1987). It is therefore possible in the not too distant future for workers to amend genes in cattle to obtain the desirable effects with regard to dairy production.

At the Agricultural Research Station, Legon, crossbreeding for the improvement of local breeds of cattle viz:- the West African Shorthorn, Sokoto Gudali and N'Dama with Jersey started in 1958. The crossbreeding of Friesian and the locals commenced in 1976. Many crossbred genotypes have since been produced. These offer the opportunity for detailed genetic studies to be carried out. In particular it is possible to examine the magnitudes of the additive and heterotic effects affecting production traits in these animals.

The objectives of the present study were therefore to compare specific genotypes produced and to estimate the additive and heterotic effects for various production traits in Jersey and local crosses mainly the West African Shorthorn and Sokoto Gudali crosses. These would throw some light on the breeding strategy best suitable for the improvement of the traits examined. The production traits of interest were:-

- i. Milk production traits involving lactation milk yield, fat yield and lactation length;
- ii. Reproductive traits including fertility, age at first calving and calving interval.
- iii. Calf growth traits like birth and weaning weights and pre-weaning average daily gains.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 CROSSBREEDING AND ITS USES

Crossbreeding refers to mating of animals from different established breeds or lines (Lasley, 1978). The major consequence of crossbreeding has been identified by Dobzhansky (1952). He proposed that crossbreeding increased heterozygosity thereby increasing genetic variation. Thus by the concept of genetic homeostasis (Lerner, 1954), heterozygotes are likely to be better buffered than homozygotes against environmental variation. Consequently, crossbreeding brings gains. These gains as suggested by Dickerson (1969, 1973) are due to:-

- i. Complementarity:- This arises from additive gene action. For tropical x exotic crosses, this is the combination of adaptation of the tropical breed with the productivity of the improved exotic breed.
- ii. Heterosis or hybrid vigour:- This is heterozygous advantage and is accounted for by dominance and epistatic gene effects. These effects are non-additively genetic and are also described as heterotic effects.

The gains from crossbreeding are used for the following purposes (Turton, 1980):-

1. To exploit heterosis in crossbreeding systems.
2. To introduce into an established breed a proportion of genes from another breed or breeds with a view to improvement of first breed.

3. To upgrade to the status of the superior breed.
4. To develop new breeds or types from crossbred foundations.

Dickerson (1973) further reported that the maximum amount of heterozygosity, is attained in the F_1 generation of the crossbred when the breeds that are crossed are homozygous for different alleles of a pair; thereby suggesting that for such crosses maximum gains may be realised in the F_1 generation. Various mating systems are used to exploit gains from crossbreeding. For example, Dalton (1985) reviewed various crossbreeding systems summarised as follows:-

- i. Two-breed cross: This is the basic first cross involving the two parental breeds which result in the F_1 crossbred progeny.
- ii. Backcrossing:- When the F_1 crossbred is mated with a sire from either of the original parental breeds.
- iii. Criss-crossing:- When sires of the parental breeds are used in alternation on the crossbred dams.
- iv. Rotational crossbreeding:- This involves a range of different sire breeds being used in a planned rotation.
- v. Inter-se mating:- This involves inter-breeding the crossbreds of a generation.

To increase dairy cattle productivity in the tropics improved breeds are used. These are crossed with the tropical breeds. For example, various workers have advocated the use of improved temperate breeds in crosses with tropical breeds (McDowell, 1972; Mason and Buvanendran,

1982; Cunningham and Syrstad, 1987). However, the appropriate system of crossbreeding to select to maximize gains depends on the levels of heterosis and additive genetic effects exhibited in the initial crosses (Mason and Buvanendran, 1982; Cunningham and Syrstad, 1987). For instance, two-breed crossing shows 100% heterosis, three-breed rotational crossing shows 87% and criss-crossing 67% heterosis. Inter-se mating among F_1 crossbreeds gives only half of the heterosis of the first cross.

However, Koch, et al (1985) have indicated that inter-se mating among crossbreeds or grading up, exploits most efficiently the favourable additive genetic contributions offered by the breeds crossed. Recently, Ahlborn-Breier and Hohenboken (1991) have reported that rotational crossbreeding has a special advantage in that it introduces new genes each time and thus utilizes both additive genetic progress and non-additive genetic effects.

2.2 BREED CHARACTERISTICS

Most of the cattle indigenous to the tropics belong to the Zebu species (Bos indicus) (F.A.O., 1987). However, in Africa the cattle population derives from three major introductions from Asia between the period 5,000 BC and 1,500 BC (Epstein, 1957; Faulkner and Epstein, 1957; Williamson and Payne, 1977; Oliver, 1983).

These are:

1. The humpless Hamitic Longhorn (Bos taurus longifrons)
e.g. N'Dama.

2. The humpless Shorthorn (Bos taurus brachyceros) e.g. Dwarf shorthorn.

3. The humped Zebu (Bos indicus) e.g. Sokoto Gudali.
Breeding among these three types in West Africa resulted in the development of the West African Shorthorn (Mason, 1951).

These breeds of cattle are well adapted to the harsh environmental conditions of the West African tropics. Essential adaptive traits include resistance to or tolerance of pests and diseases; tolerance of intense sunshine, heat and humidity, and ability to utilize high-fibre forages (Koger, 1963). However, the potential for meat and milk production of these cattle are commonly low. They mature late and produce little milk, which they often let down only in the presence of their calves (Mukasa-Mugerwa, 1989). They are also ranked far inferior in respect of meat and milk production to the specialised exotic breeds of cattle such as Jersey and Friesian (for milk) and Red-Poll and Santa Getrudis (for meat). This is the case even when environmental constraints are alleviated (Trail and Gregory, 1981). The specialised exotic breeds however, lack adaptive traits for the harsh environmental conditions in the tropics (Cunningham and Syrstad, 1987).

In the tropics in general, the appropriate producing cow may be an intermediate between a tropical adapted breed and an improved temperate breed (Mason and Buvanendran, 1982). McDowell (1985) and Cunningham and Syrstad (1987) have shown that heterosis and complementarity between highly productive and adapted breeds resulted in superior overall performance

of crossbreds in the tropics.

Comparison of West African Shorthorn and Gudali breeds with regard to cow production traits (Ahunu and Acquah, 1987), reproductive traits (Osei and Effah-Baah, 1989) and calf growth traits (Buvanendran et al, 1981; Danbaro et al, 1991) have been made. Generally, Gudali breed showed significant advantage over West African Shorthorn breed for these traits. These results were noted to be reflections of the fact that Gudali breed is generally a heavy breed compared to West African Shorthorn which is smaller in size (Buvanendran et al, 1981; Ahunu and Acquah, 1987; Osei and Effah-Baah, 1989 and Danbaro et al, 1991).

2.3 EFFECT OF CROSSBREEDING ON MILK YIELD TRAITS:

The economic returns from dairying in the tropics depend mainly on the quantity of milk produced and its fat content (Kiwuwa et al, 1983). In addition, production indices such as average daily milk yield, percent fat and lactation length are used as indicators of the production potential of dairy cattle (Roy et al, 1987).

Major differences among breeds of cattle (Bos indicus and Bos taurus) in respect of production efficiency have been found in both temperate and tropical zones for the above-mentioned traits (Gregory et al, 1978; Cundiff et al, 1981). These reviews suggest that in general, cross-breeding of tropical indigenous cattle with exotic specialised dairy breeds leads to the crossbred progeny being more productive than the pure indigenous breed. Also among the crossbred

genetic groups production increases with increasing exotic inheritance up to about 50% level whilst no significant differences are observed among genetic groups with more than 50% exotic inheritance. The following parameters of milk yield traits are dealt with:-

Lactation milk yield:

The effect of crossbreeding on lactation milk yield has been examined by several researchers. For example, Fahmy et al (1976) using Dairy Shorthorn and Egyptian native cattle and their crosses obtained 2112 kg., 2083 kg. and 1120 kg. lactation milk yields for 1/2 and 3/4 Dairy Shorthorn inheritance and pure Egyptian native cattle respectively. Taneja and Chawla (1978) using Brown Swiss and Sahiwal and their crossbreds reported 3160 kg., 2670 kg. and 1794 kg. lactation milk yields for 1/2 and 3/4 Brown Swiss inheritance and pure Sahiwal respectively. Similar results were reported by Buvanendran et al (1984) when they used Friesian and White Fulani and their crossbreds. They reported 1684 kg. 1850 kg. and 834 kg. lactation milk yields for 1/2 and 3/4 Friesian inheritance and pure White Fulani respectively. Similar estimates were made by Chacko (1983) using Brown Swiss and Red Sindhi cattle and their crosses. He obtained 2368 kg., 2314 kg., and 723 kg. for 1/2 and 3/4 Brown Swiss inheritance and pure Red Sindhi respectively.

Ahunu and Acquaaah (1987) working on Jersey crosses with either West African Shorthorn (WAS) or Sokoto Gudali reported 1120 kg and 1398 kg. and then 1555 kg and 1879 kg., respectively for 1/2 and 3/4 Jersey inheritance. The

lactation milk yields for WAS and Sokoto Gudali were estimated by Montsma (1962) and Ngere et al (1975) using the weigh-suckle-weigh method. Montsma (1962) obtained a 252-day lactation milk yield of 1001 kg. and 1531 kg. for WAS and Sokoto Gudali respectively. Ngere et al (1975) reported a mean yield for average of 295 days lactation of 774 kg. for WAS cattle.

In Nigeria, Johnson and Buvanendran (1984) reported a first lactation milk yield of 922 kg. for Sokoto Gudali cows. All the results showed an improvement of about 100% in milk yield in the crossbreds over the pure indigenous breeds when the yields of the crossbreds were compared to those of their respective pure breeds. Difference within crossbred genotypes were slight and non-significant.

Thus there was a general agreement among the various workers with regard to milk yield traits. The higher milk yield for the hybrids were attributed to hybrid vigour and gene complementarity; whilst lack of significant differences among the crossbred genotypes was attributed to decreased heterotic effect accompanied by lack of adaptation of crossbreds with high level of exotic inheritance.

Dhillon and Jain (1977) computed the average milk yield per day of lactation for Sahiwal cows and Holstein Friesian (HF) x Sahiwal crossbreds, and obtained for purebred Sahiwal, 1/2 HF and 3/4 HF inheritance, 4.52, 6.40, and 5.98 kg. milk yield per day of lactation respectively. The crossbreds were significantly better than the purebred Sahiwal but there were no significant differences between

the crossbred genetic groups. The conclusion was that crossbreeding increased the average milk yield per day of lactation.

Fat yield:

The effect of crossbreeding on milk-fat yield and milk fat percentage has been investigated by several workers. Branton et al (1966) estimated fat content of milk in Jersey and Brahman and their crosses as well as fat percentage in Holstein and Red Sindhi and their crosses from a crossbreeding experiment in the Southern United States. For fat content of milk yield in Jersey and Brahman crosses they had 51, 72, 116 and 137 kg. for 1/2, 3/4, 7/8 Jersey inheritance and pure Jersey respectively. This indicated that as Jersey inheritance increased fat production also increased. However, fat percentage decreased with increasing Jersey inheritance, though not significantly, from 5.57% through 5.4% to 5.16% for 1/2, 3/4 and 7/8 Jersey inheritance respectively. Decreases in fat percentage from 4.5% to 3.4% for 1/2 and 3/4 Holstein inheritance in Holstein and Red Sindhi crosses were also observed.

Similarly, when Letenneur (1978) analysed first and second lactation fat percentages in Jersey x N'Dama crossbreds, he noted a decrease in fat percent from 5.76% to 5.4% (for first lactation) and 5.66% to 5.36% (for second lactation) for 1/2 and 3/4 Jersey inheritance. The decreases were not however statistically significant.

Furthermore, Shah et al (1982) compared fat yield and

fat percentages among Sahiwal, Friesian x Sahiwal crossbreds and found that the crossbred cows produced nearly twice as much fat as the purebred Sahiwals. They obtained 53.2 kg for Sahiwal, 97.8 kg for Friesian x Sahiwal F_1 , and 101.2 kg for Jersey x Sahiwal F_1 crossbreds. The fat percentage decreased for Friesian x Sahiwal from $4.50 \pm 0.12\%$ for pure Sahiwal to $4.25 \pm 0.00\%$ for Friesian x Sahiwal crossbred, but remained virtually the same for Jersey x Sahiwal crossbred ($4.55 \pm 0.12\%$). A later estimate of fat percent by Sohael in 1984 also showed a decrease of fat percent from 5.72% to 5.00% for White Fulani and Friesian x White Fulani F_1 crossbred cattle.

A recent review by Cunningham and Syrstad (1987) confirmed these observations when they concluded from their study that fat production tended to increase as exotic inheritance increased while fat percentage decreased with increasing exotic inheritance. The trend apparent from these reports is that whilst milk production could be altered significantly by genetic as well as environmental factors, milk-fat yield and milk-fat percentage appeared to be strongly a breed characteristic.

Lactation length:

Lactation length is the measure of the number of days a cow stays in lactation. Foley et al (1972) have suggested that the ideal length of lactation in dairy cattle should be a 10 month-period (305 days) with calving at twelve months intervals. Such a lactation length is infact considered

advantageous for optimum lactation yield,
(Schmidt and Van Vleck, 1974).

Whilst this ideal length has been achieved in exotic breeds, it is still far from being realized among the indigenous tropical breeds (Mason and Buvanendran, 1982). For example Vohradsky (1970) and Ngere et al (1975) had observed that West African Shorthorn cows when milked went dry within a few weeks. McDowell (1985) reviewed the performance of two-breed crosses as compared to native breeds in twenty-five countries in the tropics. He noted that the mean lactation length of the two-breed crosses was significantly longer than the mean lactation length of the pure native breeds (316 against 244 days), thus suggesting some genetic influence.

The results of some other works on crossbreeding tropical indigenous breeds with exotic dairy breeds for lactation length also showed similar genetic effects as observed by McDowell (1985). For example, Buvanendran and Mahadevan (1975) working with Jersey and Sinhala cattle and their crossbreds obtained 313 days, 272 days and 244 days lactation length for 1/2 and 3/4 Jersey inheritance and Sinhala breed respectively. Similarly, Rao and Taneja (1980) also obtained for Friesian and Sahiwal cattle and their crossbred, 325 days, 322 days and 244 days for 1/2 and 3/4 Friesian inheritance and Sahiwal respectively.

These studies indicated that introduction of exotic blood significantly increased the lactation length of the indigenous breeds. Furthermore, the first generation F1

crossbreds (1/2 exotic inheritance) appeared to have the longest lactation lengths in all the cases presented.

2.4 EFFECTS OF CROSSBREEDING ON REPRODUCTIVE TRAITS:

Productivity of cattle largely depends on their reproductive performance. It has been established by various workers, for example, Verley and Touchberry (1961) and Foley et al (1972) that progress in dairy cattle breeding is impeded by the relatively long generation intervals and low reproductive rates. Verley and Touchberry (1961) suggested that any condition capable of altering significantly the efficiency of reproduction in any of the generations would correspondingly affect the possible rate of progress from breeding. Traits of major importance relating to reproduction include fertility, age at first calving and calving interval (Mukasa-Mugerwa, 1989).

Fertility:

Continuity in dairy cattle production is enhanced by prompt conception and regular calving (Donald and Russel, 1968). Conception as an index of fertility may be measured by number of services per conception (Vandeplassche, 1982). Genotype has generally been found to have no appreciable influence on fertility. On the other hand, environmental factors have been identified as the main source of variation in this trait (Legates 1954, Lasley, 1978, Choudhuri et al, 1984). Of the environmental factors, nutrition (Galina and Arthur, 1989) as well as high atmospheric temperatures

(Vandeplassche, 1982) appear to be the main components contributing to this variation.

Number of services per conception in tropical indigenous breeds ranges from 1.4 for Indu Brazil breed (Temblado and Sanchez, 1977) to 2.8 for Haryana (Choudhuri, 1984). El-Amin et al (1981) reported no significant difference in number of services per conception for Red Butan and Red Butana crosses with Friesian (average 2.6) in the Sudan. They however, noted increased number of services per conception over the study period, which was attributed to changes in management.

As far back as 1961, Vereley and Touchberry measured the number of services required for conception by purebred Holstein and crossbred Holstein x Guernsey. They found the mean differences between the purebreeds and the crossbreeds to be non-significant. The mean differences measured for four lactations were 0.14, -0.21, 0.06 and -0.05. Similarly, Hollon et al (1967) reported for Holstein x Brown Swiss or Red Sindhi crossbreeds, 1.73 and 1.68 mean services per conception respectively. They found no significant difference between purebreeds and crossbreeds for this trait. Contradictory results were however reported by Azage et al (1981) in three local Ethiopian breeds, the Barca, Horro and Boran. They found that crossbred cows required 0.12 and 0.14 fewer services per conception than local zebu cows in wet and dry areas respectively.

The important role of environmental factors as the cause of variation in fertility has also been investigated by

several researchers. For example, Hollon et al (1967) found that rainfall reduced number of services per conception. Similarly, Holroyd et al (1979) reported that conception rates were highly correlated with rainfall in the month prior to insemination. Subsequent works by Butterworth (1983), Wilson et al (1986) and Galina and Arthur (1989) also demonstrated a strong relationship between the peak of the calving season and the rainfall.

It could therefore be concluded that reproductive efficiency was more directly related to the availability of good quality forage at or before the time of insemination than genotype.

Age at first calving:

The first calving marks the beginning of a cow's productive life. Heifers which calve late for the first time complete fewer lactations in their productive life compared with heifers which calve early (Pinney et al 1962; Meaker, et al, 1980). Most tropical indigenous breeds compared for age at first calving, showed no significant differences. For example, Sada (1968) obtained for Sokoto Gudali and N'Dama 38.6 months and 39.2 months respectively. Similarly, Basu et al, (1979) reported 35.6 months and 35.8 months for Red Sindhi and Sahiwal breeds respectively. Trail and Gregory (1981) found no significant difference in age at first calving between Boran and Sahiwal heifers. However, contrary to the above reports, Chhikara et al (1979) found that breed difference has a significant effect on age at

first calving in Haryana, Tharparkar and Sahiwal heifers in India. They however explained that the breed difference might be a reflection of difference in management conditions. On the other hand age at first calving is considerably reduced when exotic dairy cattle breeds are crossed with tropical indigenous breeds. Amble and Jain (1966) using Sahiwal in crosses with Friesian found the mean age at first calving for the F_1 crossbred cows to be 36.2 months as against 38.3 months for purebred Sahiwals. Similar work by Bhosrekar (1976) in Tharparkars, Sahiwals, Red Sindhis and their crossbreds confirmed findings of Amble and Jain (1966). Bhosrekar (1976) reported 20.2 months as mean age at first calving for the crossbreds and 29.1 months for the purebreeds.

Reviews by Plasse (1983), Cunningham and Syrstad (1987) and Galina and Arthur (1989) further confirmed the remarkable effect that crossbreeding had in reducing age at first calving.

Apart from the significant difference between pure indigenous breeds and crossbreds for age at first calving Fahmy et al (1976), Rao and Taneja (1980) and Buvanendran et al (1981) further examined the differences in age at first calving among the crossbred genotypic groups. Their result indicated no significant difference between the crossbred genotypic groups for age at first calving. Similarly, Ahunu and Acquah (1987) working on Jersey crosses with either West African Shorthorn or Sokoto Gudali reported no significant differences in age at first calving

between the F_1 's and their backcrosses to the Jersey.

The significant difference between pure indigenous breeds and the crossbreds have been attributed to breed complementarity and hybrid vigour (Amble and Jain, 1966, Bhosrekar, 1976, Fahmy et al, 1976, Rao and Taneja, 1980, Buvanendran et al, 1981). Additionally, the absence of significant difference between the crossbred groups has been attributed to decrease in heterotic effects in crosses beyond the F_1 generation for this trait, as well as lack of adaptation of crossbreds to the environment due to high level of exotic inheritance of the crossbred (Fahmy et al, 1976, Rao and Taneja, 1980 and Buvanendran et al, 1981).

Calving interval:

The interval between any two successive calvings is referred to as calving interval. Calving interval may easily be divided into three distinct periods (Mukasa-Mugerwa, 1989) namely:-

- (a) The gestation period;
- (b) the post-partum anoestrus period (from calving to first oestrus).
- (c) the service period (first postpartum oestrus to conception).

The postpartum anoestrus and service periods are usually referred to as "days open".

A shorter calving interval is indicative of a higher reproductive efficiency and a higher lifetime production. Mukasa-Mugerwa (1989) has even suggested that the best index

of a cattle herd's reproductive efficiency is the calving interval.

Verley and Touchberry (1961) have recognised days open as the most probable period during which calving interval could be altered in cattle. The average gestation length is noted to be fairly constant against a flexible "days open" period. Sada (1968) also stated that the "days open" is the part that can be shortened by improved herd management.

Genotype as well as environmental effects were advanced by Plasse (1973) as being responsible for variation in length of calving interval. Lasley (1978) on the other hand identified environment as the only important factor which caused variation in calving interval.

Significant contributions of genotype as well as environment pointed out by Plasse (1976) appeared to be supported by the results of Letenneur (1978) and Parma et al (1980). Results described by Letenneur (1978), for crossbreeding N'Dama cattle with Jersey in the Ivory Coast, showed that all the crossbred genetic groups had almost the same calving intervals while the calving interval for the purebred N'Dama was significantly shorter (about 60 days shorter). Similarly, Parma et al (1980) reported a marked difference in calving interval between Haryana cattle and Jersey x Haryana crossbreds. They obtained for purebred Haryana 540 days and for the first generation (F_1) Jersey x Haryana crossbreds 434 days and 445 days for the second (F_2) crossbreds. Both the F_1 and F_2 crossbred groups had significantly shorter calving interval than the purebred

Haryana.

On the other hand, some workers have also reported the absence of significant effects of crossbreeding on calving interval. For example, Buvanendran et al (1981) reported 367, 383 and 391 days of calving interval for pure White Fulani, White Fulani with 1/2 and 3/4 Friesian inheritance respectively. Difference between the breed groups were not significant. The results of Kiwuwa et al (1983) also showed the absence of significant differences between breed groups. They obtained 439, 427, 464 days of calving interval for pure Arsi and Arsi with 1/2 and 3/4 Friesian inheritance. Similar results were reported by Chacko (1983) when he used Red Sindhi in crosses with Brown Swiss and Sahiwal in crosses with Friesian respectively. These results indicate that calving interval may or may not be influenced by genotype.

2.5 EFFECT OF CROSSBREEDING ON CALF GROWTH TRAITS:

Most of the economic gain due to crossbreeding cattle had resulted from more rapid and more efficient growth by the crossbred individual (Gregory et al, 1965). Calf growth parameters include birthweight, average daily gain to weaning and weaning weight.

Birthweight:

Calf birthweight is a measure of prenatal growth. It is considered important because of its relationship to calving

difficulty, vigour of the calf a few days after calving and growth afterwards (Johansson, 1961). The effects of crossbreeding on calf birthweight had been studied among temperate breeds (Gregory et al, 1965, Gaines et al, 1966, Touchberry and Bereskin, 1966), and among temperate and tropical breeds (Taneja and Bhat, 1972, Plasse, 1973, Ahunu, 1975, Letenneur, 1978 and Danbaro, 1990). The results generally indicated that although crossbreds were heavier at birth than straightbreds, the differences were, however, not significant. For example, Gregory et al (1965) analysed the birthweights of calves from Hereford, Angus and Shorthorn breeds of cattle and their crossbreds. They reported the mean birthweight of crossbred calves and straightbreds as 33.39 kg and 32.18 kg. respectively. They did not find the difference between the crossbreds and the straightbreds to be significant.

Ahunu (1975) compared the birthweights of pure West African Shorthorn, Sokoto Gudali and N'Dama and their crosses with Jersey or Friesian. He reported that the birthweights of the crossbreds were higher than those of the purebred calves but the differences were not statistically significant. The mean birthweight for N'Dama was 18.3 kg while the means for Jersey x N'Dama F_1 and Friesian x N'Dama F_1 were 21.2 and 23.5 kg respectively. The mean for the West African Shorthorn (WAS) was 19.7 kg and for Jersey x WAS F_1 and Friesian x WAS F_1 the means were 22.1 and 23.0 kg respectively. For the Gudali and its crosses with Jersey and with Friesian, he obtained 23.0 kg for Gudali and 25.7 kg

for Jersey x Gudali F_1 and 27.0 kg for Friesian x Gudali F_1 .

Average daily gains and Weaning weight:

Average daily gains to weaning and weaning weights both give indications of the calf's growth rate after birth whilst still under maternal influence (Barlow, 1978). Both of these traits are closely correlated to liveweight at all ages from weaning to maturity (Barlow, 1978). The effects of crossbreeding on these traits will therefore suggest the effects of crossbreeding on growth and development later in life. The effects of crossbreeding on pre-weaning average daily gains and on weaning weights have been reported by most workers to be significant. Thus crossbreds grow faster and have significantly higher weaning weights than purebred calves (Gregory *et al*, 1965, Gaines *et al*, 1966, Plasse *et al*, 1969; Danbaro, 1990). However, Ahunu (1975) did not find any significant differences between local purebreds and their Jersey crossbreds for calf weaning weight. He attributed his non-significant results to the rather small number of animals he used in his analysis.

Significant differences between breeds for weaning weight have also been obtained. Roberts and Gray (1973) reported mean six-months weights of 93.50 kg, 66.35 kg, and 129.45 kg, for N'Dama, Muturu and Zebu respectively. Similarly, Tuah (1989) noted a significant difference between the mean weaning weights of N'Dama and West African Shorthorn. He obtained 87.42 kg, and 63.2 kg for N'Dama and West African Shorthorn respectively.

2.6 ADDITIVE AND HETEROTIC EFFECTS:

The average performance of a group of animals is determined by their genetic capacity and by the environmental conditions in which they are kept. The genetic component is the aggregate effect of the actions of many genes acting individually and in concert with other genes or group of genes.

Kempthorne (1959) suggested that effects of genes could conveniently be considered at the following two levels namely:-

- i. Additive effects: this is the effect due to single genes acting independently of the remainder of the genotype.

The total genetic effect in this case would be the sum of effects of all the individual genes in the system.

- ii. Non-additive effect: This is the interaction effects of genes. It is of both intra-and inter allelic origin. The total genetic effect in this instance is the sum of all the interaction effects at all loci in the system. The inter-allelic interaction effects are usually referred to as epistasis, whilst the intra-allelic interaction effects are called dominance. A measure of non-additive genetic effects of both intra- and inter-allelic origin is referred to as heterosis or heterotic effect. In other words a measure of heterosis or heterotic effect is essentially an estimation of genetic factors due to dominance and epistasis. For a polygenic character, heterosis is estimated as the amount by which the average performance of crossbreds exceed the average of

the two parental breeds (Dickerson, 1973).

2.7 HETEROSIS IN CROSSBREEDING:

As has been pointed out in the preceding section, heterosis is due to both dominance and epistatic effects. However, the influence of dominance effects far outweigh that of epistatic effects (Falconer, 1960; McDowell, 1972 and Lasley, 1978). This is explained by the fact that dominance occurs when out of an allelic pair of genes, one member manifests itself wholly or largely to the exclusion of the expression of the other member; and this happens far more frequently than epistatic effect whose occurrence depends on the presence of certain particular combinations of genes in the system.

Heterosis is further explained by the theories put forward by Bowman (1959) as follows:-

- i. The Dominance Theory: This postulates that the parental lines are homozygous dominant for different favourable loci. When they are crossed the resulting offsprings become more heterozygous than their parents. The dominant favourable genes mask the unfavourable recessives. The performance of the hybrid will thus surpass that of the parents.
- ii. The overdominance Theory: This states that the heterozygote is superior to either homozygote. It is expected that each parent will be homozygous for some loci for favourable genes at some and for unfavourable

genes at others. If the first parental breed complements the second, the crossbred will have favourable genes at more loci than their parents. Consequently, when favourable genes are dominant, the performance of the crossbred will be superior to that of either parental line.

- iii. The Epistasis Theory: This includes advantage derived from all types of inter-locus interactions. Thus heterosis observed in any particular cross could be due to a combination of several of these reasons. The influence of the environment on the expression of heterosis has also been demonstrated (Cundiff, 1970; Turton, 1980; Barlow, 1981). Consequently, Sheridan (1981) cautioned that the level of heterosis apart from being genetic could also be influenced by environmental factors. This has been confirmed by Cunningham (1981) when he showed that heterosis is greater in stressful environment than in a favourable environment.

2.8 METHODS OF ESTIMATING ADDITIVE AND HETEROTIC EFFECTS:

Additive effect is equivalent to the mid-parent value. It is estimated as the average of the difference in performance between the parental breeds. Heterotic effect is measured as the deviation in performance of the crossbred progeny from the mid-parent value. Mather and Jinks (1971) used these concepts of additive and dominance modes of action of genes to develop the additive-dominance model. This proposes that when all values are expressed as

deviations from the overall mean (m) of the population, the expectations of the mean performance of the parents (P_1 and P_2) used in the crossbreeding are expressed in the following notations:-

$$P_1 = m + g,$$

$$P_2 = m - g,$$

Where g = additive genetic effect summed over all loci. This model is based on the assumption that the genes involved are independent of each other in producing their effects. This excludes trigenic and higher order interactions and deals with the additive part of the model.

The dominance aspect of the model is tackled in a similar manner viz:- The expectations of mean performance of half-bred first generation F_1 is given as:-

$$\bar{F}_1 = m + h$$

Where h = the dominance deviation summed over all loci. Combining these factors, the Mather and Jinks additive-dominance model expression is:-

$$m = 1/2 P_1 + 1/2 P_2$$

$$g = 1/2 P_1 - 1/2 P_2$$

$$h = \bar{F}_1 - 1/2 P_1 - 1/2 P_2$$

This model is used in estimating additive and heterotic effects in crossbreeding experiments. However, the model as proposed makes it imperative that both performance values of the parents must be known.

Under certain circumstances in livestock breeding experiments, for example, where the germplasm of exotic

breed is imported through frozen semen, the performance of the exotic parent under tropical conditions is unknown. Hence the model of Mather and Jinks (1971) cannot be applied under such situations. There have been two main approaches to circumvent such difficulties.

The first approach used is to produce genotypes of different levels of exotic inheritance and to use multiple regression techniques taking genotypic means as dependent variables; and fraction of exotic inheritance of sire and dam and level of heterozygosity of crossbred progeny as independent variables (Touchberry, 1970, Parmar and Dev, 1978 and Taneja and Bhat, 1978).

The multiple regression method is based on the following model (Taneja and Bhat, 1978):

$$Y_k = a + b_1S_i + b_2D_j + b_3H_k + e_k$$

Where $Y_k = k^{\text{th}}$ breed group least squares mean independent of environmental effects;

a = the intercept and it is the value for the indigenous breed, given "00" exotic breed inheritance.

b_1 = the partial regression coefficient for breed of sire on fraction of exotic inheritance accounting for the deviation from the intercept due to paternal additive genetic effects;

b_2 = the partial regression coefficient for breed of dam on fraction of exotic inheritance accounting for the deviation from the intercept due to

maternal additive genetic effect;

b_3 = the partial regression coefficient for the crossbred on fraction of heterozygosity accounting for deviation from intercept due to the non-additive genetic effect.

S_i = the fraction of i^{th} exotic inheritance of sire;

D_j = the fraction of j^{th} exotic inheritance of dam;

H_k = the fraction of heterozygosity of the k^{th} crossbred; and

e_k = the random error associated with different gene combinations in k^{th} crossbred to its generation.

This method brings out the respective additive effects of the Sire and the dam separately. However, the efficiency of this method in terms of reliability of estimated values and cost has been questioned (Jain, 1982 and Cunningham and Syrstad, 1987).

Jain (1982) pointed out that the genotypic means are not used directly to estimate the genetic parameters i.e. the additive and heterotic effects. Also the value of heterozygosity is obtained assuming one locus with two alleles. Again, most livestock production traits are quantitative and are polygenically determined. Besides these, Cunningham and Syrstad (1987) have also noticed that many generations are required to produce sufficient genotypic grades for this estimation leading to higher cost in accumulating data.

The second approach was proposed by Jain (1982). He suggested that the estimation of additive and heterotic

effects could be based on the fitting of genetic models specifying the contributions of additive and dominance effects to genotypic means. Making use of the additive dominance model as earlier developed by Mather and Jinks (1971), he expressed the missing parent's value in terms of other known genotypic means, as follows:- Backcross (B_1) is derived from F_1 and P_1 parents giving it a genetic constitution which is equivalent to $1/2 F_1$ and $1/2 P_1$. As such B_1 mean is equal to the mean of F_1 and P_1 . This can be expressed in the following model as:-

$$\bar{B}_1 = 1/2 \bar{F}_1 + 1/2 \bar{P}_1$$

or

$$1/2 P_1 = \bar{B}_1 - 1/2 \bar{F}_1 \text{ ----- model 1}$$

Also, from the definition of heterosis, the heterotic effect (h) can be expressed in the following model as:-

$$h = \bar{F}_1 - 1/2 P_1 - 1/2 P_2 \text{ ----- model 2.}$$

From models 1 and 2, the heterotic effect could again be expressed as:-

$$h = F_1 - (\bar{B}_1 - 1/2 \bar{F}_1) - 1/2 P_2.$$

This could be simplified to give:

$$h = 3/2 \bar{F}_1 - \bar{B}_1 - 1/2 P_2 \text{ ----- model 3.}$$

The comparison of models 2 and 3 which express the same heterotic effect in different terms makes it apparent that

$\bar{F}_1 - 1/2 P_1$ in Mather and Jinks (1971) model also equals $3/2 \bar{F}_1 - \bar{B}_1$. Mather and Jinks (1971) model and Jain (1982) modification can be summarised thus:

Mather & Jinks (1971)

$$m = 1/2 P_1 + 1/2 P_2$$

$$g = 1/2 P_1 - 1/2 P_2$$

$$h = \bar{F}_1 - 1/2 P_1 - 1/2 P_2$$

Jain (1982)

$$m = \bar{B}_1 - 1/2 \bar{F}_1 + 1/2 P_2$$

$$g = \bar{B}_1 - 1/2 \bar{F}_1 - 1/2 P_2$$

$$h = 3/2 \bar{F}_1 - \bar{B}_1 - 1/2 P_2$$

Roy et al (1987) using Jain's version of the additive dominance model calculated percentage heterosis from a dairy cattle crossbreeding experiment as follows:-

$$\text{Percentage heterosis} = h/m \times 100$$

where h = the heterotic effect and m = the overall mean of the breeds used for crossing.

Jain's method needs only two generations as compared to several generations of the regression method to be able to estimate the additive and heterotic effects. Also genetic parameters (i.e. additive and heterotic effects) are estimated directly from genotypic means unlike the regression method. Jain's model is also adequate for quantitative traits unlike the regression method where the heterozygosity is determined assuming one locus with two alleles. The validity of the additive-dominance model for use in cattle crossbreeding experiments have been proved by various researchers. For example, Cunningham and Syrstad (1987) reviewing works done using additive-dominance model on mice, dogs, corn and beef cattle provided strong support for the additive-dominance model. This means that for most purposes the additive-dominance model when used for dairy cattle crossbreeding in the tropics will be adequate for estimating additive and heterotic effects.

2.9 ADDITIVE AND HETEROTIC EFFECTS ON MILK YIELD TRAITS:

It has been reported by many workers (Taneja and Bhat, 1974, 1978; Parmar and Dev, 1978, Taneja and Chawla, 1978; McDowell, 1985) that the additive as well as the heterotic effects imparted to crossbred tended to increase the total lactation milk yield and the average daily milk yield. Positive and significant additive and heterotic effects have been realised for these traits. Experiments by Roy et al (1987) for these traits also yielded similar positive additive and heterotic effects but failed to show significance for additive effects. Heterotic effects were however, significant. Roy et al (1987) using Jersey and Sahiwal crosses estimated for first lactation milk yield a positive but non-significant additive effect of 297 ± 214.9 kg. For average daily milk yield they obtained a positive and non-significant additive effect of 20.66 ± 18.58 kg; and a negative and non-significant heterotic effect of -8.54 ± 21.34 kg. In a recent study involving Holstein-Friesian and Jersey crossbreds, Ahlborn-Breier and Hohenboken (1991) found positive and significant additive and heterotic effects of 454 kg and 171 kg respectively for lactation milk yield and 4.8 kg and 10.3 kg respectively for lactation fat yield. For percent butterfat content, Ahlborn-Breier and Hohenboken (1991) reported a negative but significant additive effect of -0.62% and a negative but non-significant heterotic effect of -0.00%.

Heterosis for lactation milk yield in the temperate regions has been commonly low and non-significant (McDowell,

1976). Bereskin and Touchberry (1966) reported a heterosis of only 2% in Guernsey and Holstein crossed in the United States. Similarly, low estimates of 3.7% and 5.1% were obtained by Johnson et al (1964) and Robinson et al (1981) respectively in temperate crosses for total lactation milk yields.

In the tropics, higher and significant heterosis for lactation milk yield has been reported for crossbreds involving temperate and tropical breeds (Katpatal, 1977; Parmar and Dev, 1978; Taneja and Chawla, 1978; McDowell, 1985 and Roy et al, 1987). For example, Katpatal (1977) and Roy et al (1987) obtained for lactation milk yield heterosis of 34.0% and 21.6% respectively.

With regard to average daily milk yield Roy et al (1987) reported very high and significant heterosis in the tropics. They found as high as 29.16% heterosis in Jersey x Sahiwal crosses for this trait. Taneja and Bhat (1974) using Sahiwal and Friesian crossbreds in India, on the other hand, did not find heterosis to be significant. They obtained only 3.31% for lactation milk yield. They however, attributed the non-significance of heterosis for this trait to the small number of observations they used for the study. McAllister (1986) has also suggested that in such studies, the significance of beneficial genetic effects observed could potentially be masked by large standard errors (S.E.) of crossbred means due to small sample sizes.

Significant heterosis of 7.24% was found by Ahlborn-Breier and Hohenboken (1991) for lactation fat yield in

Friesian x Jersey crossbreds. Prior to this, Pearson and McDowell (1985) in a review of crossbreeding of dairy cattle in temperate zones had reported that heterosis for milk fat ranged from + 3% to + 11% and fat percentage, -4% to -1%. McDowell (1972) in a much earlier paper had also reported a heterosis of 12% for fat yield in Holstein Guernsey crosses.

Several researchers such as Parmar and Dev (1978), Taneja and Chawla, (1978) and Roy et al (1987) have shown that environmental factors are rather responsible for the variation in lactation length. Genetic effects are negligible. For example, Roy et al (1987) estimated non-significant additive and heterotic effects of 20.66 ± 18.8 days and 8.54 ± 21 days respectively for lactation length. They used Jersey and Sahiwal crossbreds. Parmar and Dev (1978) and Taneja and Chawla (1978) using Brown Swiss and Sahiwal and Friesian and Sahiwal crossbreds respectively obtained non-significant partial regression coefficients for the additive and heterotic effects. On the contrary, Taneja and Bhat (1978) reported positive and significant additive effects for lactation length in Holstein x Sahiwal crossbreds. They found significant partial regression coefficients of 11.81 for breed of Sire and 3.07 for breed of dam, representing additive effects. They however, obtained a non-significant partial regression coefficient of -1.12 for heterotic effect.

Studies have also shown that heterosis for length of lactation has been low and non-significant in temperate breed crosses as well as in tropical x temperate breed

crosses (McDowell and McDaniel, 1968; Taneja and Bhat, 1978; Roy et al 1987). For example, McDowell and McDaniel (1968) reported -1.4% heterosis for temperate crosses whilst Taneja and Bhat (1978) found only -0.39% for tropical x temperate crosses. These results are in agreement with the very low and non-significant additive and heterotic effects realised by workers such as Parmar and Dev (1978) Taneja and Chawla (1978) and Roy et al (1978). Genetic factors are therefore not seen to be important in accounting for variation in length of lactation.

2.10 ADDITIVE AND HETEROTIC EFFECTS ON REPRODUCTIVE TRAITS:

The additive and heterotic effects on age at first calving have been reported to be negative and significant by most workers. These workers showed that both additive and heterotic effects were important in reducing age at first calving in crossbred cattle (Taneja and Bhat, 1974, 1978; Parmar and Dev, 1978; Taneja and Chawla, 1978). On the other hand, the results of a few workers have not shown that both additive and heterotic effects were simultaneously important in reducing age at first calving. For instance, Roy et al (1987) showed that additive effect decreased age at first calving (-250.48 ± 39.92 days) whilst heterotic effect increased age at first calving (4.89 ± 49.05 days). The results of the estimates of percent heterosis for age at first calving have ranged from very low to high. Wilcox et al (1966) reported the percentage heterosis for age at first calving to be non-significant (0.0%) in

Jersey x Holstein crosses in the temperate region. Results in the tropics ranged from as low as 0.44% (Taneja and Bhat, 1978) to as high as -21.12% (Taneja and Chawla, 1978). The inference is that in the tropics heterosis for age at first calving may or may not be significant. Furthermore, the use of only genetic effects as basis for improvement in this trait may not be completely appropriate.

With regard to number of services per conception, McDowell et al (1974) using Jersey, Holstein, Brown-Swiss and Ayrshire crosses in the U.S., obtained a non-significant heterosis of -1.3%. Earlier on Legates (1954) and later Lasley (1978) reported that the heritability for fertility measured by number of services per conception in dairy cattle was approximately zero. Furthermore, Choudhury et al (1984) also estimated the repeatability of number of services per conception to be 0.19 for Haryana cattle indicating a similarly low heritability for this trait. The indication is that genetic factors have no appreciable influence on fertility.

With regard to calving interval, only heterotic effect was responsible for shortening the length of this period (Taneja and Bhat, 1974, 1978; Parmar and Dev, 1978; Taneja and Chawla, 1978; Roy et al, 1987). Heterotic effects were negative and significant whilst additive effects were positive and non-significant. For example, Taneja and Bhat (1978) using Holstein and Sahiwal crosses obtained for additive effects (for sire and dam) non-significant partial regression coefficients of 0.20 and 0.24 days respectively.

They obtained a significant partial regression coefficient of -1.19 days for heterotic effect. Furthermore, Roy et al (1987) using Jersey and Sahiwal crosses also found non-significant additive effect of 51.63 ± 17.41 days and a significant heterotic effect of -70.1 ± 29.83 days. Contrary to these results, McDowell et al (1974) reported non-significant heterotic effect for calving interval for crosses among temperate breeds in the U.S. They obtained only 0.8% heterosis when estimates were made using, Jersey, Holstein, Brown-Swiss and Ayrshire crossbreds.

Among temperate x tropical crossbreds in the tropics however, the heterosis observed were negative and significant (Taneja and Bhat, 1974, 1978; Parmar and Dev, 1978 Katpatal, 1982 and Roy et al, 1987). The estimates of these authors varies from -8.83% (Taneja and Bhat, 1984) to -22.1% (Katpatal, 1982). These results suggest that shorter calving intervals could be achieved by exploiting the gains arising from heterosis in crossbreeding temperate and tropical breeds in the tropics.

2.11 ADDITIVE AND HETEROTIC EFFECTS ON CALF GROWTH TRAITS:

The study by Taneja and Bhat (1978) using Holstein and Sahiwal crosses inferred that the higher birth weights and higher weaning weights obtained for crossbreds were both due to additive and heterotic effects. They found for additive effects partial regression coefficients of 0.02, 0.05, 0.30 and 0.44 kg for sire and dam effects for birth weight and weaning weight respectively. For heterotic effects they

obtained partial regression coefficient of 0.06 kg and 0.2 kg. for birth and weaning weights respectively. Both additive and heterotic effects were significant. The percentage heterosis realised were 9.56% for birth weight and 7.14% for weaning weight.

On the other hand, low and non-significant heterosis for birth weight and weaning weight in Angus, Hereford and Shorthorn crosses were estimated by Mason (1966). He obtained 1-2% heterosis for birth weight and 5-6% for weaning weight. Similar results were also reported by Cundiff (1970). Gray et al (1978) also found only 4.8% heterosis for weaning weight. For pre-weaning average daily gain, Gregory et al (1966) reported a positive and significant heterotic effect of 0.049 kg. which amounted to 28.3% heterosis in Hereford, Shorthorn and Aberdeen-Angus crosses.

These results agree with the observations of McDowell et al (1974), Barlow (1981), Sheridan (1981) and Mason and Buvanendran (1982). They noted that heterosis in crossbred animals has been generally low and non-significant for most production traits in temperate breeds. On the other hand higher and significant heterosis has been found in crosses of temperate and tropical breeds in the tropics. Mason and Buvanendran (1982) among others attributed these observations to two factors:-

- i. The limited genetic variability in these traits among temperate breeds.
- ii. The larger genetic variability between temperate and

tropical indigenous breeds coupled with the stressful tropical environment.

CHAPTER THREE

3. MATERIALS AND METHODS:

3.1 SOURCE OF DATA:

Data on production records of cattle kept at the University of Ghana Agricultural Research Station, Legon were used. The station is located 32 kilometres East of Accra on latitude 05° 40'N and longitude 00° 16'W in a gently rolling country of low elevation typical of the Accra plains. The climate of the station is of the coastal savanna type. The annual average rainfall (1967 - 1982) is 870.5mm with a range of 390mm - 1399.03mm showing an erratic distribution over the years. The rainfall distribution in the year is double peaked: with peaks in June and September. Mean monthly temperatures vary from 24.8° to 28.3° in the year. February to April represents the hottest months, whilst August and September are the coolest months in the year. The relative humidity fluctuates between an average of 69% at 1500 hours GMT and 94% at 0600 hours GMT (Personal Communication, Meteorological Services Department, Accra).

The vegetation is natural grassland composed mostly of medium height perennial grasses with scattered shrubs. The quantity and nutritive values of the grassland, however, have a high seasonal variability. The nutritive value is only high when they are in active growth. These are however, progressively reduced to standing hay of low nutritive value with the onset of the dry season, (Landsbury, 1960;

Rose-Innes, 1963 and Rose-Innes and Mabey, 1964).

3.2 BREEDING

The crossbreeding programme was started in 1958 with four Jersey bulls imported from Britain for crossing with West African Shorthorn, Sokoto Gudali, and N'Dama cows. The objective was to develop a suitable type of milk cow for the West African humid tropics.

A later modification to the programme in 1966 saw the introduction of artificial insemination using deep frozen Jersey semen imported from Britain. In 1967 Friesian semen was used in crosses with local breeds and the Jersey crossbreds. The aim was to increase milk yield and to lower the high butter fat content of the milk of the Jersey crossbreds (Vohradsky, 1970).

The mating plan followed was mainly upgrading of the local breeds; that meant the crosses were inseminated by the improver breeds. However, inter-se mating of the crossbreds also featured in the programme. Production of advanced generations from F_2 was however, discontinued in 1970 largely as a result of deterioration in the overall performance of the F_2 generation (Vohradsky, 1970). Contemporary pure local breeds were also produced concurrently.

3.3 MANAGEMENT PRACTICES:

Details of the management practices have been described by Vohradsky (1970). Briefly, crossbred calves were allowed to suck milk from their crossbred dams for the first twenty-four hours for colostrum. They were then moved into calf-pens for bucket feeding. Calves whose dams could not be milked for various reasons, for example, due to poor milk yield, small teats or refusal to let down milk were allowed to run with their dams and to suck milk until weaning. Calves were usually weaned at the age of seven months. The cows were grazed on the natural grassland pastures of the plains in and around the station and on cultivated pastures on the station. Preserved forage in the form of hay, maize or sorghum silage and also ensiled wetspent malt were fed as supplement in the dry season. These were given at 2-3% bodyweight on dry matter basis.

Lactating cows were fed additional concentrate ration. This was given according to the level of milk production of each cow. Trace mineral saltlicks and fresh clean water were made available to all animals ad-lib.

All lactating cows with well developed teats and good temperament were machine-milked, whilst others were hand-milked. Milking was done twice a day. In the morning and in the afternoon. Milk yield of each cow was recorded at each milking. These gave daily yields which were summed up for the monthly yields. The butterfat percentage was determined from samples taken fortnightly throughout lactation and

worked out for total monthly butterfat production. Milking of the pure local breeds was finally stopped in 1970 because of their low milk output. Dipping or spraying was done weekly during the wet season and fortnightly during the dry season using either Gamatox or Backdip or Delnav for the control of ectoparasites. Drenching was done monthly using Hexachlorophane, Thibenzole or Coopane for the control of intestinal parasites. All animals were weighed at birth and then at monthly intervals thereafter.

3.4 DATA COLLECTION:

Data covering the period from 1967 to 1982 were considered. Production data pertaining to all two-breed crosses involving Jersey and local breeds viz: West African Shorthorn or Sokoto Gudali were extracted from the record books kept on dairy cattle at the station. The following parameters were taken or calculated:- Age of cow at first calving, number of services per conception, calf birth weight, calf weaning weight, pre-weaning average daily weight gains, calving interval, lactation length, first lactation milk yield, average lactation milk yield, average daily milk yield, annualized milk yield, lactation fat yield and fat percentage.

Annualized milk yield was calculated as:

$$\frac{\text{average lactation milk yield (kg)} \times 365 \text{ days}}{\text{calving interval (days)}}$$

This parameter is of particular importance because it gives an indication of the annual milk yield potential of the cow

which accounts for the dry period as well and thus represents the economic producing ability of the cow.

Different numbers of animals existed in the different breed groups. These gave rise to unequal and disproportionate sub-class frequencies for the various traits.

Populations of various genotypes ranging from $\frac{1}{2}$ to $\frac{15}{16}$ Jersey inheritance were created over the years of Jersey crossings, but the number of observations in some breed groups were too few. Consequently, the genotypic classes used in the analysis were as follows:-

1. WAS = pure West African Shorthorn,
2. WAS F_1 = $\frac{1}{2}$ Jersey $\frac{1}{2}$ WAS
3. WAS Bc = $\frac{3}{4}$ Jersey and $\frac{1}{4}$ WAS (first backcross),
4. GUD = pure Sokoto Gudali,
5. GUD F_1 = $\frac{1}{2}$ Jersey $\frac{1}{2}$ Gudali,
6. GUD Bc = $\frac{3}{4}$ Jersey and $\frac{1}{4}$ GUD (first backcross)

Three seasons of calving were delineated based on geo-climate as follows:-

Season 1: April - July (major rainy season)

Season 2: August - November (minor rainy season)

Season 3: December - March (dry season)

3.5 ANALYSIS OF DATA:

Least squares means for the genetic groups for the milk yield traits, reproductive traits and calf growth traits were estimated using the General Linear Model (GLM) Type III procedures of Statistical Analysis System (SAS) (1987).

I. For first lactation milk yield and age at first calving the following model was used to describe the observations:-

$$Y_{ijkl} = U + G_i + Y_j + S_k + e_{ijkl} \dots\dots\dots \text{model I}$$

where Y_{ijkl} = lactation milk yield or age at first calving,

U = the overall mean,

G_i = the effect of the i^{th} cow genotype, $i = 1, \dots, 6$,

Y_j = the effect of the j^{th} year of calving, $j = 1, \dots, 16$,

S_k = the effect of the k^{th} season of calving, $k = 1, \dots, 3$,

e_{ijkl} = the random error term, assumed NID $(0, \sigma_e^2)$.

II. For average lactation milk yield, average daily milk yield, annualized milk yield, lactation fat yield, lactation length and number of services per conception, the following model was used to describe the observations:-

$$Y_{ijklm} = U + G_i + Y_j + S_k + P_l + e_{ijklm} \dots\dots\dots \text{model II}$$

where Y_{ijklm} = response variable,

U = the overall mean,

G_i = the effect of the i^{th} cow genotype, $i = 1, \dots, 6$,

S_k = the effect of the k^{th} season of calving, $k = 1, \dots, 3$,

Y_j = the effect of the j^{th} year of calving, $j = 1, \dots, 16$,

P_l = the effect of the l^{th} parity, $l = 1, \dots, 5$,

e_{ijklm} = the random error term, assumed NID $(0, \sigma_e^2)$.

III. The following model was used to describe the observations for calving interval, birthweight and pre-weaning average daily gain.

$$Y_{ijklmn} = U + G_i + Y_j + S_k + P_l + X_m + e_{ijklmn} \dots\dots \text{model III}$$

where Y_{ijklmn} = response variable,

U = the overall mean,

G_i = the effect of the i^{th} cow genotype, $i = 1, \dots, 6$,

Y_j = the effect of the j^{th} year of calving, $j = 1, \dots, 16$,

S_k = the effect of the k^{th} season of calving $k = 1, \dots, 3$,

P_l = the effect of the l^{th} parity, $l = 1, \dots, 5$,

X_m = the effect of the m^{th} sex of calf, $m = 1, 2$,

e_{ijklm} = the random error term, assumed NID $(0, \sigma_e^2)$.

IV. For weaning weight the following model was used to describe the observations:-

$$Y_{ijklmno} = U + b_1 (W_i - \bar{W}) + G_j + Y_k + S_l + P_m + X_n + e_{ijklmno}$$

.....model IV

where $Y_{ijklmno}$ = weaning weight,

U = the overall mean,

W_i = the effect of the i^{th} weaning age,

G_j = the effect of the j^{th} genotype, $j = 1, \dots, 6$,

Y_k = the effect of the k^{th} year of calving, $k = 1, \dots, 16$,

S_l = the effect of the l^{th} season of calving, $l = 1, \dots, 3$,

P_m = the effect of the m^{th} parity, $m = 1, \dots, 5$,

X_n = the effect of the n^{th} sex of calf, $n = 1, 2$,

b_1 = the regression coefficient of weaning weight on weaning age;

$e_{ijklmno}$ = the random error term, assumed NID $(0, \sigma_e^2)$.

S.A.S. procedures for planned single degree of freedom comparisons using F-tests were employed to contrast

the following genotypes:-

1. WAS - WAS F_1 ,
2. WAS F_1 - WAS Bc,
3. GUD - GUD F_1 ,
4. GUD F_1 - GUD Bc,
5. WAS - GUD ,
6. WAS F_1 - GUD F_1 ,
7. WAS Bc - GUD Bc.

Additive and heterotic effects were estimated using the additive-dominance model of Jain (1982). The mean performance (m) of parental breeds used for crossing were estimated as follows:-

$$m = \bar{B}_1 - \frac{1}{2} \bar{F}_2 + \frac{1}{2} \bar{P}_2$$

The additive effects (g) expressed as deviations from mean (mid-parent) were estimated from the following formula:-

$$g = \bar{B}_1 - \frac{1}{2} \bar{F}_1 - \frac{1}{2} \bar{P}_2$$

Individual heterotic effects (h) also expressed as deviations from mean (mid-parent) were obtained from the following:-

$$h = 3/2 \bar{F}_1 - \bar{B}_1 - \frac{1}{2} \bar{P}_2$$

where: \bar{P}_2 = the local breed genotypic mean. In this case West African Shorthorn or Sokoto Gudali.

\bar{F}_1 = the genotypic mean of halfbreds

\bar{B}_1 = the genotypic mean of crossbreds having $\frac{3}{4}$ Jersey inheritance.

The standard errors (S.E.) for the estimates of the additive and heterotic effects were obtained by the formula

employed by Roy et al (1987) as follows:-

$$\text{S.E. (g)} = \sqrt{V_{\bar{B}_1} + \frac{1}{4}V_{\bar{F}_1} + \frac{1}{4}V_{\bar{P}_2}}$$

$$\text{S.E. (h)} = \sqrt{9/4 V_{\bar{F}_1} + V_{\bar{B}_1} + \frac{1}{4}V_{\bar{F}_2}}$$

where: $V_{\bar{F}_1}$, $V_{\bar{B}_1}$, $V_{\bar{P}_2}$ are the variances of \bar{F}_1 , \bar{B}_1 and \bar{P}_2 respectively.

Percentage heterosis for each trait was obtained from the following relationship:-

$$\text{Percentage heterosis} = h/m \times 100\%$$

where h = the corresponding heterotic effect for the trait and

m = the mean performance of the parental breeds for the trait.

As an approximate test for significance of estimates of additive and heterotic effects, the values of the additive and heterotic effects which are more than twice their respective standard errors were taken as significant at 5% level (Finchman, 1983; Roy et al, 1987).

CHAPTER FOUR**4.****RESULTS****4.1 MILK YIELD TRAITS:**

The analysis of variance for first lactation milk yield, average lactation milk yield, average daily milk yield and annualized milk yield are presented in Table 1(a). Table 1(b) shows the analyses of variance for fat yield, percentage butter fat and lactation length. Genotype was a highly significant ($P < .01$) source of variation in all the milk yield traits. Year of calving also significantly ($P < .01$) affected all the milk yield traits except first lactation milk yield. Parity had no significant effect on lactation length but was a highly significant ($P < .01$) source of variation in all other traits. Season of calving was not significant for any of the milk yield traits.

Least square means of cow genotypes are detailed in Tables 2(a) and 2(b). For first lactation milk yield, GUD, producing 1,222 kg of milk was significantly ($P < .01$) better than WAS which produced only 40 kg of milk. Comparing WAS F_1 and GUD F_1 it was found that even though the GUD F_1 gave more milk (319 kg) than the WAS F_1 the difference was not significant. Similarly the difference between WAS Bc and GUD Bc was not significant, even though GUD Bc produced 282 kg more milk than WAS Bc. Whilst the first lactation milk yield of WAS F_1 was significantly ($P < .01$) more than that for WAS (1,370 kg versus 40 kg), no significant differences were found for the remaining contrasts.

TABLE 1(a) ANALYSIS OF VARIANCE OF MILK YIELD TRAITS

Source of variation	df	FLMY (kg) MS	ALMY (kg) MS	ADMY (kg) MS	AMY (kg) MS
Genotype	5	1482283.28**	5744228.3**	41.85**	4784888.74**
Year of calving	11	490892.36	1850916.84**	10.03**	1559063.37**
Season of calving	2	323689.10	29662.50	1.02	225648.40
Lactation length	4		2778552.1**	39.00**	196609.07**
Sex	1				660308.09
Error (FLMY)	44	310477.90	383317.11	3.54	400747.31
(ALMY)	371				
(ADMY)	370				
(AMY)	310				

** Significant (P<0.01)

TABLE 1(b) ANALYSIS OF VARIANCE OF MILK YIELD TRAITS

Source of variation	df	LFY kg MS	BF% MS	LL days MS
Genotype	5	14766.75**	4.55**	131093.92**
Year of Calving	11	8109.59**	7.14**	36188.73**
Season of Calving	2	547.08	1.44	3132.75
Lactation length	4	6569.99**	2.15**	16495.75
Error (LFY)	360	968.03	0.78	6937.94
(BF%)	358			
(LL)	378			

** Significant (P<0.01)

FLMY = First lactation milk yield

ALMY = Average lactation milk yield

ADMY = Average daily milk yield

AMY = Annualized milk yield

FY = Lactation fat yield

BF% = Percent butterfat

LL = Lactation length

MS = Mean square

TABLE 2(a)

**LEAST SQUARES MEANS OF COW GENOTYPES AND
SELECTED CONTRASTS FOR MILK YIELD TRAITS.**

COW GENOTYPE	TRAIT			
	FLMY (kg)	ALMY (kg)	ADMY (kg)	AMY (kg)
WAS	40±335.7 (4)	44±207.7 (10)	1.1±0.63 (10)	98±40.0 (8)
WAS F ₁	1370±191.0 (26)	1533±58.7 (208)	5.2±0.18 (207)	1574±63.0 (175)
WAS Bc	1623±178.6 (13)	1770±74.9 (92)	5.9±0.23 (92)	1604±79.0 (78)
GUD	1222±327.7 (5)	1145±226.3 (9)	5.3±0.69 (9)	1051±241.5 (9)
GUD F ₁	1689±250.2 (10)	1807±89.8 (55)	6.0±27 (55)	1688±993 (46)
GUD Bc	1905±286.2 (5)	1848±134.3 (24)	5.7±0.41 (24)	1948±1443 (22)
SELECTED COMPARISONS				
WAS - GUD	-1182**	-1101**	-4.2**	-953**
WAS F ₁ - GUD F ₁	-319	-274**	-0.8**	-114
WAS F ₁ - WAS	1330**	1489**	4.1**	-1476**
GUD F ₁ - GUD	467	662**	0.6	637*
WAS Bc - WAS F ₁	253	237**	0.7**	30
GUD Bc - GUD F ₁	216	41	-0.3	260
WAS Bc - GUD Bc	-282	-78	0.2	-344*

* Significant (P<0.05)

** Significant (P<0.01)

() Number of observations

ADMY = Average daily milk yield

FLMY = First lactation milk yield

AMY = Annualized milk yield

ALMY = Average lactation milk yield

Similar significant levels were obtained for the comparisons involving: WAS/GUD, WAS Bc/GUD Bc, WAS F_1 /WAS and GUD Bc/GUD F_1 for average lactation milk yield as for first lactation milk yield. The average lactation milk yield of GUD F_1 (1,807 kg) was significantly ($P < .01$) higher than that of WAS F_1 (1,533 kg). In addition, the GUD F_1 also produced significantly ($P < .01$) more milk (662 kg) than GUD. WAS Bc also gave significantly ($P < .01$) higher average lactation milk yield than WAS F_1 (1,770 kg versus 1,533 kg).

For average daily milk yield, the results obtained were similar to those obtained for average lactation milk yield in terms of significance except that the difference of 0.6 kg/day between the GUD F_1 and GUD was not significant.

Annualized milk yield was significantly ($P < .01$) higher in GUD than WAS. The difference between their respective F_1 's was however not significant. But when the respective backcrosses were compared it was found that GUD Bc gave significantly ($P < .05$) higher annualized milk yield than WAS Bc (1,948 kg versus 1,604 kg). WAS F_1 gave a significantly ($P < .01$) higher milk yield than WAS (1,574 kg as against 98 kg) but was not significantly different from WAS Bc. Similarly, GUD F_1 gave significantly ($P < .05$) higher annualized milk yield than GUD but no significant difference was found between GUD F_1 and GUD Bc.

For lactation fat yield, GUD produced significantly ($P < .01$) more milk fat than WAS (66 kg versus 1.6 kg).

TABLE 2(b) LEAST SQUARES MEANS OF COW GENOTYPES AND
SELECTED CONTRASTS FOR MILK YIELD TRAITS:

COW GENOTYPE	TRAITS		
	LFY (kg)	BF%	LL days
WAS	1.6±1.1 (9)	3.3±0.28 (9)	-7±27.9 (10)
WAS F ₁	86±3.0 (203)	4.9±0.08 (203)	237±7.4 (214)
WAS Bc	93±3.8 (92)	4.7±0.10 (91)	266±9.7 (93)
GUD	66±12.0 (8)	4.6±0.30 (8)	167±30.4 (9)
GUD F ₁	101±4.7 (51)	4.9±0.12 (51)	247±11.9 (55)
GUD Bc	100±6.8 (24)	5.1±0.17 (23)	277±17.9 (24)
SELECTED COMPARISONS			
WAS - GUD	-64.4**	-1.30**	-175**
WAS F ₁ - GUD F ₁	-15**	-0.0	-10
WAS F ₁ - WAS	84.4**	1.6**	244**
GUD F ₁ - GUD	35**	0.3	79*
WAS Bc - WAS F ₁	7	-0.2	29**
GUD Bc - GUD F ₁	-1	0.2	30
WAS Bc - GUD Bc	7	-0.4*	-11

* Significant (P<0.05)

** Significant (P<0.01)

() Number of observations
 LFY = Lactation fat yield
 BF% = Percent butterfat
 LL = Lactation length

Milk fat yield in GUD F_1 was also significantly ($P < .01$) higher than in WAS F_1 but no significant difference was observed between the respective backcrosses. Both F_1 's produced significantly ($P < .01$) more milk fat than their corresponding purebreds (86 kg versus 1.6 kg for WAS F_1 and WAS; and 101 kg versus 66 kg for GUD F_1 and GUD). However, the backcrosses were not significantly different from their F_1 s in milk fat yield.

Percentage milk fat was significantly ($P < .01$) higher in GUD than in WAS (4.6% as against 3.3%). Similarly, WAS F_1 was significantly ($P < .01$) richer in milk fat than WAS. With regard to the two backcrosses the percentage milk fat were $4.7 \pm 0.10\%$ for WAS Bc and $5.1 \pm 0.17\%$ for GUD Bc. The difference of 0.4% was significant ($P < .05$). Differences between the other groups compared were not significant.

For lactation length, GUD significantly ($P < 0.01$) produced milk over a longer period than WAS. The least squares mean of length of lactation of WAS was -7 days. This indicates that WAS milked for only a brief period and thus WAS has a negligible lactation length. On the other hand, mean lactation length of GUD was 168 days. No significant differences were found between GUD F_1 and WAS F_1 and GUD Bc and WAS Bc. However, both GUD F_1 and WAS F_1 stayed significantly longer in lactation than their respective purebreds (179 days longer in GUD F_1 and 244 days longer in WAS F_1). Lactation length of WAS Bc was significantly ($P < .01$) greater than that of WAS F_1 (266 days versus

237 days). On the other hand, the difference between GUD Bc and GUD F_1 for lactation length was not significant.

ADDITIVE AND HETEROTIC EFFECTS FOR MILK YIELD TRAITS:

Estimates of additive and heterotic effects for the milk yield traits are presented in Table 3. All estimates were positive except for a slight negative heterotic effect for percentage butterfat in GUD. In the WAS crossbred group, the additive and heterotic effects for all the milk yield traits were significant ($P < .05$) except the heterotic effect for first lactation milk yield. However, only additive effect for average lactation milk yield, annualized milk yield and lactation length were significant in GUD.

4.2 REPRODUCTION TRAITS

Analysis of variance for reproductive traits are presented in Table 4. All the reproductive traits studied were significantly ($P < 0.01$) affected by genotype and year of calving. The effect of parity on calving interval was also significant ($P < .01$). However, the effect of parity on number of services per conception was not significant. Season of calving and sex of calf did not have any significant effect on the reproductive traits.

Table 5 shows least squares means for cow genotypes and selected contrasts for reproductive traits. GUD and WAS did not differ significantly in age at first calving. The differences between the two F_1 groups and the two backcross groups were also not significant.

TABLE 3.

**ESTIMATES OF ADDITIVE (a) AND HETEROTIC (h) EFFECTS
FOR MILK YIELD TRAITS FOR JERSEY X WEST AFRICAN
SHORTHORN (WAS) AND SOKOTO GUDALI (GUD) CROSSES**

TRAIT		m	g	h	% het
FLMY (kg)	WAS	958±263.0	917.6±263.0*	412.3±377.0	43.0
	GUD	2671.5±352.7	499.1±472.7	17.6±472.1	1.1
ALMY (kg)	WAS	1025±131.4	981.1±131.4*	507.8±155.4*	49.5*
	GUD	1517±181.3	371.3±181.3*	290.5±221.3	19.1
ADMY (kg)	WAS	3.85±0.4	2.8±0.4*	1.3±0.47*	33.8*
	GUD	5.35±0.6	0.1±0.6	0.6±0.7	11.2
AMY (kg)	WAS	866±88.2	767±88.2*	709±125.4*	81.8*
	GUD	1629.5±194.6	579±194.6*	58±240.0	3.6
LFY (kg)	WAS	50.8±4.1	49.3±4.1*	35.0±5.9*	68.9*
	GUD	82.5±9.4	17.2±9.4	17.6±11.5	21.3
BF %	WAS	3.9±0.1	0.61±0.14*	0.97±0.21*	24.9*
	GUD	5.0±0.2	0.30±0.2	-0.04±0.3	-0.8
LL days	WAS	151±17.4	150.8±17.3*	93.4±22.3*	61.9*
	GUD	237±24.2	68.9±24.2*	9.7±29.5	4.1

* Significant (P<0.05)

% het = Percentage heterosis
 FLMY = First lactation milk yield
 ALMY = Average lactation milk yield
 ADMY = Average daily milk yield
 AMY = Annualized milk yield
 LFY = Lactation fat yield
 BF % = Percent butter fat
 LL = Lactation length
 m = mean performance of the parental breeds.

TABLE 4. ANALYSIS OF VARIANCE OF COW REPRODUCTIVE TRAITS.

Source of Variation	df	AFC, months MS	NSC MS	C.I. days MS
Genotype	5	645.64**	0.43*	391769.54**
Year of Calving	15	522.63**	1.79**	56942.31**
Season of Calving	2	16.65	0.32	6464.76
Parity	4	-	0.59	150361.94**
Sex	1	-	-	65569.88
Error (AFC)	212	67.72	0.48	28859.84
(NSC)	468			
(C.I.)	776			

* Significant ($P < 0.05$)

** Significant ($P < 0.01$)

AFC = Age of cow at first calving

NSC = Number of services per conception

C.I. = Calving interval

MS = Mean square

The two F_1 groups however, calved at significantly ($P < .01$ for WAS and $P < .05$ for GUD) earlier ages than their corresponding purebreeds. WAS Bc also calved significantly ($P < .05$) earlier for the first time than Was F_1 (36 as against 42.3 months), but there was no significant difference between GUD Bc and GUD F_1 for age at first calving.

Of the various types of comparisons made for number of services per conception none showed any significant difference. The interval between calvings for GUD was significantly ($P < .01$) shorter than that for WAS (475 versus 551 days). WAS F_1 also had a significantly ($P < .01$) shorter calving interval than WAS whilst the differences between the other groups compared were not significant.

ADDITIVE AND HETEROTIC EFFECTS FOR REPRODUCTIVE TRAITS:

Estimates of additive and heterotic effects for cow reproductive traits in WAS crosses and in GUD crosses are presented in Table 6. In the WAS crossbreds additive effects for age at first calving was negative (-10.2 months) and significant ($P < .05$), while additive effects for number of services per conception and calving interval were negative but not significant. Heterotic effects, relative to additive effects, were large and important in reducing calving interval (-102 days, $P < .05$). Heterotic effects for age at first calving and number of services per conception on the other hand were positive but non-significant.

TABLE 5. LEAST SQUARES MEANS OF COW GENOTYPES AND
SELECTED CONTRASTS FOR COW REPRODUCTIVE TRAITS

COW GENOTYPE	AFC Months	NSC	C.I. days
WAS	50.0±1.16 (93)	1.33±0.071 (119)	551±11.3 (343)
WAS F ₁	42.3±1.38 (54)	1.47±0.063 (168)	429±14.8 (16)
WAS Bc	36.0±2.33 (15)	1.35±0.080 (92)	470±22.0 (70)
GUD	49.3±1.45 (51)	1.37±0.113 (48)	475±15.7 (160)
GUD F ₁	42.5±2.49 (16)	1.46±0.098 (56)	453±27.0 (44)
GUD Bc	40.4±3.54 (6)	1.20±0.186 (15)	417±42.2 (18)
SELECTED COMPARISONS			
WAS - GUD	0.7	-0.04	76**
WAS F ₁ - GUD F ₁	-0.2	0.01	-24
WAS F ₁ - WAS	-7.7**	0.14	-122**
GUD F ₁ - GUD	-6.8*	0.09	-22
WAS Bc - WAS F ₁	-6.3*	-0.12	-41
GUD Bc - GUD F ₁	-2.1	-0.26	-36
WAS Bc - GUD Bc	-4.4	0.15	53

* Significant (P< 0.05) NSC = Number of services

** Significant (P< 0.01) per conception

() Number of observations C.I.= Calving interval

AFC = Age at first calving

TABLE 6. ESTIMATES OF ADDITIVE (g) AND HETEROTIC (h)
EFFECTS FOR REPRODUCTIVE TRAITS FOR JERSEY
X WEST AFRICAN SHORTHORN (WAS) AND SOKOTO
GUDALI (GUD) CROSSES

TRAIT		m	g	h	% het
AFC Months	WAS	39.85±2.5	-10.2±2.5*	2.5±3.17	6.3
	GUD	43.8±3.8	-5.5±3.8	-1.3±5.2	3.0
NSC	WAS	1.28±0.09	-0.06±0.09	0.20±0.13	15.6
	GUD	1.16±0.2	-0.22±0.2	0.3±0.24	25.9
C.I. days	WAS	531.0±23.9	-20.0±23.9	-102±31.8*	-19.2
	GUD	428±45	-46±54.0	24±59.0	5.6

* - Significant (P<0.05)

% het = Percentage heterosis

AFC = Age of cow at first calving

NSC = Number of services per conception

C.I. = Calving interval

m = Mean performance of the parental breeds crossed

In GUD crosses, even though additive effects for age at first calving, number of services per conception and calving interval were negative, none was significant. None of the heterotic effects on reproductive traits in GUD crosses was significant.

4.3 CALF GROWTH TRAITS:

Table 7 shows the analysis of variances for calf growth traits. The effect of genotype on all the growth traits were highly significant ($P < .01$). Year of calving also significantly affected all the growth traits. Age at weaning significantly affected weaning weight of calves. The effects of parity and sex on birth weight and on weaning weight were significant ($P < .01$ and $P < .05$ for effect of parity on birthweight and on weaning weight). Average daily gain was however, not significantly affected by parity and sex. Season of calving did not have any significant influence on any of the growth traits.

Least squares means of genotypes and selected contrasts for calf growth traits are presented in Table 8. GUD calves weighed significantly ($P < .01$) more at birth than WAS calves (23.3 kg as against 19.8 kg). Similarly, GUD F_1 calves and GUD Bc calves weighed significantly ($P < .01$) higher at birth than WAS F_1 and WAS Bc calves respectively. The backcrosses also had significantly ($P < .01$) higher birth weights than their corresponding F_1 s. However, when the F_1 s were compared to their purebreds no significant differences were found.

TABLE 7. ANALYSIS OF VARIANCE OF CALF GROWTH TRAITS

Source of Variation	df	BWT (kg) MS	ADG (g/d) MS	WWT (kg) MS
Calf Genotype	5	345.00**	0.2886**	10210.26**
Year calved	15	40.28**	0.1094**	5130.16**
Season calved	2	14.19	0.0202	366.34
Parity	4	24.97**	0.0245	986.76*
Sex	1	55.23**	0.0654	6650.14**
Regr.	1			10992.15**
Error (BWT)	681	5.25	0.0229	413.80
(ADG)	483			
(WWT)	482			

* Significant ($P < 0.05$)

** Significant ($P < 0.01$)

MS = Mean square

BWT = Birth weight

ADG = Preweaning average daily weight gains

WWT = Weaning weight

Regr.= Regression of weaning weight on weaning age.

ABLE 8. LEAST SQUARES MEANS OF GENOTYPES AND SELECTED CONTRASTS FOR CALF GROWTH TRAITS

COW GENOTYPE	TRAIT		
	Birthweight kg	ADG (g/d)	Weaning weight kg
WAS	19.8±0.21 (280)	276±19.2 (235)	80.5±2.58 (75)
WAS F ₁	20.1±0.26 (103)	339±25.5 (61)	95.9±3.43 (75)
WAS Bc	21.7±0.25 (108)	361±22.9 (61)	102.3±3.08 (66)
GUD	23.3±0.26 (154)	379±23.3 (102)	112.2±3.14 (103)
GUD F ₁	23.1±0.45 (38)	489±34.0 (31)	128.5±4.57 (32)
GUD Bc	24.6±0.47 (26)	378±40.8 (16)	107.0±5.49 (16)
SELECTED COMPARISONS			
WAS - GUD	-3.5**	-103**	-31.7**
WAS F ₁ - GUD F ₁	-3.0**	-150**	-32.6**
WAS F ₁ - WAS	0.3	63*	15.4**
GUD F ₁ - GUD	-0.2	110**	16.3**
WAS Bc - WAS F ₁	1.6**	22	6.4
GUD Bc - GUD F ₁	1.5**	-111*	-21.5**
WAS Bc - GUD Bc	-2.9**	-17	-4.7

* Significant (P<0.05)

** Significant (P<0.01)

() Number of observations

ADG = Pre-weaning average daily weight gains

GUD was significantly ($P < .01$) better than WAS in ADG with GUD gaining 379g/day as against 276g/day in WAS. The GUD F_1 made significantly ($P < .01$) faster gains than WAS F_1 while the WAS F_1 also grew at a significantly ($P < .05$) faster rate to weaning than pure WAS. ADG of GUD F_1 was significantly ($P < .01$) higher than the pure GUD, and GUD F_1 calves gained significantly ($P < .05$) faster than GUD Bc calves. No significant difference was however found between WAS Bc and GUD Bc. Comparison between WAS Bc and WAS F_1 for ADG also revealed no significant difference. The results for weaning weight closely followed those for ADG. GUD F_1 calves were significantly ($P < .01$) heavier at weaning than GUD Bc calves (128 kg versus 107 kg).

ADDITIVE AND HETEROTIC EFFECTS FOR CALF GROWTH TRAITS:

Table 9 shows estimates of additive and heterotic effects for calf growth traits in WAS crosses and in GUD crosses. Additive effects in WAS crossbreds were positive and significant for birthweight (1.7 kg, $P < .05$), ADG (53.6 g/d, $P < .05$) and weaning weight (14.1 kg, $P < .01$). However, there was a negative significant ($P < .05$) heterotic effect of -1.4 kg for birthweight. Heterotic effects on ADG and weaning weight were positive but non-significant. In GUD crosses, additive effect on birthweight was 1.4 kg and significant ($P < .05$). For ADG and weaning weight, however, additive effects were negative and significant only for weaning weight (-13.4 kg, $P < .05$).

TABLE 9. ESTIMATES OF ADDITIVE (a) AND HETEROTIC (h)
EFFECTS FOR CALF GROWTH TRAITS

TRAIT		m	g	h	% het
Birthweight (kg)	WAS	21.55±0.31	1.7±0.30*	-1.4±0.48*	6.5*
	GUD	24.7±0.54	1.4±0.54*	-1.6±0.60*	6.5*
ADG (g/d)	WAS	329.5±25.91	53.6±25.91*	10.1±45.60	3.1
	GUD	323±45.71	-56.4±45.71	166.3±110.74*	51.5*
Weaning-Weight (kg)	WAS	94.6±3.75	14.1±3.75*	1.3±6.13	1.4
	GUD	98.95±6.15	-13.4±6.15*	29.6±8.92*	29.9*

* Significant (P<0.05)

m = Mean performance of the parental breeds crossed

% het = Percentage heterosis

The heterotic effect for birthweight was negative and significant (1.6 kg, $P < .05$), a result similar to that obtained in WAS crossbreds. Heterotic effects for ADG (166.3g/day) and for weaning weight (29.6 kg) were positive and significant ($P < .05$).

CHAPTER FIVE

5. DISCUSSION

The main interest in this study was to determine additive and heterotic effects on production traits in crossbred cattle at the Agricultural Research Station (A.R.S), Legon. In addition comparisons of the genotypic means for the various traits were made to elucidate the relative performance of the genotypes. The author of this study had no hand in the design, inputs or management practices of the breeding programme established at A.R.S. The discussion was done with these factors in mind.

5.1 EFFECT OF GENOTYPE ON MILK YIELD TRAITS

Genotype had a highly significant influence on all the milk yield traits.

LACTATION LENGTH

At the purebred level, GUD milked for significantly longer period than WAS. The least squares mean lactation length of GUD was 168 days and that for WAS was -7 days. The least squares mean of -7 days for WAS indicate that WAS lactated for only a brief period and hence its lactation length is effectively negligible. Ngere et al (1975) have also observed similar brief period of lactation for WAS. They suggested that WAS cows when milked in the absence of the calf went dry within a few weeks which accounted for the negligible lactation length. On the other hand, the longer lactation length for GUD in this study may be due to the

better inherent milk let-down ability of this breed. This is in agreement with the reports of Montsma (1962), Sada (1968) and Vohradsky (1979). They all have classified GUD, a Zebu animal, as being better than other local breeds in milk let-down.

Both WAS F_1 and GUD F_1 milked for significantly longer days and gave significantly higher yields of milk than their corresponding pure local breeds. Similarly, the backcross cows milked for longer days and produced more milk than the F_1 cows. It has been well established that milking for a minimum of 305 days is an inherent characteristic of exotic pure breeds like the Jersey (Schmidt and Van Vleck, 1974; Mason and Buvanendran, 1982). Furthermore, an average lactation of 4057 kg is noted for the Jersey breed (Schmidt and Van Vleck, 1974). In this study lactation length for WAS was negligible. Lactation length for WAS F_1 was 237 days and for WAS Bc it was 266 days. The percentage Jersey inheritance in WAS F_1 and in WAS Bc are 50% and 75% respectively. Therefore the increase in lactation length for the WAS F_1 and WAS Bc could be directly related to the proportion of Jersey inheritance in the crossbreds. This is further confirmed by the fact that both the additive and heterotic effects were positive and significant in the desired direction for WAS crossbred group (Table 3).

Comparison of lactation lengths of GUD (168 days) and GUD F_1 (247 days) show that lactation length of GUD F_1 improved by 47%. The additive effect was positive and significant and the heterotic effect was also positive but

not significant. Thus, this increase may be due to the influence of the exotic gene. Similar improvement (54%) has also been reported by Parekh (1974) for Friesian x Tharparkar F_1 over purebred Tharparkar. He ascribed the increase to gene complementarity and heterosis. Lactation lengths of WAS F_1 and GUD F_1 are similar (237 days and 247 days respectively). These results are in agreement with values obtained by some workers in West Africa. Letenneur (1978) in the Ivory Coast reported 255 days lactation length for F_1 derived from Friesian x N'Dama cross. Sohael (1294) in Nigeria obtained 246 days for F_1 derived from Friesian x Fulani cross. It therefore appears that effect of exotic gene on lactation length is about the same on the local breeds.

With regard to the backcrosses, similar percentage increases for WAS and GUD with respect to their F_1 's were obtained (12.24% and 12.15% respectively). Again Sohael (1984) had similar increase for his backcross (10.16%). These increases were however, not significant; suggesting that not much will be gained in lactation length by going beyond the 50% level of exotic inheritance in the local breeds.

LACTATION MILK YIELD

For first lactation milk yield, GUD out yielded WAS by 1182 kg; and for average lactation milk yield, GUD was again superior by 1101 kg. The higher milk yield of GUD was expected because of the negligible lactation length of WAS.

This makes GUD a better breed for milking purposes than WAS. These results confirm earlier observations made by Montsma (1962) and Vohradsky (1970) using the same WAS and GUD breeds. They noted that GUD is significantly superior to WAS in lactation milk yield. It therefore appears that for dairying purposes GUD is a better breed as compared to WAS. GUD crossbreds also out yielded their WAS crossbred counterparts for first and average lactation milk yields despite the fact that additive and heterotic effects had greater positive impact on WAS crosses than on GUD crosses (Table 3). GUD F_1 gave 319 kg and 274 kg more milk than WAS F_1 for first lactation and average lactation milk yields respectively. Similarly, GUD Bc produced 282 kg and 78 kg more milk than WAS Bc for the same traits. The difference in milk production between these crossbred genotypes may therefore be ascribed to the milk production potential of the local breeds from which they were derived. These findings are in agreement with earlier observations made by Vohradsky (1970), Ahunu and Acquah (1987) and Danbaro et al (1991). These workers also found GUD crossbreds to be superior in milk production when compared to WAS crossbreds and attributed this superiority to the higher milk production potential of GUD.

Both WAS F_1 and GUD F_1 gave significantly higher yields of milk than their corresponding pure local breeds. Similarly, the backcrosses produced more milk than the F_1 cows, though this difference was not significant for GUD crossbreds. First and average lactation milk yields for

WAS F_1 were 1370 and 1533 kg respectively as against 40 kg and 44 kg for WAS. The yields of WAS Bc for first and average lactation milk yields were 1623 kg and 1770 kg respectively. First and average lactation milk yields for GUD were 1222 kg and 1145 kg respectively. For GUD F_1 the first and average lactation milk yields were 1689 kg and 1807 kg and for GUD Bc they were 1905 kg and 1848 kg respectively. The additive effect for all these crosses were positive and significant for average lactation milk yield. The heterotic effect for average lactation milk yield was only positive and significant for the WAS crosses but not for the GUD crosses. For first lactation milk yield it was only the additive effect for WAS crosses which was positive and significant. The additive and heterotic effect for the rest of the crosses were not significant. It is therefore being suggested that the progressive increase in first and average milk yield in the crosses is likely to be due to the ratio of exotic to indigenous genes in the crossbreds. The higher yields of WAS F_1 and GUD F_1 than their corresponding pure breeds is in agreement with results obtained from exotic x indigenous crosses elsewhere in tropics.

Buvanendran et al (1981) reported lactation milk yields of 1648 kg and 834 kg for Friesian x White Fulani F_1 and pure breed White Fulani cattle respectively. Chacko (1983) reported yields of 2368 kg and 723 kg for Brown Swiss x Red Sindhi F_1 and pure Red Sindhi cows respectively. The better performance of F_1 animals compared to purebred dams were attributed to hybrid vigour and gene complementarity by

these workers. Thus, the milk production levels of tropical cows could be improved considerably by crossbreeding with appropriate exotic sire breeds.

For the standardized milk yield traits, the average daily milk yield of GUD (5.3 kg) was significantly superior to WAS (1.1 kg). Similarly, the annualized milk yield of GUD (1051 kg) was also significantly higher than that of WAS (98 kg). These results are directly related to the values obtained for average lactation milk yield, lactation length and calving interval. WAS did not only milk for shorter days as compared to GUD but also had longer calving interval (551 days) as against 475 days for GUD. WAS also produced significantly smaller quantity of milk (44 kg) as against 1146 kg for GUD. These results again confirm the inherent superior milk production character of the GUD.

Crossbreeding GUD dams and WAS dams with Jersey sires to produce F_1 's did not alter the advantage GUD had over WAS for average daily milk yield and for annualized milk yield. Both GUD F_1 and GUD Bc were still superior to WAS F_1 and WAS Bc respectively for average daily milk yield and annualized milk yield. However, the crossbreds significantly outyielded their respective purebreeds for average daily milk yield and annualized milk yield. These results agree with the findings of Dhillon and Jain (1977) who showed that crossbreeding increased average daily milk yield. They found the F_1 to be significantly superior to the purebreed (6.4 kg vs 4.5 kg) when they crossed Sahiwal cows with Holstein Friesian sires.

FAT YIELD

The results showed that the F_1 's produced more fat than their corresponding purebreeds (Table 2b). These results are expected when the lactation milk yield of which fat is a component are compared. Milk yield in GUD was significantly higher than in WAS. Similarly, milk production in the F_1 's was significantly higher than in their corresponding purebreeds. No significant difference were found when the backcross and F_1 crossbred genetic groups were compared for fat yield. Estimates of fat yield per lactation by other workers in the tropics also indicated that crossbreds produced significantly more fat than their local purebreeds. Branton et al (1966) using Jersey and Brahman obtained 51 kg fat for Brahman, 72 kg for the F_1 and 116 kg for the first backcross. Similarly, Shah et al (1982) using Jersey and Sahiwal obtained 52.2 kg for pure Sahiwal and 101.2 kg for the F_1 .

Except for WAS whose fat percentage was a low 3.3%, the fat percentage obtained for all the other genetic groups were similar. For WAS F_1 the fat percentage was 4.9% and for WAS Bc, GUD, GUD F_1 and GUD Bc the fat percentages were 4.7%, 4.6%, 4.9% and 5.1% respectively showing no exotic gene influence for this parameter.

Fat content of milk has been reported to rise during the process of udder evacuation (Johansson, 1961). The first portion of the milk drawn from the udder may contain only 1-2% fat, while the last portion usually contains 8-12%. The WAS purebred is noted for its strong maternal instinct to

withhold milk from the calf. It was not investigated if this instinct led to the incomplete udder evacuation in WAS to account for the low fat percentage for WAS. Other workers using exotic and tropical breeds have reported no significant differences between the genetic groups they examined for fat percentage. Branton et al (1966) found no significant difference in fat percentage derived from crossbreds having 1/2 and 3/4 Jersey inheritance in a Jersey x Brahman crossbreeding experiment. They obtained for F_1 5.7%, for B_1 5.4% and for B_2 5.1%. Letenneur (1978) also found no significant difference between the F_1 (5.76%) and the B_1 (5.40%) crossbreds derived from Jersey and N'Dama. Furthermore, Shah et al (1982) obtained similar values (4.55%) for F_1 and B_1 crossbreds derived from Jersey x Sahiwal crosses, and Sohael (1984) using Friesian and White Fulani also obtained no significant difference between the F_1 and the B_1 crosses. He reported for F_1 , 5.7% and B_1 , 5.0%.

The overall results for the milk production traits for WAS and its crossbreds and GUD and its crossbreds revealed that at the 50% level of Jersey inheritance, the advantage of GUD over WAS diminished and the differences persisted only in average milk yield, average daily milk yield and lactation fat yield. At the 75% level of Jersey inheritance only the difference in percentage fat and annualized milk yield were significant. Thus as exotic blood increased in the local breeds, the response of WAS to improvement in the milk yield traits was greater than that of GUD. This would

seem to indicate a clear difference in combining ability for milk production traits between the two indigenous breeds. This may be due to the greater disparity in level of milk production between WAS and Jersey than between GUD and Jersey. Heterosis levels can therefore be expected to be higher in Jersey x WAS crossbreds than in Jersey x GUD crossbreds as Table 3 makes clear.

The fact that GUD Bc cows were not significantly different from GUD F_1 cows in all the milk production traits could indicate that for the GUD, crossbreeding need not go beyond the F_1 for economic gains. This observation agrees with the statement made by Turton (1980) that backcrossing to the taurus parent generally resulted in poorer overall performance than in the F_1 . For the WAS, crossbreeding beyond the F_1 to obtain a backcross may be necessary to achieve significant increases in average lactation milk yield, average daily milk yield and lactation length.

5.2 EFFECTS OF GENOTYPE ON REPRODUCTIVE TRAITS

Age at First Calving (AFC)

Various reports have shown that when exotic dairy breeds are crossed with tropical indigenous breeds, there is a significant reduction ranging from 2 months to 9 months in the age at first calving (AFC) of the indigenous breeds (Amble and Jain, 1966; Bhosrekar, 1976; Fahmy et al, 1976; Rao and Taneja, 1980; Buvanendran et al, 1981). The results of the present study are in agreement with the above reports. WAS calved for the first time at 50 months and WAS F_1 calved at 42 months, resulting in a significant reduction

in age at first calving of 8 months. WAS Bc calved at still an earlier age (36 months) than even WAS F_1 . Similarly, while GUD calved for the first time at a mean age of 49 months, GUD F_1 calved at 43 months giving a significant mean difference of 6 months, and GUD Bc calved at 40 months. The usual AFC for Jersey is between 23 and 24 months (Bucket, 1977). Consequently, the progressive reduction in AFC in the F_1 and the Bc in this study could be directly related to the proportion of Jersey genes in these crossbreds.

Comparison of GUD and WAS showed slightly lower AFC for GUD than WAS but this difference was not significant. Significant breed differences in AFC have however been reported by Chhikara, et al (1979) in Haryana, Tharparkar and Sahiwal heifers in India. They explained that breed differences probably reflect differences in management conditions. This is because the time taken by an animal to attain puberty and sexual maturity depends on the quality and quantity of feed available, which affects growth rate. In this study GUD and WAS dams were kept under the same management conditions and hence the similarity in their ages at first calving. However, age at first calving of 38.6 months was reported by Sada (1986) for GUD at the same research station. The difference of 10.7 months between the AFC for GUD in the present study and that obtained by Sada (1968) may be due to management differences between the period up to 1967 and the period after 1967 over which this review was undertaken (Aboagye, personal communication).

CALVING INTERVAL (C.I.)

The calving interval of WAS was significantly longer (76 days) than the C.I. of GUD. WAS had a C.I. of 551 days whilst GUD had a C.I. of 475 days. Similarly, WAS had a significantly longer C.I. of 122 days and 81 days than WAS F₁ and WAS Bc respectively. However, all the other genotypic comparisons for C.I. were not significant. WAS dams which did not let down their milk were allowed to suckle their calves until weaning. The significantly longer C.I. for WAS dams may therefore be attributed to the suckling effect. The effect of suckling on C.I. was not measured in this study. But, Eduvie and Dawuda (1986) and Wells, et al (1986) measured effect of suckling on the postpartum anoestrus period using Bunaji cows and Africander cows respectively. They found that suckling delayed ovarian activity and thus prolonged the postpartum anoestrus period, which resulted in significantly longer C.I. Thus suckling appears to be a cause of prolonged C.I.

Marked difference between purebred and crossbred for C.I. has also been reported by Letenneur (1978) using N'Dama and Jersey in the Ivory Coast. The N'Dama F₁ crossbred had significantly shorter C.I. than the pure N'Dama. He also noted that the pure N'Dama cow would not let-down milk without the calf suckling. Thus, this result is similar to the result obtained for WAS in this study. In GUD there was no suckling, which may be responsible for the absence of significant differences in the calving interval. Similar observations have been made by Buvanendran et al (1981)

using White Fulani and Friesian and Kiwuwu et al (1983) using Arsi and Friesian. They all found no significant differences between the genetic groups.

NUMBER OF SERVICES PER CONCEPTION (NSC)

Comparison of genotypic means for NSC show that no significant differences exist between the genotypes for this trait. Similar, non-significant differences for NSC have been reported by Verley and Touchberry (1961) for Holstein, Guernsey and their crossbreds. Hollon et al (1967) using Holstein, Brown Swiss and Red Sindhi and their crossbreds and McDowell et al (1974) using Ayrshire, Brown Swiss, Holstein and their crossbreds also found no significant differences between the genotypes for NSC. Contradictory results were reported by Azage et al (1981) in three local Ethiopian breeds, the Barca, Horro and Boran. They found that crossbred cows required 0.12 and 0.14 fewer services per conception than local Zebu cows in wet and dry areas respectively. El-Amin et al (1981) have suggested that differences in NSC may be due to changes in management practices and the particular month of calving.

5.3 EFFECT OF GENOTYPE ON CALF GROWTH TRAITS

GUD was significantly heavier both at birth and at weaning and maintained a higher pre-weaning growth rate than WAS. GUD calves weighed 3.5kg more at birth and 31.7kg more at weaning than WAS and gained 104 grammes per day than WAS. The pre-weaning growth advantage of GUD over WAS in this

analysis may be due to the fact that GUD is generally a bigger animal than WAS (Payne, 1970; Vohradsky, 1970).

GUD F_1 was also significantly superior to WAS F_1 for the pre-weaning growth traits. This superiority may be attributed to advantage derived from the larger size of the GUD dams compared to the WAS dams. Indeed, Danbaro (1990) had reported GUD halfbreds to be significantly superior to WAS halfbreds for pre-weaning growth traits; the reason being the larger size of GUD dams as compared to WAS dams.

WAS Bc significantly weighed 1.6kg more than WAS F_1 at birth and GUD Bc also significantly weighed 1.5kg more than GUD F_1 at birth. Evidence for the influence of the dam on birthweight is shown in the result of birthweights obtained for F_1 and purebred calves for WAS and GUD breeds. No significant differences were found between F_1 calves and their respective purebred calves for birthweight. Both F_1 and purebred calves are derived from purebred dams. These results agree with the findings of Gregory *et al* (1965), Touchberry and Bereskin (1966) using temperate breeds and Ahunu (1975) and Letenneur (1978) using temperate and tropical breeds. They all showed that although F_1 crossbreds were slightly heavier at birth than purebreds the differences were not significant.

The results further indicate that the F_1 's had significantly higher weaning weights and higher ADG than the purebreeds. Thus the superiority of the halfbreds in pre-weaning growth measures may be attributed to genetic factors

(Table 9) as the dams had no post-partum pre-weaning influence on the F_1 crossbred calves. Other workers using both temperate and tropical breeds and their crossbreds have also reported the F_1 to be faster growing and weighing significantly more at weaning than the purebred calves (Gregory et al 1985, Danbaro, 1990). This is attributed to hybrid vigour. Thus crossbreeding WAS and GUD breeds with Jersey to produce F_1 crossbreds will improve the growth rate of the indigenous breeds. Furthermore, where a fast growing indigenous breed is required then GUD would be preferred. Except for birthweight which was significantly higher, backcrossing both GUD F_1 and WAS F_1 to the Jersey breed resulted in a marked decline in growth rate and weaning weight in GUD. However, no significant gains were obtained with regard to growth rate and weaning weight in WAS. This suggests that crossbreeding beyond the F_1 level may not lead to increase in preweaning growth.

Significant differences were obtained between WAS and GUD for all the calf growth traits at the 0% and 50% levels of exotic inheritance. However, at the 75% level of exotic inheritance, WAS and GUD had similar preweaning average daily gains and weaning weights (Table 8). Thus as exotic blood increased in the local breeds beyond the 50% level, WAS tended to make relatively faster gains than GUD. This indicates that for preweaning growth, WAS is more responsive to higher exotic gene introduction.

5.4 ADDITIVE AND HETEROTIC EFFECTS FOR MILK YIELD TRAITS:

With regard to WAS crossbred group, the percentage heterosis realised for first lactation milk yield, average lactation milk yield, average daily milk yield, annualized milk yield, lactation fat yield, percentage milk fat and lactation length were 43%, 50%, 34%, 82%, 69%, 25%, 62% respectively. These results reflect the importance of both additive and heterotic effects in improving milk yield in WAS crosses. However, the relative magnitudes of additive and heterotic effects (Table 3) indicate that additive genetic factors made the greater contribution to the improvement. Nevertheless, the significant heterotic effects suggest that exploitation of heterosis by crossbreeding could be a useful tool in increasing milk production traits in the WAS breed. The results for the WAS crossbreds are in conformity with those of other workers who also found heterotic effects to be significant for milk yield traits in the tropics (Parmar and Dev, 1978; Taneja and Bhat, 1978; Taneja and Chawla, 1978; McDowell, 1985; Roy *et al*, 1987).

It has also been suggested by some workers that stressful environments could enhance heterotic effects (Cundiff, 1970; Barlow, 1981; Cunningham, 1981). In contrast, heterosis was not important in GUD crosses. This discrepancy of the results of the GUD crossbreds in this study may be attributed to the small number of observations employed (88) as compared to other workers who used observations ranging from 300 to 1,700.

Significant additive effects for lactation milk yield

(371.3 ± 181.3 kg), annualized milk yield (579 ± 194.6 kg) and lactation length (68.9 ± 24.2 days), in GUD crosses indicated that the increases in performance were mainly due to additive genetic effects from the breeds crossed.

5.5 ADDITIVE AND HETEROTIC EFFECTS FOR REPRODUCTIVE TRAITS

In the WAS crosses, it was only AFC which was significantly reduced by additive genetic effect (-10.2 ± 2.5 months). Additive effects were not significant but were negative for the other reproductive traits in both WAS and GUD crossbred groups. This signified that additive effect made only limited contribution to the improvements observed in the reproductive traits (Table 5). Except for the heterotic effects of C.I. (-102 ± 31.8 days) which was negative and significant in the WAS crosses, all the other heterotic effects for the reproductive traits in both WAS and GUD crossbred groups were not significant. These results for WAS crosses suggest that additive genetic effect could be exploited to achieve significant reduction in AFC and also heterotic effects could as well be used to reduce C.I. considerably in local WAS through crossbreeding.

The significant desirable genetic effects on these traits in WAS are of particular importance because the combined consequence of reduced AFC and shortened C.I. would enhance genetic progress in selection. Similar negative and significant additive effect for AFC has been reported by Roy et al, (1987) when they crossed Jersey with Sahiwal. They found that additive effect decreased AFC in Sahiwal

breed significantly by 8 months. Most other workers using tropical indigenous breeds and exotic dairy breeds have found both additive and heterotic effects to be significant in reducing AFC in the tropical indigenous breeds (Taneja and Bhat, 1974 and 1978; Parmar and Dev, 1978; Taneja and Chawla, 1978). Roy et al (1987) used the same method of analysis as was used in the present study whilst the other workers used the regression method. The differences in the significant levels for the heterotic effects may be attributed in part to the different methods of analysis employed.

The lack of significant heterotic effect for C.I. in GUD crosses in contrast to WAS crossbreds, may in part be attributed to small number of observations. For C.I. the GUD observations were 222 as against 582 for WAS. Similar non-significant heterotic effects for C.I. had been reported by Pearson and McDowell (1968) and Parekh (1974) using Holstein x Guernsey crosses. Taneja and Bhat (1978) indicated that small sample size could suppress significant effects; and attributed the non-significant heterotic effect for C.I. as reported by Pearson and McDowell (1968) and Parekh (1974) to the small number of records they used in their estimates. The results obtained in the present study for WAS crosses confirmed reports by Parmar and Dev (1978), Taneja and Bhat, (1978) and Roy et al (1987) who studied tropical x exotic crosses and showed that heterotic effect, significantly reduced C.I. in tropical breeds.

The non-significant additive and heterotic effects for

NSC in both WAS and GUD crosses indicate that genetic factors had no effect on NSC. Similar non-significant genetic effects have been reported by other workers. McDowell et al (1974) using Jersey, Holstein, Brown Swiss and Ayrshire crosses obtained a non-significant heterosis (-1.3%) for NSC. Lasley (1978) reported heritability for NSC in dairy cattle to be approximately zero. Holroyd et al (1979) Butterworth (1983), Wilson et al (1986) and Galina and Arthur (1989) all estimated the effect of nutrition on NSC. Their common observation was that nutrition rather than genotype was significantly responsible for variation in NSC in cattle.

5.6 ADDITIVE AND HETEROTIC EFFECTS FOR CALF GROWTH TRAITS

Additive and heterotic effects were significant for both WAS crosses and GUD crosses for birthweight. However, whilst additive effects were positive, heterotic effects were negative. The net effect is that there is no significant increases in birthweight of the F_1 's over the purebreds. Additive effects for birthweight in WAS crosses and GUD crosses were 1.7 ± 0.3 kg and 1.4 ± 0.5 kg respectively. The heterotic effects were -1.4 ± 0.5 kg. for WAS crossbreds and -1.6 ± 0.6 kg for GUD crossbreds giving rise to -7% and -6% heterosis respectively. The significant negative heterotic effects suggest that genes for lower birthweight were dominant over genes for higher birthweight. This would have resulted in lowering of birthweight. However, this is

counteracted by the positive additive effect.

The observations in this study are in agreement with works of Touchberry and Bereskin (1966) and Johnson et al (1968). On the other hand, Taneja and Bhat (1978) have reported that both additive and heterotic effects significantly increased birthweight in Holstein x Sahiwal crossbreds.

Additive and heterotic effects for weaning weight (WWT) and preweaning average daily gains (ADG) were positive for WAS crosses. The additive effects were significant while the heterotic effects were not significant (Table 9). The inference is that additive effects of breeds used for crossing were mainly responsible for the higher WWT and the higher ADG obtained for the WAS crossbreds (Table 8). For GUD crossbreds additive effects for WWT and ADG were negative and heterotic effects were positive. All effects were significant except additive effect for ADG. Percentage heterosis were 30% and 52% for WWT and ADG respectively. The relative sizes of additive and heterotic effects (Table 9) for the GUD crossbreds indicate that heterotic effects were more predominant and were mainly responsible for the overall desirable increase in WWT and ADG.

Additive effects for body weights in temperate regions have been commonly high and significant (Touchberry, and Bereskin, 1966; Touchberry, 1970). In the tropics, however, significant additive and heterotic effect for body weights have been reported for crossbreds involving temperate and tropical breeds (Katapal, 1977; Taneja and Bhat, 1978). It

is apparent that crossbreeding led to the improvement in growth rate.

CHAPTER SIX

6.

SUMMARY AND CONCLUSIONS

This study was carried out to estimate the additive and heterotic effects on production traits in Jersey crossbred cattle at A.R.S., Legon. Evaluation of purebred and crossbred performance for the production traits were also made. These cattle consisted of local West African Shorthorn (WAS), Sokoto Gudali (GUD) and their F_1 and backcrosses (Bc) with Jersey.

Data on the first five parities were used in the analysis. All traits were analysed by least squares fixed model procedures using the GLM method in SAS (1987). The model for analysis of the traits included the fixed effects of genotypes, year of calving, season of calving and parity. The effect of sex of calf was included in the model with regard to analysis of calving interval, birthweight, preweaning average daily gain and weaning weight. Similarly, age at weaning was incorporated as a covariate in the model for analysing weaning weight.

Additive and heterotic effects were estimated using the additive-dominance model of Jain (1982). Relative breed performance for the various production traits were also evaluated using SAS procedures for planned single degree of freedom comparisons using F-tests. Effect of genotype on all traits studied were highly significant ($P < 0.01$). At the purebred level, except for age at first calving and number of services per conception, GUD was clearly superior to WAS for all the traits examined; indicating that significant

differences exist between the GUD and WAS with respect to growth and production ability.

The results of milk production from F_1 Jersey x WAS or GUD crosses is markedly superior to that obtained from the respective purebreeds. Backcrossing the WAS F_1 to the Jersey breed resulted in further significant increases in milk production, whilst backcrossing GUD F_1 to the Jersey breed did not result in significant increases in milk production. Thus the exotic parent has positive influence on the performance of the F_1 for both breeds and on the WAS backcross. There was also a clear difference in combining ability between the two local breeds and Jersey for milk production to such an extent that significant improvement in milk production may be achieved by increasing the level of exotic inheritance in WAS crossbreds to 75%, whilst that of GUD need not go beyond the 50% level.

The reproductive traits generally showed lack of significant differences between the breed groups examined, thereby confirming widely held views that environmental rather than genetic factors are the main sources of variation in reproductive traits. The significantly longer calving interval of WAS as compared to its crossbreds and to GUD, is attributed to suckling effect. WAS F_1 and GUD F_1 heifers calved for the first time at significantly earlier ages than their corresponding purebreeds. The high genetic merit of Jersey for age at first calving is given as a reason for the significantly shorter calving ages obtained for both WAS F_1 and GUD F_1 .

Results for calf growth traits show that the F_1 's were significantly heavier at weaning and also had higher pre-weaning average daily gains than the local breeds from which they were derived. The F_1 's however had similar birthweight as their corresponding purebreeds. Also GUD F_1 had higher birthweights, pre-weaning average daily gain and weaning weight than WAS F_1 . GUD Bc increased significantly in birthweight as compared to GUD F_1 birthweight. Thereafter, GUD Bc declined significantly in growth rate and in weaning weight relative to GUD F_1 . WAS Bc and WAS F_1 were similar in weaning weight and growth rate. However, WAS Bc was significantly higher in birth weight than WAS F_1 . Thus no significant improvements in pre-weaning average daily gains and weaning weight may be achieved by increasing the level of exotic inheritance in the crossbreds to 75%. The increase in size of the crossbred dams explains the significantly higher birthweights of the backcrosses compared to their corresponding halfbreeds whose dams were the local purebreeds.

Both additive and heterotic effects were important in enhancing the milk production traits in WAS crosses, with additive genetic factors making the greater contribution to this improvement. Thus with WAS crosses, a breeding system which could exploit both additive and heterotic effects efficiently could maximize gains so far as milk production is concerned. On the other hand, both additive and heterotic effects were positive but not significant for the milk production traits in GUD crosses, showing that these two

factors made a favourable albeit limited contribution to the higher yields obtained. This inference should, however, be treated with caution in view of the small number of observations involved.

Age at first calving was significantly reduced by additive genetic effect in WAS crosses. Heterotic effects also significantly reduced calving interval in WAS crossbreds. Hence additive gene effects of Jersey could be used to reduced age at first calving in WAS and heterosis could be exploited in WAS crosses to obtain desirable effects on calving interval. In GUD crosses none of the reproductive traits was significantly affected by additive or heterotic effects, so that the variations in the reproductive traits, may be attributed to environmental factors.

Additive effects increased birthweight while heterotic effects decreased birthweight in WAS and GUD crosses. Both changes were significant when considered separately. However, the overall effects of additive and heterosis did not lead to significant changes in birthweight. Consequently, any breeding strategy in which heterotic effect would outpace additive effect would lead to greater ease in calving and an increase in calf survival. Additive and heterotic effects were important in improving weaning weight and pre-weaning average daily gain.

Additive and heterotic effects were significant for most of the production traits. It therefore would be worthwhile trying rotational crossbreeding between the local and exotic

breeds, as rotational crossbreeding system permits the utilization of both additive and heterotic effects. It must be emphasized that the magnitude of the additive and heterotic effects obtained in this study may have been influenced by environmental factors, so that a change in the husbandry practices at the Agricultural Research Station, Legon, may alter the relative importance of additive and heterotic effects.

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