**Universität für Bodenkultur Wien**
University of Natural Resources and Applied Life Sciences, Vienna

**Department für Nachhaltige Agrarsysteme**
**Deparment of Sustainable Agricultural Systems**

# COMPARISON OF PRODUCTION SYSTEMS WITH PUREBRED ANKOLE VS. CROSSBRED ANKOLE - FRIESIAN ANIMALS ON-FARM USING A COMBINED CROSS-SECTIONAL AND LONGITUDINAL APPROACH (KIRUHURA DISTRICT OF UGANDA)

**Esau Geofrey Galukande M.Sc.**

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# Dedication

To

My Wife

**Christine Sewankambo Galukande**

My Children

**Kirabo Emmanuel Galukande**

**Suubi Andrew Galukande**

My Mother

**Margaret Esther Galukande**

My Brothers and Sisters

**Michael, Jennifer, Mirembe,**

**David, Sarah, Miriam**

**and**

**Christopher**

In memory of my Father

**Esau Bitalo Galukande** (1923 – 1979 ) R.I.P.

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**To God Be the Glory**

…..all things are possible with God (Mark 10:27b)

He who begun the good work in you shall see it to completion (Philippians 1:6)

# Chapter 1

## General Introduction

Results presented in this thesis are part of a study entitled "Evaluation of ecological and economic sustainability of breeding strategies in pastoral systems: The case of Ankole cattle" in which the economic and ecological sustainability of a new livestock farming system in South Western Uganda is being evaluated.

The livestock sector in Uganda accounts for about 17% of the Gross Domestic Product and cattle are its most important economic component (MAAIF, 2002). Of the estimated 11.4 million cattle in the country, 93.6% are indigenous cattle in the following main groups: Zebu/Nganda (70% of the 93.6%) and Ankole (30% of the 93.6%). The rest (6.4%) are exotic or crossbreds (MAAIF, 2008). For many years the Bahima, a pastoralist community found in South Western Uganda have kept the Ankole cattle. This cattle breed is characterized by a relatively large body frame with long white horns. Their coat colour is usually solid cherry red but other colours like light brown with black stripes, red with white spots and black also exist. Ankole is a stabilized interbreed of *Bos indicus* (Zebu) and *Bos taurus* cattle (Mbuza, 1995). Traditionally the Ankole cattle play a central role in the lives of Bahima who have kept these animals as source of milk for the owners, a store of wealth and pride.

In response to a number of factors which include: increased demand for cattle products in urban centres due to increasing population and growing demand from new markets like Southern Sudan and the Democratic Republic of Congo, increased pressure on land due population growth, policies promoting individual land ownership and major developments in the rural infrastructure (improved roads, rural electrification and communication) major changes are taking place in South Western Uganda (MAAIF 2009; Wurzinger *et al.*, 2006; Petersen *et al.*, 2004; Kisamba-Mugerwa, 2001). The Ankole pastoralists who for many years have grazed their cattle extensively, with no supplementation and minimum supply of water are now becoming sedentary and have started crossbreeding Ankole with exotic cattle, mainly the Holstein Friesian. This is in a bid to get animals with higher milk yields. There are however many farmers who still want to keep the Ankole in its pure form. Some of these have resorted to keeping two herds, one of Ankole and the other of Holstein Frisian–Ankole crosses on one farm. A production system where two separate herds i.e. a pure Ankole herd and a herd of Friesian - Ankole crosses are kept on one farm has emerged. In this system Friesian-Ankole crosses are kept for commercial milk production, while the Ankole are kept for multiple reasons namely: cultural, a buffer against shock in case of prolonged drought and disease outbreak and for income through sale of live animals.

Judging from the rapidly increasing numbers of crossbred animals in South-western Uganda, the constant improvement in rural infrastructure and wide availability of milk coolers and specialized milk transport facilities to the urban centres, many farmers keeping the two separate herds may resort to the Friesian crosses only in the near future.

The above changes raise a number of questions which include:

- What is the performance of the different levels of crossbreds under the existing conditions?
- Is the emerging production system in which two separate genotypes are kept one farm economically sustainable?
- What effect will the new production system have on the environment in terms of availability of palatable pasture species, soil fertility and available water resources?
- What gaps in knowledge and supportive technical logistics exist?
- What technical support and advice is available to farmers on this new system?
- What options do farmers have who are breeding beyond the F1 generation in terms of sustainable supply of breeding services?
- What could be the future role of the Ankole breed in the current and future milk production systems?

The objectives of this study are therefore:

- To study and evaluate the lactation and body characteristics of the different genotypes in the production system i.e. the Ankole and different levels of crosses of Friesian and Ankole.

- To study and evaluate reproductive performance of the different genotypes in the production system

- To dentify:
    - existing knowledge gaps
    - management and logistical challenges faced by the farmers
    - existing technical support services for the farmers
    - attitude of farmers towards breeding the Ankole and crossbreeding the Ankole with the Friesian.

Results are presented in 3 chapters and an overview of each is given below:

In chapter 2, a review on studies on crossbreeding for milk production in the tropics is presented. Achievements and challenges of the different crossbreeding methods are discussed. Results from 50 studies in which performance of the different grades of crossbreeds had been evaluated along with the local breeds are compared. There is a general agreement from studies by Rege (1998); Demeke *et al.* (2004), Gaur et al. (2005) that there is an improvement in performance among crossbreds as compared to the indigenous at *Bos taurus* inheritance level of 50% and 75%. At those levels of crossing the animals calve earlier than the indigenous stock and produce more milk. Crossbreeding as a livestock improvement tool is however not being used widely in many tropical countries due to various challenges which include: i) Poor design of crossbreeding programs ii) poor funding of programs iii) absence of livestock recording systems. Recent advances in genomic technology and assisted reproductive technologies are discussed and their potential role in fast tracking and improving crossbreeding breeding results are discussed.

An on-farm study carried out in Kiruhura district in South Western Uganda between 2007 and 2009 is presented in Chapter 3. A total 1786 animals of complete age/sex range, assigned to 3 genetic groups namely: pure Ankole, HF50% for F1 (first generation) crossbreeding of Ankole with Holstein Friesian and HF>50% for animals with more than 50 % Holstein Friesian inheritance, were monitored on a monthly basis. The aims of the study were to evaluate the lactation traits and growth characteristics of the 3 genetic groups. Prior to the study, an enumerator originating from the study area was recruited. Farmers keeping pure Ankole and crossbreds of Ankole with Holstein Friesian in separate herds on one farm were then identified with assistance of the local veterinary personnel. The aims of the study were presented to the farmers at a 'start-up' workshop. Four other feedback workshops were held at different times during the study period. The crossbreds had higher daily milk yields, lower age at first calving and calving interval as compared to the Ankole. It is likely that crossbreeding will continue and perhaps in future the numbers of Ankole in the area will reduce. Farmers need technical guidance to identify the most suitable level of exotic inheritance for their area and to establish an organized breeding program. A number of problems were encountered during the study some of which have had an effect on the quality of collected data. These are discussed at the end of the chapter.

A study on the possibilities of setting up a community based breeding program is presented in chapter 4. During this study 34 farmers were interviewed on various aspects like existing cattle breeding practices and on their social economic background. From the interviews it was clear that there was a well established system through which breeding activities were controlled, breeding information was shared with in the family and with friends and that farmers still had an interest in keeping both the Ankole and the Holstein Friesian Ankole crossbreds. A breeding program can be established in this community and will bring numerous benefits to the farmers. Apart from genetic improvement communities will benefit from organized market channels for milk and livestock. Success of programs will however depend on interest of the cattle keepers in such a program, long term commitment and involvement of the cattle keepers while designing the breeding program.

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# Chapter 2

## Crossbreeding cattle for milk production in the tropics: Achievements, challenges and opportunities

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**Abstract**

The paper reviews experiences with crossbreeding for milk production in the tropics. Data from 50 separate studies in which performance of the different grades of crossbreeds had been evaluated along with the local breeds were compiled. Relative performance of the indigenous breeds compared to the different grades of crossbreeds in 3 climatic zones in the tropics was calculated. Traits considered were milk yield per lactation, age at first calving, services per conception, life time milk yield and total lactations completed. At 50% *Bos taurus* level lactation milk yields were 2.6, 2.3 and 2.3 times higher than those of local cattle in the Highland, Tropical Wet and Dry and in Semi Arid Climatic zones respectively. Lactation length increased by 1.2 to 2.3 times and calving interval reduced by 0.8 to 1 times. Further upgrading or *inter se* mating (F2 production) does not have a clear trend. Although crossbreeding faces a number of challenges, opportunities for its use are numerous. It is therefore likely it will continue as an important livestock improvement tool in the future.

*Keywords*: Cattle, Crossbreeding, Milk production, Tropics

## Introduction

Crossbreeding of native cattle in the tropics, often of *Bos indicus* type, with European *Bos taurus* cattle is now widely used as a method of improving production and productivity of cattle in the tropics (Van Randen and Sanders, 2003). Although indigenous cattle are well adapted to local production conditions they are usually late maturing, have poor growth rates and low milk yields (Syrstad, 1988).

Reports on crossbreeding in the tropics date back to 1875 (Gaur *et al.,* 2005) when Short Horn bulls were crossed to native cows in India. Other reports (Buvanendran and Mahadevan, 1975) indicate that livestock improvement using this method in the tropics began more than 300 years ago when European cattle were introduced into Sri Lanka. Results on performance of the crosses under well designed experiments have however only been available since 1930 onwards and thereafter, numerous reports have been published (Cunningham *et al.,* 1998). It is now clear from studies by Amble and Jain

(1967); Manson (1974); Katpatal (1977); Kimenye (1978); Rege (1998); Demeke *et al.* (2004a), Gaur *et al.*(2005) that where management is good, there is an improvement in performance among crossbreds with increasing *Bos taurus* genes, with 50% and 75% performing better than all other levels of exotic inheritance. Animals with these levels of *Bos taurus* blood, calve earlier than the indigenous stock, produce more milk and have longer lactations and shorter calving intervals. Crossbreeding is therefore a very attractive short-term livestock improvement tool because these improvements can be made in a population within one generation. However, despite the impressive results and high demand for milk in the tropics, the well organized and successful crossbreeding programs remain few (McDowell *et al.,* 1996). For example, in India with 187 million head of cattle, only 12% of these are crossbreds (Ahlawat and Singh, 2005), while in Bangladesh crossbred cattle comprise only 2% of the total milking cows (Miazi *et al.,* 2007). Reasons for the low uptake include: 1) Lack of strategies and policies in most of the tropics to utilize advantages of the crosses (Rege, 1998). 2) Gaps in knowledge as to what the appropriate levels of exotic inheritance should be for a particular production system (Kahi, 2002) and 3) Lack of an in depth analysis of the socio-economic and cultural values of livestock in the different production systems or production environment thereby leading to wrong breeding objectives (Chagunda, 2002).

This paper reviews the achievements that have been made in crossbreeding for milk production in the different climatic zones in the tropics and discusses the challenges and opportunities for its future use.

## Crossbreeding: The genetic background

The genetic basis for crossbreeding is broadly classified into two components; additive and non additive. The additive component is due to the average effect of the strains involved (breeds or parental lines), with weighting according to level of representation of each parental breed in the crossbreed genotype. The non additive effect of crossbreeding is heterosis (Swan and Kinghorn, 1992). Heterosis is defined as the difference between the increase in crossbreeds from the additive component based on the mean performance of the purebred parental lines. Levels of heterosis are presented as percentage values and can be used to calculate the expected performance of the crossbred individuals (Bourdon, 2000). Heterosis is caused by dominance (interactions within loci) and epistasis (interactions between loci). The positive effects of dominance are due to increased levels of heterozygosity allowing an individual to react to environmental challenge in different ways (Swan and Kinghorn, 1992). Epistasis interactions on the other hand can lead to negative effect due to a breakdown of favourable interactions between loci in purebred animals which prior to crossbreeding had been built by both natural and artificial selection within breeds (Roso et al., 2005). These effects have been observed in crossbreeding studies for milk production in tropics. Syrstad (1989) reviewed results on F1 and F2 *Bos indicus* and *Bos taurus* crosses for milk production. A deterioration in performance due to break down of epistatic gene effects was found from F1 to F2 for all traits studied, i.e. age at first calving, calving interval, milk yields and lactation length.

## Types of crossbreeding

Crossbreeding can be grouped into three classes/types namely: grading up, rotational crossing or criss-crossing and formation of synthetic or composite populations (Cunningham and Syrstad, 1997).

### Grading up

This is a common crossbreeding strategy employed in most parts of the tropics. Usually an indigenous female animal is mated with an exotic male. The first cross generation (F1) performs very well in all aspects; they have higher milk yields, shorter calving intervals and calve at a younger age than the indigenous stock. However, further upgrading usually gives mixed results (McDowell, 1985; Rege, 1998). These changes are due to reduction in heterozygosity as the generations proceed (Cunningham and Syrstad, 1987). Although the average performance of the (F1) usually exceeds that of the indigenous breeds in milk yields, performance of the crossbreds can be variable, this could be due to the large variations in the environmental conditions that exist in the tropics and to the two genotypes involved (Cunningham, 1981; McDowell 1985; Dhara *et al.*, 2006).

***Achievements with grading up***

The relative performance of different grades of crosses with the indigenous genotypes from different climatic zones (CZ) in the tropics was compared. Data used in the study was obtained from published records from the different parts of the tropics and grouped in CZ as classified by World Book (2009). Data from several studies on crossbreeding for dairy production in the tropics were compiled (the complete data set compiled is provided in supplementary Tables 1, 2and 3 in part 2 of this chapter). From this studies in which performance of the different grades of crossbreeds had been evaluated along with the local breeds (*Bos indicus*) were extracted. Reports that did not have local breeds in the design were excluded. At the end of the exercise 50 studies were obtained as summarized in Table 1. The data were further clustered into three production environment groups according to the whether the study was conducted on-research stations, on-farm and according to the climatic zone in which the study was undertaken. On-farm 1 was for studies undertaken on large commercial farms and on-farm 2 for studies in which data originated from several small scale farmers. The final data set comprised data from three CZs namely, Highlands (H), Tropical Wet and Dry (TWD) and Semi Arid (SA). Traits compared in the study were, milk yield per lactation (MYL), lactation length (LL), calving interval (CI), age at first calving (AFC), services per conception (SPC), life time milk yield (LMY) and total lactations completed (TLC). Some of data sets used did not have all these traits evaluated in which case only the traits reported were considered. Relative performance of the different grade crosses was compared to the local breeds by dividing the least squares mean of a given trait in the different cattle grades by least squares mean of the same trait in local cattle in a particular study. Finally means of relative performance for the different grade crosses for a given CZ were computed.

**Table 1:** Summary data used in the analysis

| No | Bos indicus | Bos taurus | Climatic zone | Country | Location | Production environment | Source |
|---|---|---|---|---|---|---|---|
| 1 | Boran | Holstein-Friesian | Highlands | Ethiopia | Holeta station | On Station | Demeke et al. , 2004a |
| 2 | Boran | Jersey | Highlands | Ethiopia | Holeta station | On Station | Demeke et al. , 2004a |
| 3 | Boran | Holstein-Friesian | Highlands | Ethiopia | Holeta station | On Station | Demeke et al. , 2004b |
| 4 | Boran | Jersey | Highlands | Ethiopia | Holeta station | On Station | Demeke et al ., 2004b |
| 5 | Arsi | Holstein-Friesian | Highlands | Ethiopia | Aresela region | On Station | Kiwuwa et al. , 1983 |
| 6 | Arsi | Jersey | Highlands | Ethiopia | Aresela region | On Station | Kiwuwa et al. , 1983 |
| 7 | Zebu | Holstein-Friesian | Highlands | Ethiopia | Aresela region | On Station | Kiwuwa et al. , 1983 |
| 8 | Barca | Holstein-Friesian | Highlands | Ethiopia | Aresela region | On Station | Tadesse and Tadelel., 2003 |
| 9 | Sahiwal | Ayrshire | Highlands | Kenya | Nanyuki | On-Farm1 | Gregory and Trail, 1981 |
| 10 | Sahiwal_S | Ayrshire | Highlands | Kenya | Nanyuki | On-Farm1 | Gregory and Trail, 1981 |
| 11 | Sahiwal | Ayrshire | Highlands | Kenya | Ngong | On Station | Kimenye, 1978 |
| 12 | Sahiwal_S | Ayrshire | Highlands | Kenya | Ngong | On Station | Kimenye,1978 |
| 13 | White Fulani | Holstein-Friesian | Tropical WD | Nigeria | Vom | On Station | Knusden and Sohel, 1970 |
| 14 | White Fulani | Holstein-Friesian | Tropical WD | Nigeria | Vom | On Station | Soheal, 1984 |
| 15 | White Fulani | Holstein-Friesian | Tropical WD | Nigeria | Vom | On-Farm1 | Olutogun et al 2006 |
| 16 | Sahiwal | Holstein-Friesian | Tropical WD | India | Ambala | On Station | Amble et al., 1967 |
| 17 | Sahiwal | Holstein-Friesian | Tropical WD | India | Meerut | On Station | Amble et al., 1967 |
| 18 | Sahiwal | Brown Swiss | Semi Arid | India | Karnal OS | On Station | Bala and Nagarcenkar,1981 |
| 19 | Deshi | Holstein-Friesian | Tropical WD | India | Haringhata | On Station | Bala and Nagarcenkar,1981 |
| 20 | Hariana | Holstein-Friesian | Tropical WD | India | Haringhata | On Station | Bala and Nagarcenkar,1981 |
| 21 | Hariana | Brown Swiss | Tropical WD | India | Haringhata | On Station | Bala and Nagarcenkar,1981 |
| 22 | Deshi | Jersey | Tropical WD | Srilanka | Karagoda -Uyan. | On Station | Buvanendean, 1974 |
| 23 | Sinhala | Holstein-Friesian | Tropical WD | Srilanka | Karagoda -Uyan. | On Station | Wijerante 1970 |
| 24 | Sindi | Jersey | Tropical WD | Srilanka | Undugoda | On Station | Buvanendean, 1975 |
| 25 | Jenubi | Holstein-Friesian | Tropical WD | Srilanka | Undugoda | On Station | Buvanendean, 1975 |
| 26 | Criollo | Jersey | Tropical WD | Costa Rica | Turrialba | On Station | Alba & Kennedy, 1985 |
| 27 | Local | Jersey | Tropical WD | India | Chalakudy | On Station | Katpatal 1977 |
| 28 | Local | Jersey | Tropical WD | India | Vikas Nagar | On Station | Katpatal 1977 |
| 29 | Local | Jersey | Tropical WD | India | Visakhapatnam | On Station | Katpatal 1977 |
| 30 | Local | Sahiwal | Tropical WD | Bangladesh | Comilla | On Farm 2 | Miazi et al., 2007 |
| 31 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Comilla | On Farm 2 | Miazi et al.,2007 |
| 32 | Local | Jersey | Tropical WD | Bangladesh | Comilla | On farm 2 | Miazi et al., 2007 |
| 33 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Khulna | On farm 2 | Ashraf et al.,l 2000 |
| 34 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Dhaka | On Station | Majid et al 1996 |
| 35 | Local | Jersey | Tropical WD | Bangladesh | Dhaka | On Station | Majid et al., 1996 |
| 36 | Sahiwal | Holstein-Friesian | Tropical WD | Bangladesh | Dhaka | On station | Majid et al., 1996 |
| 37 | Local | Jersey | Tropical WD | Bangladesh | Dhaka | On Station | Rahman et al., 2007 |
| 38 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Dhaka | On Station | Rahman et al., 2007 |
| 39 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Barisal/Patuakahli | On Station | Al-Amin and Nahar, 2007 |
| 40 | Sahiwal_S | Ayrshire | Semi Arid | Kenya | Machkos | On Station | Kimenye 1978 |
| 41 | Sahiwal | Ayrishire | Semi Arid | Kenya | Machkos | On Station | Kimenye 1978 |
| 42 | Sahiwal | Holstein-Friesian | Semi Arid | Pakistan | Bahadurnagar | On Station | McDowell et al 1996 |
| 43 | Sahiwal_S | Ayrshire | Semi Arid | Kenya | Kilifi | On Farm1 | Gregory and Trail , 1981 |
| 44 | Sahiwal | Ayrshire | Semi Arid | Kenya | Kilifi | On Farm1 | Gregory and Trail , 1981 |
| 45 | Sahiwal | Holstein-Friesian | Tropical WD | India | Northern | On-Farm1 | Matharu and Gill 1981 |
| 46 | Ratini | Red Dane | Semi Arid | India | Bikaner | On Farm1 | Singh *et al*. 1997 |
| 47 | Ongole | Jersey | | India | Visakhapatnam | On Farm1 | Sreemannarayana et al.,1996 |
| 48 | Local | Holstein-Friesian | Tropical WD | Bangladesh | Dhaka | On Station | Majid et al., 1996 |
| 49 | Local | Jersey | Tropical WD | Bangladesh | Dhaka | On station | Majid et al., 1996 |
| 50 | Sahiwal | Holstein-Friesian | Tropical WD | Bangladesh | Dhaka | On Station | Majid et al., 1996 |

**Abbreviations used** Tropical WD = Tropical Wet and Dry

In all CZs the crossbreds had higher milk yields, increased lactation length, shorter calving intervals and lower age at first calving compared to the local breeds (Tables 2 and 3). In the Highland CZ it was observed that mean MYL of 50% *Bos taurus* cows were 2.6 times as high as those of the indigenous cows. At the next stage of exotic inheritance 75% *Bos taurus,* performed similarly, with a relative level of 2.7 compared to local cows. In the Tropical Wet and Dry CZ  increasing *Bos taurus* genes beyond

**Table 2**: Relative performance of production traits

| **Trait** | **Milk yield per lactation** | | | | **Lactation length** | | | |
|---|---|---|---|---|---|---|---|---|
| **Breed group** | **1/4** | **1/2** | **3/4** | **F2** | **1/4** | **1/2** | **3/4** | **F2** |
| **Climate zone** | | | | | | | | |
| Highlands | | | | | | | | |
| n = 10 | | | | | | | | |
| Mean | | 2.6 | 2.7 | 3.3 | 1.2 | 1.2 | 1.3 | |
| S.D. | | 1 | 1 | 0.4 | 0.2 | 0.2 | 0.2 | |
| Range | | 1.4 – 4.5 | 1.7 – 4.5 | 3 – 3.6 | 1 – 1.3 | 1 – 1.5 | 1.2 – 1.5 | |
| Tropical wet & dry | | | | | | | | |
| n = 27 | | | | | | | | |
| Mean | 1.7 | 2.3 | 1.8 | 1.9 | 1 | 1.2 | 1.1 | 1.1 |
| S.D. | 0.4 | 0.8 | 0.6 | 0.64 | 0.01 | 0.2 | 0.1 | 0.1 |
| Range | 1.1 - 2 | 1.2 - 3.9 | 1.4 – 2.8 | 1.2 -2.9 | 1.05 – 1.07 | 1 – 1.7 | 0.9 – 1.3 | 1 – 1.3 |
| Semi arid | | | | | | | | |
| n = 4 | | | | | | | | |
| Mean | 1.4 | 2.3 | 1.5 | 1.36 | | 1.87 | | |
| S.D. | 0.5 | 0.4 | 0.5 | 0.48 | | 0.64 | | |
| Range | 1.1-1.7 | 1.8 -2.6 | - | 1.2 -1.5 | | 1.2 -2 | | |

**Table 3:** Relative performance of reproduction traits

| Trait | Calving Interval | | | | Age at first calving | | | Service/conception | |
|---|---|---|---|---|---|---|---|---|---|
| **Breed group** | **1/4** | **1/2** | **3/4** | **F2** | **1/2** | **3/4** | **F2** | **1/2** | **F2** |
| **Climate zone** | | | | | | | | | |
| Highlands | | | | | | | | | |
| n = 7 | | | | | | | | | |
| Mean | | 0.9 | 1 | 0.9 | 0.8 | 0.8 | 0.9 | 0.8 | 0.89 |
| S.D. | | 0.1 | 0.1 | 0.01 | 0.01 | 0.01 | 0.01 | 0.1 | 0.1 |
| Range | | 0.8 -1 | 0.9 - 1 | 0.91 – 0.92 | 0.8 - 1 | 0.8 – 0.9 | 0.92 – 0.93 | 0.7 – 0.8 | 0.8 – 0.9 |
| Tropical wet & dry | | | | | | | | | |
| n = 16 | | | | | | | | | |
| Mean | | 0.92 | 1 | 1 | 0.8 | 0.8 | 0.8 | 1 | |
| S.D. | | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.01 | 0.17 | |
| Range | | 0.8 - 1 | 0.8 -1.3 | 0.9 – 1.1 | 0.6 - 1 | 0.8 - 1 | 0.84 – 0.85 | 0.8 – 1.2 | |
| Semi arid | | | | | | | | | |
| n = 4 | | | | | | | | | |
| Mean | | 0.9 | 1.01 | | 0.83 | 0.7 | 0.8 | | |
| S.D. | | 0.01 | 0.06 | | 0.1 | 0.03 | 0.02 | | |
| Range | | 0.89 -0.9 | 0.9 -1.0 | | 0.7 -0.9 | 0.7-0.75 | 0.8-0.84 | | |

75% resulted in lower milk yields than that observed in the 50% crosses. The F2 in this CZ performed significantly lower than the F1. In the semi arid regions there was an increase of MYL by 2.3 times in the 50% *Bos taurus* level. These results confirm earlier studies (Cunningham and Syrstad, 1987), who observed a similar improvement trend with increasing *Bos taurus* levels. In all the CZ, all crossbreds apart from 25% level in the Tropical wet and dry CZ had longer lactation lengths. The overall range of change was between 1.1 – 4.5 and 0.9 – 1.5 times for milk yield and lactation length respectively. In the Tropical wet and Dry CZ, the F2 had poorer overall productivity due to lower lactation milk yields, longer lactation lengths, longer calving intervals and higher age at calving as compared to the F1s. Comparison of F1 with F2 was not possible in the highlands because of the limited records, especially for the latter

Most reports available on crossbreeding studies are based on single lactation records and therefore do not represent lifetime productivity of cows, an important determinant of overall profitability of dairy cattle (Matharu and Gill, 1981). Reports on life time milk production (LMY) and lactations completed (LC) for indigenous cattle and the different cross grades were compiled (Table 4). Unlike in the previous section results from the different CZ were grouped together because only few studies were available. Crossbred animals with 50% *Bos taurus* genes had between 1.4 to 2.6 times more LMY and 1.2 times more LC than the indigenous cattle. An increase in LMY and LC among crossbreds has also been reported by Singh (2005), who reviewed life time parameters on two and three breed crosses from different studies conducted on government and research farms in various parts of India and involving several local breeds and exotic breeds. Holstein-Friesian crosses of 50% - 62.5% *Bos taurus* genes had higher LMY and LC than those above this level of crossing (75% or 87.5%). These results were confirmed by a later study by Goshu (2005) who compared life time performance of different grades of crosses of Holstein–Friesian with Ethiopian Boran under an intensive grazing system with supplementation at Chefa farm in Ethiopia. Level of crossing significantly affected herd life and LMY. Both the herd life and LMY decreased with increasing *Bos taurus* genes. The F1 and 75% *Bos taurus* crossbreds had significantly more LMY and longer herd life than the other crossbreeds (87.5% and 93.7%).

**Table 4:** Relative performance of life time production traits

| **Trait** | **Life time milk yield** | | | | **Total lactations completed** | | | |
|---|---|---|---|---|---|---|---|---|
| **Breed group** | **1/4** | **1/2** | **3/4** | **F2** | **1/4** | **1/2** | **3/4** | **F2** |
| n = 6 | | | | | | | | |
| Mean | | 1.8 | | | | 1.2 | | |
| SD | | 0.5 | | | | 0.03 | | |
| Range | | 1.4 - 2.6 | | | | 1.21 – 1.26 | | |

To enable proper all round comparison of the different genotypes some studies on upgrading have focused on economic performance in different production environments. Madalena *et al.* (1990) undertook a study involving 65 commercial co-operator farms in the states of Minas Gerais , Sao Paulo, Rio De Genaro and Esperito Santo and two research centres (Santa Monica and UEPAE São Carlos) in Brazil. Six Red and White Holstein-Friesian (HF) x Guzeera crosses (25, 50, 62.5, 75 and 87.5 crosses and pure HF) were compared in two types of management systems, one with high and another with low level management and inputs. The F1 had longer herd life, better productive and reproductive performance than the other groups and as such had highest profits. Superiority of the F1 over all the HF back crosses was more marked under low levels of management.

In a more recent study, Haile *et al*. (2007), carried out economic comparisons among Ethiopian Boran and their crosses of 50, 75, and 87.5% Holstein Friesian inheritance all reared on an intensive and stall-fed system in the Central Highlands of Ethiopia. Data for one calendar year (2003) collected from experimental cattle at the Debre Zeit Research station in Ethiopia was used. Returns per day per cow were calculated from dung and milk production. Results showed that the cost of producing one litre of milk was significantly higher in the Ethiopian Boran than in the crosses. The 87.5 % had a significantly higher profit per day per cow and profit per year per cow than the 50%. The 75% on the other hand did not have significantly higher profit per day per cow and profit per year per cow than the 50% or the 87.5%. It was concluded that intensive dairy production with indigenous tropical breeds is not economically viable.

Variations between different breeds in economic performance have also been observed. Hemalatha *et al.* (2003) compiled reports in which Friesian crosses, Jersey crosses and local cattle had been compared in different parts of India. The reports showed that the crossbreds had higher profit per kilogram of milk produced than the indigenous zebu animals. It was however noted that maintenance cost was highest for Friesian crosses, followed by Jersey crosses and least in local cattle. The economic impact of crossbred cows in small holder farming systems has also shown in a number of studies. Some studies (Patil and Udo, 1997; Bhownik *et al*., 2006 and Policy note 2007) reported that in areas where crossbred animals can be maintained, farmers that incorporated them in their production systems had higher household incomes than those with pure indigenous breeds.

**Rotational crossing**

Rotational crossing is used or widely advocated in different parts of the tropics as a strategy of maintaining high levels of heterozygosity and at same time to achieve specific proportions of the domestic and exotic strains (Cunningham 1981; Gregory and Trail, 1981). Madalena (1981) describes four forms of this method. The first is one in which two bulls one exotic and the other indigenous are used in alternate generations, the first one on the indigenous cow breed, and the second one on the resulting crossbred cows. In a few generations the system stabilizes at two types of grades (2/3 and 1/3), co-existing on one farm at the same time. The second form also involves two breeds: one exotic and one indigenous bull. In this system the indigenous bulls are only mated to cows with more than 75% of exotic blood. This leads to a herd that is composed of three simultaneous grades (3/7, 5/7 and 6/7). In other words the exotic bull breed is used for two generations and followed by an indigenous bull for one generation. The third form is a modification of the first one, instead of the indigenous bull, a crossbred bull is used. In the fourth model three breeds are used, two exotic bulls and one indigenous bull. In the first stage the exotic breed is mated with the indigenous breed to produce F1 population. These are mated to the second exotic breed to produce off spring with 75% exotic genes. To complete the cycle these are mated to the local breed to produce off spring with 37.5% exotic genes.

***Achievements of rotational crossbreeding programs***

One well documented rotational crossbreeding program is from Kilifi plantations in the humid low lands of Kenya. A rotational crossbreeding program on this farm dates back to 1939. Gregory and Trail (1981) analyzed data for two groups of cattle produced in a two breed continuous rotation crossbreeding on this farm. Group 1 comprised of 67% Sahiwal and 33% Ayrshire, while group 2 comprised of 67% Ayrshire and 33 % Sahiwal. Records analyzed were collected between 1972 to 1978. For milk production traits, group 2 with 463 observations had significantly superior performance in age at first calving (1019 days), lactation milk yield (2843 litres) and annual lactation yield (2616 litres) but had significantly higher calving intervals (398 days) than group 1. In a follow up study, Thorpe *et al.* (1994) analyzed life time performance of the two groups and their cross between them (interbreeds). LMY was 48% higher for group 2 (67% Ayrshire and 33% Sahiwal) than group 1. The interbreeds (F2) yielded 34% less than average of the rotational crosses (groups 1 and 2). This decline was thought to be due to recombination loss, which is due to a breakdown of favourable epistatic interactions between genes on different loci.

In later years, two more breeds (Brown Swiss and Holstein Friesian) were introduced into the breeding program. Mackinnon *et al.*, (1996) analyzed data for a three breed rotation comprising Brown Swiss, Ayrshire and Sahiwal in various combinations. The data comprised 8447 observations. Lactation milk yield (MYL) for the herd was 3268 Kg and had LL and CI of 322 days and 398 days, respectively. The improved performance of the three breeds crosses as compared to the two breed crosses was attributed to the large amount of heterosis from the crosses of Sahiwal and the two *Bos taurus* genomes. In a more recent study Kahi *et al*. (2000), performance of the herd was analyzed after the introduction of Holstein Friesian and the data comprised of 25 cross combinations. Overall herd MYL, CI and LL observed were 3,446 Kg, 402 days and 326 days, respectively. Crosses with 50% Holstein Friesian genes had significantly higher MYL, longer LL and shorter CI than those with 50% Brown Swiss genes. It was concluded that the improved MYL in the herd relative to the earlier study (Mackinnon *et al*., 1996) was due to the introduction of the Holstein Friesian because management on the farm did not change.

**Synthetic breeds**

Both Grading up and rotational crossbreeding have some limitations. Firstly, in the two breed rotational system the genes contributed by the breeds of the sire and maternal grand sire fluctuate between 1/3 and 2/3 between generations. This makes it difficult to harmonize adaptability and performance characteristics that appropriately match the management level or the prevailing natural environment. Secondly, a large decline occurs in the performance, especially milk yields of F2 crossbreds is lower compared to their F1s counterparts due to the reduction of heterozygosity and break down of epistatic gene effects or recombination loss (Syrstad, 1989). In order to overcome the above two phenomena, formation of synthetic breeds is often opted for.

Synthetic breeds are made up of two or more component breeds and are designed to benefit from hybrid vigour without crossing with other breeds (Bourdon, 2000). Synthetic breeds can be formed in many ways. Cunningham and Syrstad (1987) describe two methods. The simplest form involves two parental breeds which are crossed to produce an F1 generation and thereafter selected F1 individuals are inter-se mated to produce an F2 generation. This process is repeated in subsequent generations. Figure 1 shows a summary of the crossbreeding program followed in development of the Australian Milking Zebu (AMZ) a Sahiwal: Jersey synthetic.

**Figure 1: Summary of the breeding program used to develop the Australian Milking Zebu**

**Stage 1 : Parental breeds crossed and filial generations mated *per se* up to**

Sahiwal (10) or Red Sindi (8) X Jersey Females (212)

↓

F1 males from top producing Jersey females used as sires X all F1 females milked one lactation

↓

F2 males from top producing Jersey females used as sires X all F2 females milked one lactation

↓

F3

(146 F1, F2and F3 Sahiwal descendants produced and 124 F1, F2 and F3 Red Sindi descendants produced)

↓

**Stage 2 : Progeny testing of young bulls**

40 bulls were available each year for consideration as progeny test sires two screening tests were done. Artificial climatic stress and infestation with ticks. The 7 highest ranking bulls were retained for entry into the progeny test

↓

**Stage 3 :Final stage**

Only sons of sires selected for progeny testing from high yielding females were admitted for screening and progeny testing. Target was to develop animal with of between 3/8 and ½ *Bos Indicus* blood and selected for milk production , tolerance to hot climatic stress and resistant to ticks

**Source: Developed from Hayman, 1974**

There are other methods of forming synthetic breeds. A program using three breeds could produce a synthetic with 25% local genes (*Bos indicus*), 25% from one of the *Bos taurus* breeds and 50% *Bos taurus* genes from a second exotic.

***Achievements with formation of synthetics populations***

Several attempts have been made to form synthetic groups (Hayman 1974; Katyega 1987; Madalena *et al*. 1999; Gaur *et al*. 2005; Singh 2005; Cerutti *et al.* 2006) give accounts of 13 synthetic breeds from different parts of the tropics at varying levels of development. McDowell (1985) compared data of five of these groups comprising of Jamaica Hope, Pitanguei-Ras, Australian Milking Zebu, Karan Swiss and Sibovey originating from Jamaica, Brazil, Australia, India and Cuba, respectively. Performance in each group was superior to the native breeds. Some of analyzed

traits showed the following means with ranges: milk yield per lactation: 2623 (1987 – 2930) kg; age at first calving: 33.6 (31.3 – 34.5) months; calving interval: 419 (405 – 439) days. In India, several synthetic breeds have evolved from crossbreeding research work. Singh (2005) assembled production data from five of the new strains namely; Karan Swiss, Karan Fries, Sunandini (farm-bred), Sunandini (field) and the Frieswal. Performance and production traits are summarized as: milk yield of 3024 (2487 – 3686) kg; age at first calving of 33.7 (30.5 – 31.9) months; lactation length of 321.3 (317- 326) days and calving interval of 412 (401 – 426) days.

A well documented synthetic is the Australian Friesian Sahiwal (AFS): a 50:50 Sahiwal: Friesian synthetic developed by the government of Queensland, Australia from 1960 until sold to a private company in 1994. The program is now under the management of AFS association of Australia which continues breed development, genetic management and progeny testing for AFS Bulls (Meat and Livestock Australia, 2006).The AFS was bred for milk letdown, tick resistance and milk yield. Under extensive grazing of tropical pasture the AFS averaged 2556 litres of milk and 105 kg fat as compared to Holstein-Friesian performance of 2291 litres of milk and 82kg fat (Alexander, 1986). Another equally successful synthetic is the Girolando, a 62.5:37.5 Holstein Friesian: Gir synthetic developed in Brazil. The Girolando produces 80% of the milk in Brazil and has an average of 3,600kg of milk with 4% fat content and a calving interval of 410 days (Girolando, 2005).

## Discussion

### Challenges

In spite of the potential of crossbreeding as a livestock improvement method, it has not resulted into a wide-spread overall increase in milk production in the tropics (Bayemi et al., 2005). Neither has crossbreeding been successfully and sustainably adopted and practiced in the region (Rege, 1998; Kumar *et al*., 2003; Miazi *et al*., 2007) due to several challenges discussed in this section under different subheadings.

#### ***Limitations of the crossbreeding methods***

From our comparative study, results from grading up show that in all CZs there is a marked improvement in production up to the 50% level while further upgrading or inter se mating (F2 production) does not have a clear trend. The widest mean range (1.4 – 4.5) for relative performance was observed for MYL among the F1 and 75% level crosses in the Highlands. This could be as a result of the large differences in levels of management between farms or due to the different *Bos taurus* and *Bos indicus* breeds used in the various crossbreeding programs from which the data were derived. Holstein-Friesian crosses had highest relative performance for MYL followed by the Jersey and Ayrshire crosses. Similar effects of the *Bos taurus* breeds on performance (MYL, AFC) have been reported in other earlier studies. Cunningham and Syrstad (1987) compared production in projects in which two or more *Bos taurus* breeds were used simultaneously. The study included Holstein-Friesian, Brown Swiss and Jersey. Jersey crosses were the youngest and Brown Swiss crosses the oldest at first calving, both differing significantly from Friesian crosses. Friesian crosses had the highest and Jersey crosses the lowest milk yield, the differences were significant.

A major limitation of upgrading is that maximum heterosis is only attainable at F1. Any further upgrading usually leads to mixed results, unless further grading up towards the exotic dairy breeds is accompanied with significant husbandry improvement as well as selective breeding (Cunningham, 1981). Results presented in the previous sections are mostly from research stations and from commercial farms where the level of management and nutrition of stock is good ( e.g. Thorpe *et al*., 1994; Katpatal, 1977;

Tadesse and Tadelle, 2003; Demeke *et al*., 2004a; Tadesse et al., 2006). The smallholder sector in the tropics, which constitutes majority of the farmers are at times unable to raise the levels of management and nutrition in line with the requirements of the new genotypes (Kahi, 2002). This often leads to low productivity and high mortality among the animals (Chagunda, 2002; Philipsson *et al*., 2006).

Although results from rotational crossbreeding have shown marked improvement in animal productivity, this improvement method can only be used on large scale operations where management is good. Programs associated with it are not practical for small scale farmers whose herd sizes may not justify keeping more than one bull. In the two breed rotation there is great variability in genotypic composition from generation to generation depending on the sire breed used. This is not practical for small scale operations (Trail and Gregory, 1981; Syrstad, 1989). The most widely reported success, the Kilifi Plantation rotation program (Mackinnon et al., 1996; Kahi et al., 2000), has never been expanded beyond the single ranch program or replicated elsewhere. Thus this program has had limited impact, as source of improved genetics to a wider dairy farming community in the hot and humid coastal region of Kenya.

Like all other crossbreeding strategies development of synthetic populations has its draw backs too. Firstly it takes many years to develop a synthetic population and the exercise can be costly. For example development of the Australian Friesian Sahiwal started in 1960s and the costs were $30 Million Australian dollars. The breeding program was later sold off to a private company in 1994 for continued commercial development (Meat and Livestock Australia, 2006; Chambers, 2006). During the development period of the AFS there were drastic changes in the infrastructure in Australia. This made access to the more naturally favoured milk production areas of northern Australian coastal regions easy. As a result production systems changed and the synthetic could not compete with breeds like Holstein-Friesian and the Jersey under the new intensive systems. It is now estimated that only 250 purebred AFS remain in Australia. Currently exports of AFS continue to many tropical countries which include Mexico, Brunei, Thailand, India and Malaysia (Chambers, 2006). However, as will be later discussed under the opportunities section, innovative application of a combination of the emerging assisted reproductive technologies, genomics and dense single nucleotide polymorphism (SNP) marker technologies, development of synthetics can be significantly hastened.

***The production environment and production system***

Another deterrent to crossbreeding has been the poor infrastructure and access to markets, especially in rural areas with lower agricultural potential where crossbreds are best suited and are often promoted. In addition, pricing policies for milk in some countries are often poor. Prices paid to the farmers are low and cannot support purchase of feeds or investment in the necessary infrastructure all of which are necessary to make the production system economically viable (McDowell, 1985 ; Mwale et al., 1999).

Failure to recognize different needs for different production systems has also affected success rate of the crossbreeding programs. In many tropical countries past, and in some cases, ongoing crossbreeding programs have often been based on a *one genotype combination-fits-all* premise, with Holstein-Friesian being the preferred improver breed even under production systems such as stall feeding (zero-grazing) under the hot and humid tropics where other breeds might be better suited (King et al., 2006). The result of such genotype-production systems mismatches, in which the important genotype-by-environment interaction effects are ignored are partly responsible for the largely disappointing or poor performance of crossbred cattle in the tropics and often their insignificant impacts (McDowell, 1986; King et al., 2006; Philipsson et al., 2006).

Choice of *Bos taurus* breeds and level of crossing for different production systems should not only be based on genetic potential for milk yield but also on farmer's ability to offer adequate husbandry as well as the available health care services and markets. In addition, availability of good quality and adequate feeds and water need to be all considered. Increasing genetic potential of the animals without due consideration of the above will not allow the full beneficial heterotic effects to be realized (Ansell, 1985; Chantalakhana, 1998).

### ***Intermittent funding of programs and lack of appropriate policies***

Adequate funding is required for a well planned crossbreeding program (Kumar *et al*., 2003). This however is not always possible and has led to interruptions in many programs (Shem and Mdoe, 2003; Cardoso *et al.,* 2006; Shem, 2007). In addition lack of supportive national breeding policies and appropriate strategies have contributed greatly to the failure of many programs. Rege (1998) and Chantalakhana (1998) observed that there is hardly a country in the tropics that has developed appropriate policies to utilize the advantages of crossbreeding. This issue is of major concern to both farmers and technical personnel who are constantly seeking answers on how to maintain an appropriate level of crossing or what level of crossing is appropriate for a given production environment (Chantalakhana 1998; Ansell 1985). Lack of proper guidelines has led to undesirable consequences especially on smallholder units where indigenous breeds are being upgraded to higher exotic grades without following a defined crossbreeding program (Kahi, 2002).

## **Opportunities**

This section discusses the various opportunities that exist to improve livestock through crossbreeding.

### ***Availability of large base populations***

Of the estimated 1.4 billion cattle in the world, more than 2/3 is found in the tropics (Wint and Robinson, 2007). Most of these are indigenous cattle and belong to the zebu type. The zebu can be classified into a number of sub-groups according to the external traits, such as size, origin and on basis of utility (Tawah *et al*., 1996). Considerable improvement can be made by crossing the Zebu with *Bos taurus* breeds as outlined in the previous sections. The important questions that remain are; which breed of *Bos taurus* to use for the different production systems? What levels of exotic blood are to be maintained in crossbred genotypes? How will the desirable genotype be continuously produced? (Kahi 2002; Mpofu 2002).

***Assisted reproductive technologies***

In cattle, assisted reproductive technologies (ART) are defined as techniques that manipulate reproductive-related events and/or structures to achieve pregnancy with the final goal of producing healthy off spring in bovine females (Velazquez, 2008). ART began with the development of Artificial Insemination (AI) about 50 years ago. Utilization of AI was greatly enhanced by ability to freeze semen. Following the success of AI, methods of recovering, storing and implantation of embryos, i.e. embryo transfer (ET) were developed. It is now possible to recover up to 30 embryos at a time. Since the middle 1990s another important technique in vitro fertilization (IVF) has been developed. Oocytes are harvested from females and are fertilized in vitro (Van der Werf and Marshal, 2003; Cunningham 1999). Potential use of IVF includes supply of embryos from slaughter houses, for twinning purposes to increase calf crop without increasing herd size and to obtain viable embryos from females unable to produce by conventional means (Faber and Ferre´, 2004; Seidel and Seidel, 1991). In well structured crossbreeding programs in the tropics, AI has the potential of increasing the rate at which genetic change is made in the local population by increasing the reproductive rates of the bulls (Cunnigham, 1999). Through MOET or IVF reproductive rates in females can also be increased. Benefits of this are twofold for crossbreeding programs; the numbers of required females in the program is significantly reduced and it is possible to multiply rapidly the number of animals with the required qualities (Cunningham, 1991). If sexed semen is used with *in vitro* fertilization then sex of the offspring can be predetermined. This opens additional opportunity for repeatedly and rapidly producing crossbreds of specific breed combinations and preferred sex (Wheeler *et al*., 2006). Rutledge (2001) proposed that IVF should be widely used as a method of continuous production of F1s by using oocysts from spent dairy cows and semen from adapted breeds. In this way lactation in F1 cows can be initiated by transfer of F1 in-vitro produced embryos. Wide scale use of the above technologies i.e. MOET and IVF is however still not possible in the tropics because of the high costs involved, poor communication in many countries and shortage of technical personnel (Kahi *et al*., 2000).

### *Alternative recording methods*

It has been pointed out (Cunningham, 1981) that any crossbreeding program adopted for a population requires at some point in the program an indigenous selection operation. A serious constraint to this is that performance records are not readily available in the tropics. The extensive milk recording programs which support dairy breeding in the temperate region are virtually non existent in the tropics (Syrstad and Ruane, 1998). Reasons for this are outlined by different authors (Buvanendran 1982; Ansell 1985; Islam et al., 2002; Singh 2005) and include; small herd sizes which are at times scattered, poor communication, low level of farmer education and wide diversity in feeding and management regimes. Manson and Buvanendran (1982) argue that recording systems in the tropics should not be as elaborate as in the temperate regions. They propose the following approaches which are simpler, cheaper to operate and less demanding to the farmers and yet would still enable progeny testing to be done; *(i)Bi-monthly recording:* In the system the recorder visits the farm every alternate month and records milk yield obtained during a 24-hour period. *(ii) AM-PM sampling:* in this method, the morning milk is weighed one month and the evening milk the next month. It maintains monthly visits but is cheaper*. (iii) Sampling at particular stages of lactation*: At early, mid or late lactation. This system is difficult in herds calving all year round since cows will be at different stages of lactation. Another approach that could be employed to reduce costs of sampling is to contract selected herds in a given region to produce the desired crossbreeds. With this approach detailed recording would only take place in the contracted herds.

### *Genomic technology – current and future opportunities*

Recent developments in molecular genetics now provide a powerful tool that will help speed up the improvement of livestock. A new technology called genomic selection is changing dairy cattle breeding. Genomic selection refers to selection decisions based on Genomic breeding values GEBV (Hayes et al., 2009). The GEBV is the sum of the effects of dense genetic markers or haplotypes of these markers, across the genome (Hayes *et al*., 2009). Genomic selection is now becoming feasible because of the availability of large numbers of single nucleotide polymorphism (SNP) markers. In the case of crossbreeding purebreds can be selected for performance of crossbreds by estimating the effects of SNPs on crossbred performance using phenotypes and SNP genotypes evaluated on crossbreds, and applying the results estimates to SNP genotypes obtained on pure breeds (Dekkers, 2007). This is a major achievement because *Bos taurus* breeds used in most crossbreeding programs in the tropics are selected in temperate regions under different management environments. Due to genetic differences between purebreds and crossbreds and the environmental differences between the two production systems, performance of pure bred parents is not a good predictor of their crossbred descendants. This development makes it possible to identify pure breed parents whose decedents will perform best as crossbreds. Other benefits of genomic selection for crossbreeding include the following (i) it does not require pedigree information on crossbreds (ii) after estimates of the SNP effects have been obtained, using genotype and phenotypic data prediction can continue for several generations and (iii) it reduces the rate of inbreeding (Ibánz-Escriche et al., 2009).

## Conclusions

Crossbreeding shall remain an attractive option for livestock improvement in the tropics because of the quick results that can be obtained and the potential benefits it has for farmers. In most cases the F1 crosses have performed better than other genotypes. Continuous production of F1s remains a challenge. Strengths and weak points of the different crossbreeding methods have been discussed. We propose that maintaining of suitable genotype combination from generation to generation will be best achieved through development of synthetic breeds for the different production environments. Such an approach will ensure that a self replacing population is created. It will also ensure that the farmers deal with one kind of animal. This will make management easier especially in the harsh production environments. Developments in reproductive technologies and in molecular genetics provide opportunities to develop and multiply synthetic breeds at a much faster rate than in previously conducted breeding programs. However there are still high costs associated with these techniques making their wide use in the tropics impossible at the moment.

Studies on the various merits of the indigenous tropical genotypes need to be undertaken exhaustively. This will assist in determining which combinations of exotic and indigenous breeds to use and the level of exotic blood to maintain in the new genotypes.

The conservation of indigenous breeds should not be ignored but also built into national breeding programs because this group of animals possesses qualities for present and future generations.

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# Chapter 2B

## Supplementary tables

**Supplementary table 1**: A summary of the data assembled: Production traits

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Africa | Cameroon | Wakwa station | T. Wet | | Hosltein Friesian(HF) | HF | 2626 (171.8) | 2391 (200.6) | 247 (18.8) | Tawah et al., 1999 |
| 2 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Hosltein Friesian(HF) | 1/2HF 1/2G | 1554 (96.1) | 1555 (104.8) | 261 (10.5) | Tawah et al., 1999 |
| 3 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Hosltein Friesian(HF) | 3/4HF 1/4G | 1041 (229.5) | 1266 (239.2) | 251 (25.2) | Tawah et al., 1999 |
| 4 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | 1/2 M 1/2 G | 1095 (115.6) | 1165 (126.0) | 214 (12.7) | Tawah et al., 1999 |
| 5 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | 3/4 M 1/4G | 1226 (238.4) | 1447 (237.7) | 259 (26.1) | Tawah et al., 1999 |
| 6 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | F2 | 1040 (111.9) | 1217 (131.9) | 237 (12.2) | Tawah et al., 1999 |
| 7 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | | Boran | 529 (65) | 514 (61) | 193 (6) | Demeke et al., 2004a /2004b |
| 8 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/2HF 1/2Br | 2355 (71) | 2057 (57) | 348 (6) | Demeke et al., 2004a /2004b |
| 9 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | F2 | 1928 (108) | 1740 (94) | 308 (9) | Demeke et al., 2004a /2004b |
| 10 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 5/8HF 3/8Br | 2187 (203 ) | 2091 (99.5) | 351(17) | Demeke et al., 2004a /2004b |
| 11 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 3/4HF 1/4Br | 2528 (141) | 2093 (88.1) | 331(12) | Demeke et al., 2004a /2004b |
| 12 | Africa | Ethiopia | Holeta station | Highland | | Hosltein Friesian(HF) | HF | 3319 (55) | 2879 (45) | 346(4) | Demeke et al., 2004a /2004b |
| 13 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | 1/2J 1/2Br | 2092 (75) | 1861 (60) | 343 (6) | Demeke et al., 2004a /2004b |
| 14 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | F2 | 1613 (107) | 1480 (94) | 304 (9) | Demeke et al., 2004a /2004b |
| 15 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | 3/4J 1/4Br | 1956 (133) | 1758 (89.5) | 337(11) | Demeke et al., 2004a /2004b |
| 16 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | HF / J | 1/4F:1/4J:1/2Br | 1790 (143) | 1752 (98) | 325 (13) | Demeke et al., 2004a /2004b |
| 17 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | | Ar | 809 (233)* | 689(149)* | 272 (233)* | Kiwuwa et al., 1983 |
| 18 | Africa | Ethiopia | Arsi region | Highland | Zebu (Z) | | Z | 929 (104)* | 770(90)* | 303 (104)* | Kiwuwa et al., 1983 |
| 19 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Jersey(J) | 1/2J 1/2 Ar | 1741 (115)* | 1534 (91)* | 334 (115) | Kiwuwa et al., 1983 |
| 20 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Hosltein Friesian(HF) | 1/2F 1/2Ar | 1977 (392)* | 1704 (304)* | 356 (392) | Kiwuwa et al., 1983 |
| 21 | Africa | Ethiopia | Arsi region | Highland | Zebu (Z) | Hosltein Friesian(HF) | 1/2F 1/2Z | 2352 (220)* | 1913 (185)* | 378 (220) | Kiwuwa et al., 1983 |
| 22 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Hosltein Friesian(HF) | 3/4F 1/4Ar | 2374 (98)* | 2043 (64)* | 408 (98)* | Kiwuwa et al., 1983 |
| 23 | Africa | Ethiopia | Arsi region | Highland | Zebu (Z) | Hosltein Friesian(HF) | 3/4F 1/4Z | 2356 (53)* | 1930 (41)* | 378 (53)* | Kiwuwa et al., 1983 |

**Abbreviations**

**( )** = Standard error , **( )*** = number of records observed in the study, **Climatic Z**= Climatic Zone, **An Milk pd**= Annual milk production , **Lact L**.= lactation length
**Genetic grp**= genetic group **1/4HF H.Mgt** = 25% Exotic Inheritance on High management production system **1/4HF L.Mgt =** 25% Exotic Inheritance on a low management system **Highland =** Highlands climatic zone, **T. Wet** = Tropical Wet climatic zone, **T.wet /dry** = Tropical wet and dry
**Holstein Friesian(A)*=** Study in which Ayrshire bulls used initially used but later replaced by Holstein Friesian bulls

**Table 1: Continued**

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca (B) | | Barca | 672 (196) | 674 (224) | 279 (24) | Tadesse and Dessie, 2003 |
| 25 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 1/2F 1/2B | 2316 (98) | 2042 (106) | 326(11) | Tadesse and Dessie, 2003 |
| 26 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/2Br 1/2F | 2088 (118) | 1887 (136) | 328 (13) | Tadesse and Dessie, 2003 |
| 27 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 1/4B 3/4F | 2373 (105) | 1953 (111) | 360 (12) | Tadesse and Dessie, 2003 |
| 28 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/4Br 3/4 F | 2336 (96) | 1975 (106) | 358 (11) | Tadesse and Dessie, 2003 |
| 29 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 7/8 F 1/8 B | 2189 (183) | 1558 (239) | 351 (22) | Tadesse and Dessie, 2003 |
| 30 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 7/8Br 1/8 F | 1915 (163) | 1501 (173) | 341 (20) | Tadesse and Dessie, 2003 |
| 31 | Africa | Ethiopia | Debre Zeit Centre | Highland | | Hosltein Friesian(HF) | HF | 3183 (111) | 2679 (120) | 362 (13) | Tadesse and Dessie, 2003 |
| 32 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 75%S 25%A | 1234 (46) | 1251 (51) | 274 (6) | Thorpe et al., 1994 |
| 33 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 1537 (50) | 1458 (54) | 284 (7) | Thorpe et al., 1994 |
| 34 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/2F 1/2S | 1611 (69) | 1465 (72) | 290 (10) | Thorpe et al., 1994 |
| 35 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 75%A 25%S | 1638 (51) | 1423 (52) | 299 (7) | Thorpe et al., 1994 |
| 36 | Africa | Kenya | Kilifi Plantations | S. Arid | Sahiwal(S) | Ayrshire(A) | 2/3S 1/3A | 2662 (39) | 2503 (32) | | Thorpe et al., 1994 |
| 37 | Africa | Kenya | Kilifi Plantations | S. Arid | Sahiwal(S) | Ayrshire(A) | 2/3A 1/3S | 2843 (50) | 2616 (42) | | Thorpe et al., 1994 |
| 38 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 3/4A 1/4S | 1674(138) | | 197(17) | Trial and Gregory, 1981 |
| 39 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 1952 (193) | | 220(24) | Trial and Gregory, 1981 |
| 40 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 1/2S 1/2A | 1417 (266) | | 186 (33) | Trial and Gregory, 1981 |
| 41 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 3/4 S 1/4 A | 1464 (141) | | 191 (18) | Trial and Gregory, 1981 |
| 42 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | | Sahiwal | 956 (261) | | 143 (33) | Trial and Gregory, 1981 |
| 43 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | | | 486 (148) | | 109 (19) | Kimenye ,1978 |
| 44 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | Ayrshire(A) | 1/2S1/2A | 1276 (184) | | 224 (24) | Kimenye ,1978 |
| 45 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 1163 (276) | | 263 (36) | Kimenye ,1978 |
| 46 | Africa | Kenya | Machakos | S.Arid | | Ayrshire(A) | Aryshire | 1888 (137) | | 292 (18) | Kimenye ,1978 |

## Table 1: Continued

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | | | 1177(159) | | 242 (15) | Kimenye ,1978 |
| 48 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 3/4S 1/4A | 1857 (216) | | 253 (20) | Kimenye ,1978 |
| 49 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 1/2S 1/2A | 1710 (126) | | 250 (12) | Kimenye ,1978 |
| 50 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 1940 (115) | | 265 (11) | Kimenye ,1978 |
| 51 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 3/4A 1/4S | 2381 (192) | | 303(18) | Kimenye ,1978 |
| 52 | Africa | Kenya | Ngong | Highland | | Ayrshire(A) | Aryshire | 2185 (112) | | 280 (10) | Kimenye ,1978 |
| 53 | Africa | Nigeria | Vom | T.Wet/dry | White Fulani(WF) | | WF | 772.6 (263.03) | | 174.19 (49) | Olutogun et al., 2006 |
| 54 | Africa | Nigeria | Vom | T.Wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2WF | 4095.3(278.1) | | 288.97 (34) | Olutogun et al., 2006 |
| 55 | Africa | Nigeria | Vom | T.Wet/dry | | Hosltein Friesian(HF) | HF | 6588.67(384.5) | | 284.43 (20) | Olutogun et al., 2006 |
| 56 | Africa | Nigeria* | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2FU | 1684 (287)* | | 243.7 (289) | Buvanedran et al., 1981 |
| 57 | Africa | Nigeria | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 3/4HF 1/4 Fu | 1850 (143)* | | 263 (143) | Buvanedran et al., 1981 |
| 58 | Africa | Nigeria* | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 7/8 HF 1/8 FU | 2051 (32)* | | 286 (33) | Buvanedran et al., 1981 |
| 59 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | | Fulani | 837 (17) | | | Knudsen and Sohael, 1970 |
| 60 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2 WF | 1690 (35) | | | Knudsen and Sohael, 1970 |
| 61 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 3/4 HF - Bull | 1625 (103) | | | Knudsen and Sohael, 1970 |
| 62 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 3/4HF semen I | 2318 (130) | | | Knudsen and Sohael, 1970 |
| 63 | Africa | Nigeria* | Vom | T.wet/dry | White Fulani(WF) | | W. Fulani | 834 (64)* | | 246(64)* | Shoael, 1984 |
| 64 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2WF | 1692 (71)* | | 271 (71)* | Shoael, 1984 |
| 65 | Africa | Nigeria | Vom | T.wet/dry | | Hosltein Friesian(HF) | HF | 2538 (44)* | | 304 (44)* | Shoael, 1984 |
| 66 | Africa | Nigeria* | Vom | T.wet/dry | | Hosltein Friesian(HF) | HF | 3286 (50)* | | 282 (50)* | Shoael, 1984 |
| 67 | Asia | Bangladesh | Comilla | T.wet | Local (L) | | | 2.26/day (0.19) | | 235,4 (6.95)) | Miazi et al., 2007 |
| 68 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Sahiwal(S) | 1/2S 1/2L | 4.9/day (0.95) | | 234 (24) | Miazi et al., 2007 |
| 69 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Hosltein Friesian(HF) | HF | 6.0/day (1) | | 270 (0) | Miazi et al., 2007 |

## Table 1: Continued

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 70 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Jersey(J) | J | 5.71/day (0.87) | | 274 (3.74) | Miazi et al., 2007 |
| 71 | Asia | Bangladesh | Khulna | T.wet | Local (L) | | L | 937 (183) | | 244.6 (10.1) | Ashraf et al., 2000 |
| 72 | Asia | Bangladesh | Khulna | T.wet | Local (L) | Hosltein Friesian(HF) | 1/2F 1/2L | 1633 (133) | | 271.4 (9.19) | Ashraf et al., 2000 |
| 73 | Asia | Bangladesh | Khulna | T.wet | Local (L) | Sahiwal | 1/2S 1/2L | 1863 (141) | | 299.38 (9.74) | Ashraf et al., 2000 |
| 74 | Asia | Bangladesh | Dhaka | T.wet | Local (L) | | Local | 653 (16.3)) | | | Majid et al., 1996 |
| 75 | Asia | Bangladesh | Dhaka | T.wet | Local (L) | Hosltein Friesian(HF) | 1/2HF 1/2L | 1,956 (130.5) | | | Majid et al., 1996 |
| 76 | Asia | Bangladesh | Dhaka | T.wet | Local (L) | Jersey(J) | 1/2J 1/2L | 1,743 (138.74) | | | Majid et al., 1996 |
| 77 | Asia | Bangladesh | Dhaka | T.wet | Sahiwal(S) | Hosltein Friesian(HF) | 1/2S 1/2F | 1,900 (95.1) | | | Majid et al., 1996 |
| 78 | Asia | Bangladesh | Dhaka | T.wet | Sahiwal(S) | | S | 1,056 (84.69) | | | Majid et al., 1996 |
| 79 | Asia | Bangladesh | Dhaka | T.wet | Local | Hosltein Friesian(HF) | F2 | 1,897 (235.4) | | | Majid et al., 1996 |
| 80 | Asia | Bangladesh | Dhaka | T.wet | Local | Jersey(J) | F2 | 1,543 (105.93) | | | Majid et al., 1996 |
| 81 | Asia | Bangladesh | Barisal/Patuakahli | T.wet | Local | | Local | 845 (21.5) | | 225.5 (6.1) | Al-Amin and Nahar,2007 |
| 82 | Asia | Bangladesh | Barisal/Patuakahli | T.wet | Local | Hosltein Friesian(HF) | 1/2HF 1/2L | 1836.7 (18.2) | | 339 (7.4) | Al-Amin and Nahar,2007 |
| 83 | Asia | Bangladesh | Dhaka | T.wet | Local | | L | 700 (39.9) | | 275.2 (7.9) | Rahman et al. 2007 |
| 84 | Asia | Bangladesh | Dhaka | T.wet | Local | Hosltein Friesian(HF) | 1/2F 1/2L | 1753.2 (90.31) | | 357.6 (4.9) | Rahman et al. 2007 |
| 85 | Asia | Bangladesh | Dhaka | T.wet | Local | Jersey(J) | 1/2J | 1492.8 (48.3) | | 330.7 (7.3) | Rahman et al. 2007 |
| 86 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 3/4 HF | 2324(107) | | 297 (8) | Amble and Jain ,1967 |
| 87 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 7/8 HF | 2213(108) | | 303 (9) | Amble and Jain ,1967 |
| 88 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 15/16HF | 2158 (131) | | 272 (14) | Amble and Jain ,1967 |
| 89 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 1/2 HF | 2771 (365) | | 355 (33) | Amble and Jain ,1967 |
| 90 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 3/4HF | 2601 (166) | | 335 (17) | Amble and Jain ,1967 |
| 91 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 7/8HF | 2582 (179) | | 324 (16) | Amble and Jain ,1967 |
| 92 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 15/16HF | 2199 (201) | | 287 (20) | Amble and Jain ,1967 |

**Table 1: Continued**

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 93 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 1/4HF | 1770 (295) | | 325 (21) | Amble and Jain ,1967 |
| 94 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 3/8HF | 2448 (169) | | 300 (12) | Amble and Jain ,1967 |
| 95 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 1/2HF | 2203 (272) | | 282 (22) | Amble and Jain ,1967 |
| 96 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 5/8HF | 2762 (303) | | 295 (27) | Amble and Jain ,1967 |
| 97 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 3/4HF | 2584 (153) | | 319 (12) | Amble and Jain ,1967 |
| 98 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 7/8HF | 2200 (201) | | 275 (15) | Amble and Jain ,1967 |
| 99 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 15/16HF | 2308 (197) | | 299 (15) | Amble and Jain ,1967 |
| 100 | Asia | India | Ambala | T. Wet | Sahiwal(S) | | S | 1891 (89) | | 305 (7) | Amble and Jain ,1967 |
| 101 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/8HF | 1766 (174) | | 255 (16) | Amble and Jain ,1967 |
| 102 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 1/2HF | 2346 (124) | | 276 (11) | Amble and Jain ,1967 |
| 103 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 5/8HF | 2692 (174) | | 281 (17) | Amble and Jain ,1967 |
| 104 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/4HF | 2194 (76) | | 285 (7) | Amble and Jain ,1967 |
| 105 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 7/8HF | 2096 (82) | | 296 (7) | Amble and Jain ,1967 |
| 106 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 15/16HF | 2012 (127) | | 299 (12) | Amble and Jain ,1967 |
| 107 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 31/32HF | 1832 (192) | | 263 (18) | Amble and Jain ,1967 |
| 108 | Asia | India | Meerut | T. Wet | Sahiwal(S) | | Sahiwal | 1653 (139) | | 288 (8) | Amble and Jain ,1967 |
| 109 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/8HF | 2480 (373) | | 374 (23) | Amble and Jain ,1967 |
| 110 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 1/2HF | 2342 (373) | | 308 (23) | Amble and Jain ,1967 |
| 111 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/4HF | 2716 (249) | | 316 (18) | Amble and Jain ,1967 |
| 112 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 7/8HF | 2184 (334) | | 326 (24) | Amble and Jain ,1967 |
| 113 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 1/2HF | 2484 (302) | | 332 (17) | Amble and Jain ,1967 |

## Table 1: Continued

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 114 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 5/8HF | 2286 (166) | | 296 (12) | Amble and Jain ,1967 |
| 115 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 3/4HF | 2157 (201) | | 306 (16) | Amble and Jain ,1967 |
| 116 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 1/4HF | 1708 (309) | | 263 (19) | Amble and Jain ,1967 |
| 117 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 3/8HF | 2212 (198) | | 294 (10) | Amble and Jain ,1967 |
| 118 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 1/2HF | 2969 (176) | | 329 (13) | Amble and Jain ,1967 |
| 119 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 5/8HF | 2282 (246) | | 298 (18) | Amble and Jain ,1967 |
| 120 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 3/4HF | 2390 (134) | | 317 (9) | Amble and Jain ,1967 |
| 121 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 7/8HF | 2249 (158) | | 294 (10) | Amble and Jain ,1967 |
| 122 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 15/16HF | 2125 (206) | | 292 (14) | Amble and Jain ,1967 |
| 123 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 1/4HF | 1711 (314) | | 253 (20) | Amble and Jain ,1967 |
| 124 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 3/8HF | 1663 (186) | | 263 (12) | Amble and Jain ,1967 |
| 125 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 1/2HF | 2443 (202) | | 277 (12) | Amble and Jain ,1967 |
| 126 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 5/8HF | 2054 (240) | | 291 (15) | Amble and Jain ,1967 |
| 127 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 3/4HF | 2164 (108) | | 293 (7) | Amble and Jain ,1967 |
| 128 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 7/8HF | 2220 (130) | | 278 (8) | Amble and Jain ,1967 |
| 129 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 15/16HF | 1866 (240) | | 312 (15) | Amble and Jain ,1967 |
| 130 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 1/2HF | 2750 (184) | | 308 (9) | Amble and Jain ,1967 |
| 131 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 3/4HF | 2406 (133) | | 288 (8) | Amble and Jain ,1967 |
| 132 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 7/8HF | 2399 (265) | | 299 910) | Amble and Jain ,1967 |
| 133 | Asia | India | Karnal | S. Arid | Sahiwal(S) | | Sahiwal | 1704 (3.6) | | 285 (0.57) | Taneja and Chawla, 1978 |
| 134 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 1/4BS 3/4S | 3039 (304.3) | | 299 (27.3) | Taneja and Chawla, 1978 |
| 135 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 1/2BS 1/2S | 3160 (32) | | 331 (3.2) | Taneja and Chawla, 1978 |
| 136 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | F2 | 2579 (74.08) | | 292 (7.12) | Taneja and Chawla, 1978 |
| 137 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 3/4 BS 1/4S | 2670 (78.5) | | 292 (7.6) | Taneja and Chawla, 1978 |

**Table 1: Continued**

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 138 | Asia | India | Karnal | S. Arid | | Brown Swiss(BS) | BS | 2355 (28.4) | | 401 (4.6) | Taneja and Chawla, 1978 |
| 139 | Asia | India | Haringhata | T. Wet | Deshi (D) | | D | 334 (102) | | 283(17) | Bala and Nagarcenkar, 1981 |
| 140 | Asia | India | Haringhata | T. Wet | Hariana(H) | | H | 791 (37) | | 311(18) | Bala and Nagarcenkar, 1981 |
| 141 | Asia | India | Haringhata | T. Wet | Deshi (D) | (HF) | 1/2F 1/2D | 1321(68) | | 321(11) | Bala and Nagarcenkar, 1981 |
| 142 | Asia | India | Haringhata | T. Wet | Deshi (D) | Jersey(J) | 1/2J 1/2 D | 1269(57) | | 327(9) | Bala and Nagarcenkar, 1981 |
| 143 | Asia | India | Haringhata | T. Wet | Hariana(H) | Friesian | 1/2F 1/2H | 1926 (32) | | 341(5) | Bala and Nagarcenkar, 1981 |
| 144 | Asia | India | Haringhata | T. Wet | Hariana(H) | B. Swiss(BS) | 1/2BS 1/2H | 1717 (47) | | 333(8) | Bala and Nagarcenkar, 1981 |
| 145 | Asia | India | Haringhata | T. Wet | Hariana(H) | Jersey(J) | 1/2J 1/2H | 1610 (26) | | 326(4) | Bala and Nagarcenkar, 1981 |
| 146 | Asia | India | Haringhata | T. Wet | Hariana(H) | Friesian | F/ H - F2 | 1293 (74) | | 334 (12) | Bala and Nagarcenkar, 1981 |
| 147 | Asia | India | Haringhata | T. Wet | Hariana(H) | Jersey(J) | J/H - F2 | 1139 (60) | | 322 (10) | Bala and Nagarcenkar, 1981 |
| 148 | Asia | India | Haringhata | T. Wet | | Friesian | Friesian | 2403 (97) | | 372 (16) | Bala and Nagarcenkar, 1981 |
| 149 | Asia | India | Haringhata | T. Wet | | Jersey(J) | Jersey | 2012 (95) | | 349 (16) | Bala and Nagarcenkar, 1981 |
| 150 | Asia | India | Chalakudy | T.wet | Local (L) | | L | 573 (0.24) | | | Katpatal, 1977 |
| 151 | Asia | India | Chalakudy | T.wet | Local (L) | Jersey(J) | 1/4J 3/4L | 1159(23.6) | | | Katpatal, 1977 |
| 152 | Asia | India | Chalakudy | T.wet | Local (L) | Jersey(J) | 1/2J 1/2L | 1411 (1.4) | | | Katpatal, 1977 |
| 153 | Asia | India | Chalakudy | T.wet | Local (L) | Jersey(J) | 3/4J 1/4L | 1426 (5.3) | | | Katpatal, 1977 |
| 154 | Asia | India | Chalakudy | T.wet | Local (L) | Jersey(J) | 7/8J 1/8L | 1796 (84.9) | | | Katpatal, 1977 |
| 155 | Asia | India | Chalakudy | T.wet | Local (L) | Jersey(J) | F2 | 1601 (40.3) | | | Katpatal, 1977 |
| 156 | Asia | India | Vikas Nagar | T.wet | Local (L) | | L | 492 (3.7) | | | Katpatal, 1977 |
| 157 | Asia | India | Vikas Nagar | T.wet | Local (L) | Jersey(J) | 1/2J 1/2L | 1151 (11.9) | | | Katpatal, 1977 |
| 158 | Asia | India | Vikas Nagar | T.wet | Local (L) | Jersey(J) | 3/4J 1/4L | 1102 (62.4) | | | Katpatal, 1977 |
| 159 | Asia | India | Visakhapatnam | T.wet | Local (L) | | L | 699(5.1) | | | Katpatal, 1977 |
| 160 | Asia | India | Visakhapatnam | T.wet | Local (L) | Jersey(J) | 1/4J 3/4L | 1216 (135) | | | Katpatal, 1977 |
| 161 | Asia | India | Visakhapatnam | T.wet | Local (L) | Jersey(J) | 1/2J 1/2L | 1774 (12.9) | | | Katpatal, 1977 |
| 162 | Asia | India | Visakhapatnam | T.wet | Local (L) | Jersey(J) | 3/4J 1/4L | 1999 (55.5) | | | Katpatal, 1977 |
| 163 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | | Sahiwal | 1474 (1) | | | McDowell et al., 1996 |
| 164 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/4H 3/4S | 1651 (20.4) | | | McDowell et al., 1996 |
| 165 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/2H 1/2S | 2787 (2.9) | | | McDowell et al., 1996 |

## Table 1: Continued

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 166 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 3/4H 1/4S | 2239 (13) | | | McDowell et al., 1996 |
| 167 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | F2 | 1820 (5.8) | | | McDowell et al., 1996 |
| 168 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | | Sn | 570 (25) | | 224 (20) | Buvanendran and Mahadevan 1975 |
| 169 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Hosltein Friesian(HF) | 1/2F 1/2S | 1573 (29) | | 327 (6) | Buvanendran and Mahadevan 1975 |
| 170 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Hosltein Friesian(HF) | F2 | 987 (56) | | 302 (14) | Buvanendran and Mahadevan 1975 |
| 171 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Jersey(J) | 1/2J 1/2S | 1215 (21) | | 313 (4) | Buvanendran and Mahadevan 1975 |
| 172 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Jersey(J) | F2 | 809 (58) | | 272 (12) | Buvanendran and Mahadevan 1975 |
| 173 | Asia | Sri Lanka | Undugoda | T.wet | Sindhi (Si) | Jersey(J) | 1/2J 1/2Si | 1929 | | 295 | Buvanendran and Mahadevan 1975 |
| 174 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | F2 | 1115 (22.7) | | 265 (5.4) | Buvanendran and Mahadevan 1975 |
| 175 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | 5/8J 3/8Si | 884 | | 265 | Buvanendran and Mahadevan 1975 |
| 176 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | 3/4J 1/4Si | 1700 | | 317 | Buvanendran and Mahadevan 1975 |
| 177 | S.America | Costa Rica | Turrialba | T.wet/dry | Criollo(cr) | | Criollo | 1202 | | 207 | Alba & Kennedy, 1985 |
| 178 | S.America | Costa Rica | Turrialba | T.wet/dry | Criollo | Jersey(J) | 1/4J 3/4Cr | 1356 | | 222 | Alba & Kennedy, 1985 |
| 179 | S.America | Costa Rica | Turrialba | T.wet/dry | Criollo | Jersey(J) | 1/2J 1/2Cr | 1859 | | 286 | Alba & Kennedy, 1985 |
| 180 | S.America | Costa Rica | Turrialba | T.wet/dry | Criollo | Jersey(J) | 3/4J 1/4Cr | 1765 | | 270 | Alba & Kennedy, 1985 |
| 181 | S.America | Costa Rica | Turrialba | T.wet/dry | | Jersey(J) | | 1883 | | 301 | Alba & Kennedy, 1985 |
| 182 | S.America | Brazil | Valenca | T.Wet | | Hosltein Friesian(HF) | Holestein | | | | (source) Madalena , 1981 |
| 183 | S.America | Brazil | Valenca | T.Wet | Gir (Gi) | Hosltein Friesian(HF) | 1/2 HF 1/2Gi | | | | (source) Madalena , 1981 |
| 184 | S.America | Brazil | Valenca | T.wet | Gir (Gi) | | 3/4HF 1/4Gi | | | | (source) Madalena , 1981 |
| 185 | S.America | Brazil | Various | | Guzera(Gu) | | Guzera | | 1582 (47) | | Madalena , 1981 |
| 186 | S.America | Brazil | Various | | Guzera(Gu) | Hosltein Friesian(HF) | 1/4HF 3/4Gu | | 1992 (44.3) | | Madalena , 1981 |
| 187 | S.America | Brazil | Various | | Guzera(Gu) | Hosltein Friesian(HF) | 1/2H 1/2Gu | | 2527 (37) | | Madalena , 1981 |

## Table 1: Continued

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | Milk Yield | An. Milk pd | Lact L. | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 188 | S.America | Brazil | Various | | Guzera(Gu) | Hosltein Friesian(HF) | 3/4HF 1/4Gu | | 2435 (21.6) | | Madalena , 1981 |
| 189 | S.America | Brazil | Various | | Guzera(Gu) | Hosltein Friesian(HF) | 7/8HF 1/8Gu | | 2336 (74.4)) | | Madalena , 1981 |
| 190 | S.America | Brazil | Various | | | Hosltein Friesian(HF) | HF | | 2332 (137) | | Madalena , 1981 |
| 191 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/4HF H.Mgt | 1368 (129)** | | 197 (11) | Madalena et al. 1990 |
| 192 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/4HF L.Mgt | 1176 (108)** | | 255 (15) | Madalena et al. 1990 |
| 193 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/2HF H.Mgt | 2674 (144)** | | 281(13) | Madalena et al. 1990 |
| 194 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/2HF L.Mgt | 2569 (93)** | | 354 (13) | Madalena et al. 1990 |
| 195 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 5/8HF H.Mgt | 1520 (160) | | 209 (14) | Madalena et al. 1990 |
| 196 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 5/8HF L.Mgt | 1409 (120) | | 276 (17) | Madalena et al. 1990 |
| 197 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 3/4HF H.Mgt | 2975 (156) | | 309 (13) | Madalena et al. 1990 |
| 198 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 3/4HF L.Mgt | 2147 (107) | | 343 (15) | Madalena et al. 1990 |
| 199 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 7/8 HF H.Mgt | 2857 (133) | | 284 (11) | Madalena et al. 1990 |
| 200 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 7/8 HF L.Mgt | 1714 (118) | | 302 (17) | Madalena et al. 1990 |
| 201 | S.America | Brazil | Various | T.wet | | Hosltein Friesian(HF) | HF H.Mgt | 3275 (156) | | 308 (14) | Madalena et al. 1990 |
| 202 | S.America | Brazil | Various | T.wet | | Hosltein Friesian(HF) | HF L.Mgt | 1304 (121.2) | | 263 (11) | Madalena et al. 1990 |

**Supplementary table 2**: A summary of the data assembled: Performance traits

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Africa | Cameroon | Wakwa station | T. Wet | | Hosltein Friesian(HF) | HF | 439(39.6) | 130(1.3) | | | Tawah et al., 1999 |
| 2 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Hosltein Friesian(HF) | 1/2HF 1/2G | 384 (20.5) | 134(1.1) | 39 (1.43) | | Tawah et al., 1999 |
| 3 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Hosltein Friesian(HF) | 3/4HF 1/4G | 400(42.2) | 164(1.3) | | | Tawah et al., 1999 |
| 4 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | 1/2 M 1/2 G | 387(24.8) | 176(1.2) | 39.9 (2.16) | | Tawah et al., 1999 |
| 5 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | 3/4 M 1/4G | 367(46.9) | 108(1.4) | | | Tawah et al., 1999 |
| 6 | Africa | Cameroon | Wakwa station | T. Wet | Gudali (G) | Montebeliard(M) | F2 | 373(25.8) | 196(1.1) | 45.5 (1.42) | | Tawah et al., 1999 |
| 7 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | | Boran | 473 (7) | | 42.5 (0.5) | 1.71 (0.04) | Demeke et al., 2004a /2004b |
| 8 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/2HF 1/2Br | 417 (6) | | 36.0 (0.4) | 1.49 (0.04) | Demeke et al., 2004a /2004b |
| 9 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | F2 | 435 (10) | | 39.6 (0.6) | 1.60 (0.06) | Demeke et al., 2004a /2004b |
| 10 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 5/8HF 3/8Br | 426 (18) | | 38.5 (1) | 1.41 (0.11) | Demeke et al., 2004a /2004b |
| 11 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Hosltein Friesian(HF) | 3/4HF 1/4Br | 444 (13) | | 36.7 (0.7) | 1.70 (0.09) | Demeke et al., 2004a /2004b |
| 12 | Africa | Ethiopia | Holeta station | Highland | | Hosltein Friesian(HF) | HF | 459 (4) | | 37.3 (0.3) | 1.73 (0.03) | Demeke et al., 2004a /2004b |
| 13 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | 1/2J 1/2Br | 408 (6) | | 35.4 (0.5) | 1.31 (0.04) | Demeke et al., 2004a /2004b |
| 14 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | F2 | 430 (10) | | 39.2 (0.6) | 1.44 (0.06) | Demeke et al., 2004a /2004b |
| 15 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | Jersey(J) | 3/4J 1/4Br | 426 (11) | | 37.7 (0.7) | 1.46 (0.08) | Demeke et al., 2004a /2004b |
| 16 | Africa | Ethiopia | Holeta station | Highland | Boran (Br) | HF / J | 1/4F:1/4J:1/2Br | 411 (14) | | 40.2 (0.8) | 1.42 (0.09) | Demeke et al., 2004a /2004b |
| 17 | Africa | Ethiopia* | Arsi region | Highland | Arsi (Ar) | | Ar | 439 (202)* | 165(152)* | 34.4(62)* | | Kiwuwa et al., 1983 |
| 18 | Africa | Ethiopia | Arsi region | Highland | Zebu (Z) | | Z | 451 (94)* | 154(92)* | | | Kiwuwa et al., 1983 |
| 19 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Jersey(J) | 1/2J 1/2 Ar | 403 (92)* | 76(91)* | 33.7(39)* | | Kiwuwa et al., 1983 |
| 20 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Hosltein Friesian(HF) | 1/2F 1/2Ar | 427 (306)* | 81(305)* | 33.9 (154)* | | Kiwuwa et al., 1983 |
| 21 | Africa | Ethiopia | Arsi region | Highland | Zebu (Z) | Hosltein Friesian(HF) | 1/2F 1/2Z | 458(194)* | 83(185)* | 34.8 (60)* | | Kiwuwa et al., 1983 |
| 22 | Africa | Ethiopia | Arsi region | Highland | Arsi (Ar) | Hosltein Friesian(HF) | 3/4F 1/4Ar | 464 (64) | 70(64)* | 33.7(66)* | | Kiwuwa et al., 1983 |
| 23 | Africa | Ethiopia* | Arsi region | Highland | Zebu (Z) | Hosltein Friesian(HF) | 3/4F 1/4Z | 475 (44)* | 90 (41)* | 33.6(37)* | | Kiwuwa et al., 1983 |

**Abbreviations**

**( )** = Standard error , **( )*** = number of records observed in the study, **Climatic Z**= Climatic Zone, **CI** = calving Interval, **DP**= Dry period , **AgeFC**= age at first calving, **SPC**= services per conception, **Genetic grp**= genetic group **1/4HF H.Mgt** = 25% Exotic Inheritance on High management production system **1/4HF L.Mgt =** 25% Exotic Inheritance on a low management system **Highland =** Highlands climatic zone, **T. Wet** = Tropical Wet climatic zone, **T.wet /dry** = Tropical wet and dry
**Holstein Friesian(A)*=** Study in which Ayrshire bulls used initially used but later replaced by Holstein Friesian bulls

**Table 2: Continued**

| No. | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca (B) | | Barca | 401 (24) | | | | Tadesse and Dessie, 2003 |
| 25 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 1/2F 1/2B | 400 (14) | | | | Tadesse and Dessie, 2003 |
| 26 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/2Br 1/2F | 426 (19) | | | | Tadesse and Dessie, 2003 |
| 27 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 1/4B 3/4F | 448 (16) | | | | Tadesse and Dessie, 2003 |
| 28 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/4Br 3/4 F | 436 (15) | | | | Tadesse and Dessie, 2003 |
| 29 | Africa | Ethiopia | Debre Zeit Centre | Highland | Barca | Hosltein Friesian(HF) | 7/8 F 1/8 B | 498 (30) | | | | Tadesse and Dessie, 2003 |
| 30 | Africa | Ethiopia | Debre Zeit Centre | Highland | Boran (Br) | Hosltein Friesian(HF) | 7/8Br 1/8 F | 464 (24) | | | | Tadesse and Dessie, 2003 |
| 31 | Africa | Ethiopia | Debre Zeit Centre | Highland | | Hosltein Friesian(HF) | HF | 458 (16) | | | | Tadesse and Dessie, 2003 |
| 32 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 75%S 25%A | 416(12) | | 1042 (15) | | Thorpe et al., 1994 |
| 33 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 449 (13) | | 979 (19) | | Thorpe et al., 1994 |
| 34 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/2F 1/2S | 441 (17) | | 967 (24) | | Thorpe et al., 1994 |
| 35 | Africa | Kenya | Mariakani Centre | S. Arid | Sahiwal(S) | Ayrshire(A) | 75%A 25%S | 483 (12) | | 1005 (18) | | Thorpe et al., 1994 |
| 36 | Africa | Kenya | Kilifi Plantations | S. Arid | Sahiwal(S) | Ayrshire(A) | 2/3S 1/3A | 390 (3.6) | | 1042 (8.) | | Thorpe et al., 1994 |
| 37 | Africa | Kenya | Kilifi Plantations | S. Arid | Sahiwal(S) | Ayrshire(A) | 2/3A 1/3S | 398 (4.6) | | 1019 (6.5) | | Thorpe et al., 1994 |
| 38 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 3/4A 1/4S | 453(12.3) | | 1071(10.4) | | Trial and Gregory, 1981 |
| 39 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | 445 (14.6) | | 1062 (15) | | Trial and Gregory, 1981 |
| 40 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 1/2S 1/2A | 386 (15.5) | | 1105(18.9) | | Trial and Gregory, 1981 |
| 41 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | Ayrshire(A) | 3/4 S 1/4 A | 396 (12.6) | | 1066(12.3) | | Trial and Gregory, 1981 |
| 42 | Africa | Kenya | Nanyuki | Highland | Sahiwal(S) | | Sahiwal | 450 (14.3) | | 1116(15.2) | | Trial and Gregory, 1981 |
| 43 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | | | | | 36,2 (1.4) | | Kimenye ,1978 |
| 44 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | Ayrshire(A) | 1/2S1/2A | | | 30,9 (1.8) | | Kimenye ,1978 |
| 45 | Africa | Kenya | Machakos | S.Arid | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | | | 27,7 (2.6) | | Kimenye ,1978 |
| 46 | Africa | Kenya | Machakos | S.Arid | | Ayrshire(A) | Aryshire | | | 33,6 (1.3) | | Kimenye ,1978 |

## Table 2: Continued

| No | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | | | | | 38,3 (1.1) | | Kimenye ,1978 |
| 48 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 3/4S 1/4A | | | 32,8 (1.5) | | Kimenye ,1978 |
| 49 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 1/2S 1/2A | | | 32,6 (0.9) | | Kimenye ,1978 |
| 50 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 1/2A 1/2S | | | 28,6 (0.8) | | Kimenye ,1978 |
| 51 | Africa | Kenya | Ngong | Highland | Sahiwal(S) | Ayrshire(A) | 3/4A 1/4S | | | 35,6 (1.3) | | Kimenye ,1978 |
| 52 | Africa | Kenya | Ngong | Highland | | Ayrshire(A) | Aryshire | | | 31,9 (0,8) | | Kimenye ,1978 |
| 53 | Africa | Nigeria* | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2FU | 383 (234) | | 33.2 (73) | | Buvanedran et al., 1981 |
| 54 | Africa | Nigeria | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 3/4HF 1/4 Fu | 390 (108) | | 32.5 (52) | | Buvanedran et al., 1981 |
| 55 | Africa | Nigeria* | Shika | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 7/8 HF 1/8 FU | 393 (22) | | 31.2 (13) | | Buvanedran et al., 1981 |
| 56 | Africa | Nigeria* | Vom | T.wet/dry | White Fulani(WF) | | W. Fulani | 367(64)* | | 45.4 (64)* | | Shoael, 1984 |
| 57 | Africa | Nigeria | Vom | T.wet/dry | White Fulani(WF) | Hosltein Friesian(HF) | 1/2HF 1/2WF | 358 (71)* | | 30.9 (71)* | | Shoael, 1984 |
| 58 | Africa | Nigeria | Vom | T.wet/dry | | Hosltein Friesian(HF) | HF | 368 (44)* | | 28.7(44) | | Shoael, 1984 |
| 59 | Africa | Nigeria* | Vom | T.wet/dry | | Hosltein Friesian(HF) | HF | 387(50)* | | 29.6 (50)* | | Shoael, 1984 |
| 60 | Asia | Bangladesh | Comilla | T.wet | Local (L) | | | 15,4 (0.75) | | 37,6 (1.3) | 1,32 (0.13) | Miazi et al., 2007 |
| 61 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Sahiwal(S) | 1/2S 1/2L | 15,3 (3) | | 28 (0) | 1,5 (0.5) | Miazi et al., 2007 |
| 62 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Hosltein Friesian(HF) | HF | 14,2 (0.49) | | 32,6 (2.32) | 1,6 (0.24) | Miazi et al., 2007 |
| 63 | Asia | Bangladesh | Comilla | T.wet | Local (L) | Jersey(J) | J | 14,08 (0.62) | | 31,08 (1.75) | 1,25 (0.13) | Miazi et al., 2007 |
| 64 | Asia | Bangladesh | Khulna | T.wet | Local (L) | | L | | | | 1,6 (0.18) | Ashraf et al., 2000 |
| 65 | Asia | Bangladesh | Khulna | T.wet | Local (L) | Hosltein Friesian(HF) | 1/2F 1/2L | | | | 1,1(0.17) | Ashraf et al., 2000 |
| 66 | Asia | Bangladesh | Khulna | T.wet | Local (L) | Sahiwal | 1/2S 1/2L | | | | 1,08 (0.18) | Ashraf et al., 2000 |
| 67 | Asia | Bangladesh | Barisal/Patuakahli | T.wet | Local | | Local | 415. (5) | | 1465 (59) | 1.8 (0.14) | Al-Amin and Nahar,2007 |
| 68 | Asia | Bangladesh | Barisal/Patuakahli | T.wet | Local | Hosltein Friesian(HF) | 1/2HF 1/2L | 452(6.6) | | 1029(49) | 1.5 (0.1) | Al-Amin and Nahar,2007 |
| 69 | Asia | Bangladesh | Dhaka | T.wet | Local | | L | 447.9 (14.5) | | | | Rahman et al. 2007 |
| 70 | Asia | Bangladesh | Dhaka | T.wet | Local | Hosltein Friesian(HF) | 1/2F 1/2L | 468.7 (7.3) | | | | Rahman et al. 2007 |

**Table 2: Continued**

| No | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | Asia | Bangladesh | Dhaka | T.wet | Local | Jersey(J) | 1/2J | 451.4 (9.5) | | | | Rahman et al. 2007 |
| 72 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 3/4 HF | 389 (16) | | 35.2 (0.6) | | Amble and Jain ,1967 |
| 73 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 7/8 HF | 425 (21) | | 36.4 (0.7) | | Amble and Jain ,1967 |
| 74 | Asia | India | Dalhousie | Highland | | Hosltein Friesian(A)* | 15/16HF | 382 (31) | | 36 (1.1) | | Amble and Jain ,1967 |
| 75 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 1/2 HF | 492 (45) | | 37 (6) | | Amble and Jain ,1967 |
| 76 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 3/4HF | 461 (24) | | 36.8 (1) | | Amble and Jain ,1967 |
| 77 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 7/8HF | 434 (24) | | 36.6 (0.9) | | Amble and Jain ,1967 |
| 78 | Asia | India | Kasauli | Highland | | Hosltein Friesian(A)* | 15/16HF | 387 (32) | | 36.6 (1.2) | | Amble and Jain ,1967 |
| 79 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 1/4HF | 466 (60) | | 35.0 (1.5) | | Amble and Jain ,1967 |
| 80 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 3/8HF | 442 (26) | | 35.7 (0.8) | | Amble and Jain ,1967 |
| 81 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 1/2HF | 442 (46) | | 32.7 (1.5) | | Amble and Jain ,1967 |
| 82 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 5/8HF | 377 (54) | | 35.3 (1.7) | | Amble and Jain ,1967 |
| 83 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 3/4HF | 458 (27) | | 35.4 (0.8) | | Amble and Jain ,1967 |
| 84 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 7/8HF | 478 (35) | | 34.8 (1.0) | | Amble and Jain ,1967 |
| 85 | Asia | India | Jullundur | S. Arid | | Hosltein Friesian(A)* | 15/16HF | 466 (35) | | 36.1 (1.0) | | Amble and Jain ,1967 |
| 86 | Asia | India | Ambala | T. Wet | Sahiwal(S) | | S | 392 (17) | | 37.4 (0.6) | | Amble and Jain ,1967 |
| 87 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/8HF | 369 (35) | | 37 (1.4) | | Amble and Jain ,1967 |
| 88 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 1/2HF | 407 (24) | | 37.4 (1.) | | Amble and Jain ,1967 |
| 89 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 5/8HF | 414 (37) | | 35.9 (1.4) | | Amble and Jain ,1967 |
| 90 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/4HF | 442 (14) | | 36.3 (0.6) | | Amble and Jain ,1967 |
| 91 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 7/8HF | 472 (16) | | 36.8(0.6) | | Amble and Jain ,1967 |
| 92 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 15/16HF | 438 (29) | | 37.9 (1) | | Amble and Jain ,1967 |
| 93 | Asia | India | Ambala | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 31/32HF | 463 (48) | | 36.8 (1.5) | | Amble and Jain ,1967 |
| 94 | Asia | India | Meerut | T. Wet | Sahiwal(S) | | Sahiwal | 450 (19) | | 39.2 (0.8) | | Amble and Jain ,1967 |

## Table 2: Continued

| No | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/8HF | 484 (52) | | 44.6 (2.2) | | Amble and Jain ,1967 |
| 96 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 1/2HF | 423 (57) | | 40 (2.2) | | Amble and Jain ,1967 |
| 97 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 3/4HF | 569 (40) | | 38.5 (1.4) | | Amble and Jain ,1967 |
| 98 | Asia | India | Meerut | T. Wet | Sahiwal(S) | Hosltein Friesian(A)* | 7/8HF | 439 (46) | | 34.8 (1.8) | | Amble and Jain ,1967 |
| 99 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 1/2HF | 399 (31) | | 38.3 (1.6) | | Amble and Jain ,1967 |
| 100 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 5/8HF | 490 (20) | | 36.1 (1.1) | | Amble and Jain ,1967 |
| 101 | Asia | India | Lucknow | T. Wet | | Hosltein Friesian(A)* | 3/4HF | 500 (28) | | 38.2 (1.5) | | Amble and Jain ,1967 |
| 102 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 1/4HF | 380 (41) | | 38.4 (1.6) | | Amble and Jain ,1967 |
| 103 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 3/8HF | 426 (23) | | 38 (0.9) | | Amble and Jain ,1967 |
| 104 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 1/2HF | 431 (22) | | 37 (1.1) | | Amble and Jain ,1967 |
| 105 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 5/8HF | 410 (36) | | 39.1 (1.5) | | Amble and Jain ,1967 |
| 106 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 3/4HF | 463 (17) | | 37.3 (0.7) | | Amble and Jain ,1967 |
| 107 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 7/8HF | 444 (21) | | 39.1 (0.9) | | Amble and Jain ,1967 |
| 108 | Asia | India | Jubbulpore | T. Wet | | Hosltein Friesian(A)* | 15/16HF | 446 (27) | | 36.7 (1.1) | | Amble and Jain ,1967 |
| 109 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 1/4HF | 406 (57) | | 39.2 (2.0) | | Amble and Jain ,1967 |
| 110 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 3/8HF | 503 (36) | | 37.2 (1.2) | | Amble and Jain ,1967 |
| 111 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 1/2HF | 449 (37) | | 32.9 (1.4) | | Amble and Jain ,1967 |
| 112 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 5/8HF | 472 (44) | | 32.9 (1.6) | | Amble and Jain ,1967 |
| 113 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 3/4HF | 516 (20) | | 34.2 (0.7) | | Amble and Jain ,1967 |
| 114 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 7/8HF | 490 (25) | | 34.2 (0.8) | | Amble and Jain ,1967 |
| 115 | Asia | India | Kirkee | T.wet/dry | | Hosltein Friesian(A)* | 15/16HF | 532 (50) | | 38.7 (1.5) | | Amble and Jain ,1967 |
| 116 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 1/2HF | 411 (29) | | 34.2 (1.2) | | Amble and Jain ,1967 |
| 117 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 3/4HF | 415 (25) | | 34.6(1) | | Amble and Jain ,1967 |
| 118 | Asia | India | Secunderabad | T.wet/dry | | Hosltein Friesian(A)* | 7/8HF | 510 (38) | | 35.1 (1.3) | | Amble and Jain ,1967 |

**Table 2: Continued**

| No | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 119 | Asia | India | Karnal | S. Arid | Sahiwal(S) | | Sahiwal | 458 (1.2) | | 1211 (2.5) | | Taneja and Chawla, 1978 |
| 120 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 1/4BS 3/4S | 409 (45.4) | | 930 (30) | | Taneja and Chawla, 1978 |
| 121 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 1/2BS 1/2S | 408 (4.24) | | 908 (7.2) | | Taneja and Chawla, 1978 |
| 122 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | F2 | 413 (12.2) | | 1020 (20.4) | | Taneja and Chawla, 1978 |
| 123 | Asia | India | Karnal | S. Arid | Sahiwal(S) | Brown Swiss(BS) | 3/4 BS 1/4S | 404 (12.8) | | 930 (20.1) | | Taneja and Chawla, 1978 |
| 124 | Asia | India | Karnal | S. Arid | | Brown Swiss(BS) | BS | 461 (81) | | 1077 (13) | | Taneja and Chawla, 1978 |
| 125 | Asia | India | Haringhata | T. Wet | Deshi (D) | | D | 535 (30) | | 47.9(1.9) | | Bala and Nagarcenkar, 1981 |
| 126 | Asia | India | Haringhata | T. Wet | Hariana(H) | | H | 570 (12) | | 51.6 (0.7) | | Bala and Nagarcenkar, 1981 |
| 127 | Asia | India | Haringhata | T. Wet | Deshi (D) | (HF) | 1/2F 1/2D | 431 (25) | | 36.8(1.3) | | Bala and Nagarcenkar, 1981 |
| 128 | Asia | India | Haringhata | T. Wet | Deshi (D) | Jersey(J) | 1/2J 1/2 D | 433 (18) | | 35.6 (1.1) | | Bala and Nagarcenkar, 1981 |
| 129 | Asia | India | Haringhata | T. Wet | Hariana(H) | Friesian | 1/2F 1/2H | 465 (10) | | 34 (0.6) | | Bala and Nagarcenkar, 1981 |
| 130 | Asia | India | Haringhata | T. Wet | Hariana(H) | B. Swiss(BS) | 1/2BS 1/2H | 449 (16) | | 36(0.9) | | Bala and Nagarcenkar, 1981 |
| 131 | Asia | India | Haringhata | T. Wet | Hariana(H) | Jersey(J) | 1/2J 1/2H | 443 (8) | | 32.7 (0.5) | | Bala and Nagarcenkar, 1981 |
| 132 | Asia | India | Haringhata | T. Wet | Hariana(H) | Friesian | F/ H - F2 | 592 (33) | | 42.2 (1.4) | | Bala and Nagarcenkar, 1981 |
| 133 | Asia | India | Haringhata | T. Wet | Hariana(H) | Jersey(J) | J/H - F2 | 491 (23) | | 41.7 (1.1) | | Bala and Nagarcenkar, 1981 |
| 134 | Asia | India | Haringhata | T. Wet | | Friesian | Friesian | 480 (36) | | 30.2 (1.8) | | Bala and Nagarcenkar, 1981 |
| 135 | Asia | India | Haringhata | T. Wet | | Jersey(J) | Jersey | 349 (16) | | 24.5 (1.) | | Bala and Nagarcenkar, 1981 |
| 136 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | | Sahiwal | 466 (0.3) | 288 (0.19) | 43,9 (0.03) | 1.7 | McDowell et al., 1996 |
| 137 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/4H 3/4S | 456 (5.6) | 241 (2.9) | 34,7 (0.4) | 4,5 (0.05) | McDowell et al., 1996 |
| 138 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 1/2H 1/2S | 427 (0.44) | 199 (0.2) | 32,3 (0.3) | 2,6 (0) | McDowell et al., 1996 |
| 139 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | 3/4H 1/4S | 461(2.6) | 185 (1.07) | 30,5 (0.17) | 3,4 (0.1) | McDowell et al., 1996 |
| 140 | Asia | Pakistan | Bahadurnagar | S.Arid | Sahiwal(S) | Hosltein Friesian(HF) | F2 | 473 (1.5) | 222 (0.7) | 34,8 (0.1) | 1,9 (0.006) | McDowell et al., 1996 |
| 141 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | | Sn | 391 (5) | | 44.8 (0.5) | | Buvanendran and Mahadevan 1975 |
| 142 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Hosltein Friesian(HF) | 1/2F 1/2S | 393 (7) | | 36.9 (0.6) | | Buvanendran and Mahadevan 1975 |

**Table 2: Continued**

| No | Continent | Country | Location | Climatic Z | Local breed | Exotic breed | Genetic grp | CI | DP | Age FC | Spc | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 143 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Hosltein Friesian(HF) | F2 | 448 (24) | | 38.5 (1.6) | | Buvanendran and Mahadevan 1975 |
| 144 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Jersey(J) | 1/2J 1/2S | 370 (5) | | 38.5 (1.6) | | Buvanendran and Mahadevan 1975 |
| 145 | Asia | Sri Lanka | Karagoda -Uyan. | T. Wet | Sinhala (Sn) | Jersey(J) | F2 | 412 (16) | | 38.3 (1.5) | | Buvanendran and Mahadevan 1975 |
| 146 | Asia | Sri Lanka | Undugoda | T.wet | Sindhi (Si) | Jersey(J) | 1/2J 1/2Si | 368 | | 33.7 | | Buvanendran and Mahadevan 1975 |
| 147 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | F2 | 430 (8.7) | | 33.0 (0.6) | | Buvanendran and Mahadevan 1975 |
| 148 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | 5/8J 3/8Si | 373 | | 36.3 | | Buvanendran and Mahadevan 1975 |
| 149 | Asia | Sri Lanka | Undugoda | T. Wet | Sindhi (Si) | Jersey(J) | 3/4J 1/4Si | 434 | | 39.6 | | Buvanendran and Mahadevan 1975 |
| 150 | S.America | Brazil | Valenca | T.Wet | | Hosltein Friesian(HF) | Holestein | 515 (22) | | 1368 (38) | | (source) Madalena , 1981 |
| 151 | S.America | Brazil | Valenca | T.Wet | Gir (Gi) | Hosltein Friesian(HF) | 1/2 HF 1/2Gi | 478 (143) | | 1202 (33) | | (source) Madalena , 1981 |
| 152 | S.America | Brazil | Valenca | T.wet | Gir (Gi) | | 3/4HF 1/4Gi | 519 (24) | | 1303 (36) | | (source) Madalena , 1981 |
| 153 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/4HF H.Mgt | 388 (12) | | | | Madalena et al. 1990 |
| 154 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/4HF L.Mgt | 489 (20) | | | | Madalena et al. 1990 |
| 155 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/2HF H.Mgt | 401 (12) | | | | Madalena et al. 1990 |
| 156 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 1/2HF L.Mgt | 473 (16) | | | | Madalena et al. 1990 |
| 157 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 5/8HF H.Mgt | 363 (15) | | | | Madalena et al. 1990 |
| 158 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 5/8HF L.Mgt | 565 (24) | | | | Madalena et al. 1990 |
| 159 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 3/4HF H.Mgt | 396 (14) | | | | Madalena et al. 1990 |
| 160 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 3/4HF L.Mgt | 525 (20) | | | | Madalena et al. 1990 |
| 161 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 7/8 HF H.Mgt | 402 (12) | | | | Madalena et al. 1990 |
| 162 | S.America | Brazil | Various | T.wet | Guzera | Hosltein Friesian(HF) | 7/8 HF L.Mgt | 546 (23) | | | | Madalena et al. 1990 |
| 163 | S.America | Brazil | Various | T.wet | | Hosltein Friesian(HF) | HF H.Mgt | 422 (13) | | | | Madalena et al. 1990 |
| 164 | S.America | Brazil | Various | T.wet | | Hosltein Friesian(HF) | HF L.Mgt | 559 (25) | | | | Madalena et al. 1990 |

**Supplementary Table 3:** A summary of data assembled for the review . Life time milk yields (LTMY) and lactations completed

| | Continent | Country | Locatation | Climatic Z | Local breed | Exotic Breed | Genetic grp | LTMY | Lactations | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Asia | India | | | Sahiwal(S) | | Sahiwal | 7710 | 4.3 | Singh, 2005 |
| 2 | Asia | India | | | Sahiwal(S) | Hosltein Friesian(HF) | 1/2HF 1/2S | 13375 | 5.2 | Singh, 2005 |
| 3 | Asia | India | | | Sahiwal(S) | Hosltein Friesian(HF) | 62,5HF 37.5S | 14390 | 5.3 | Singh, 2005 |
| 4 | Asia | India | | | Sahiwal(S) | Hosltein Friesian(HF) | 3/4HF 1/4S | 12120 | 4.8 | Singh, 2005 |
| 5 | Asia | India | Visakhapatnam | T.wet | Ongole (O) | | O | 4567 | 4.2 | Singh, 2005 |
| 6 | Asia | India | Visakhapatnam | T.wet | Ongole (O) | Jersey(J) | 1/2J 1/2O | 6372 | | Singh, 2005 |
| 7 | Asia | India | Bikaner | Semi Arid | Rathi (R) | | R | 5707 | 4 | Singh, 2005 |
| 8 | Asia | India | Bikaner | Semi Arid | Rathi (R) | Red Dane (RD) | 1/2RD 1/2R | 12108 | 5.04 | Singh, 2005 |
| 9 | Asia | Bangladesh | Dhaka | T.wet | Local(L) | | L | 3934 (402.2) | | Majid et al. 1996 |
| 10 | Asia | Bangladesh | Dhaka | T.wet | Local(L) | Hosltein Friesian(HF) | 1/2F 1/2L | 7147 (2,268.8) | | Majid et al. 1996 |
| 11 | Asia | Bangladesh | Dhaka | T.wet | Local(L) | Jersey(J) | 1/2J 1/2L | 10,355 (2,509.2) | | Majid et al. 1996 |
| 12 | Asia | Bangladesh | Dhaka | T.wet | Local(L) | Hosltein Friesian(HF) | F2 -1/2L 1/2HF | 8969 (897.08) | | Majid et al. 1996 |
| 13 | Asia | Bangladesh | Dhaka | T.wet | Local(L) | Hosltein Friesian(HF) | F2 -1/4L 3/4HF | 11,756 (112) | | Majid et al. 1996 |
| 14 | Asia | Bangladesh | Dhaka | T.wet | Sahiwal(S) | | S | 5,891 (808.06) | | Majid et al. 1996 |
| 15 | Asia | Bangladesh | Dhaka | T.wet | Sahiwal(S) | Hosltein Friesian(HF) | 1/2HF 1/2S | 8789 (2145.9) | | Majid et al. 1996 |
| 16 | Asia | Bangladesh | Dhaka | T.wet | Friesian | | HF | 11,134 (2916) | | Majid et al. 1996 |
| 17 | Africa | Kenya | Kilifi | Semi Arid | Sahiwal(S) | Ayrshire(A) | 2/3A 1/3S r* | 9376 (394) | 3.38 (0.11) | Thorpe et al. 1994 |
| 18 | Africa | Kenya | Kilifi | Semi Arid | Sahiwal(S) | Ayrshire(A) | 2/3S 1/3A r* | 6331 (468) | 2.53 (0.35 | Thorpe et al. 1994 |
| 19 | Africa | Ethiopia | Cheffa | Highland | Boran (Br) | Hosltein Friesian(HF) | 1/2HF 1/2Br | 14,342 (127) | 5.02 (0.04) | Goshu, 2005 |
| 20 | Africa | Ethiopia | Cheffa | Highland | Boran (Br) | Hosltein Friesian(HF) | 3/4HF 1/4Br | 12,074 (90) | 4.05(0.03) | Goshu, 2005 |
| 21 | Africa | Ethiopia | Cheffa | Highland | Boran (Br) | Hosltein Friesian(HF) | 7/8HF 1/8Br | 7891 (117) | 2.64(0.03) | Goshu, 2005 |
| 22 | Africa | Ethiopia | Cheffa | Highland | Boran (Br) | Hosltein Friesian(HF) | 15/16HF | 7343 (206) | 2.42(0.06) | Goshu, 2005 |

**Key:** r* =produced by rotational crossbreeding . Population stablized at 2/3 genes of the sire and 1/3 from breed of maternal grandsire

**Supplementary Table 4:** A summary of relative performance of production traits (of the exotic and crossbred as compared to the indigenous breeds) calculated for the different climatic zones

| No | Local B | Exotic B | Climatic Z | Country | Location | Prod Env | Milk Yield Per Lactation | | | | | | Lactation Length | | | | | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1/4 | 1/2 | 3/4 | 7/8 | 15 / 16 | F2 | 1/4 | 1/2 | 3/4 | 7/8 | 15 / 16 | F2 | |
| 1 | Boran | Holstein Friesian | Highlands | Ethiopia | Holeta station | On Station | | 4.45 | 4.46 | | | 3.64 | | | | | | | Demeke et al., 2004b |
| 2 | Boran | Jersey | Highlands | Ethiopia | Holeta station | On Station | | 3.95 | | | | 3.05 | | | | | | | Demeke et al., 2004b |
| 3 | Arsi | Holstein Friesian | Highlands | Ethiopia | Aresela region | On Station | | 2.44 | 2.93 | | | | | 1.3 | 1.5 | | | | Kiwuwa et al., 1983 |
| 4 | Arsi | Jersey | Highlands | Ethiopia | Aresela region | On Station | | 2.15 | | | | | | 1.22 | | | | | Kiwuwa et al., 1983 |
| 5 | Zebu | Holstein Friesian | Highlands | Ethiopia | Aresela region | On Station | | 2.53 | 2.5 | | | | | 1.25 | 1.25 | | | | Kiwuwa et al., 1983 |
| 6 | Barca | Holstein Friesian | Highlands | Ethiopia | Aresela region | On Station | | 3.53 | 3.44 | 3.26 | | | 1.29 | 1.17 | | 1.25 | | | Tadesse and Dessie, 2003 |
| 7 | Sahiwal | Ayrshire♂ | Highlands | Kenya | Nanyuki** | On farm | | 2.04 | 1.75 | | | | | 1.53 | 1.37 | | | | Trail and Gregory ,1981 |
| 8 | Sahiwal ♂ | Ayrshire | Highlands | Kenya | Nanyuki** | On farm | | 1.65 | 2.02 | | | | | | | | | | Trail and Gregory ,1981 |
| 9 | Sahiwal | Ayrshire♂ | Highlands | Kenya | Ngong | On Station | 1.5 | 1.6 | 2.02 | | | | 1.045 | 1.09 | 1.15 | | | | Kimenye, 1978 |
| 10 | Sahiwal ♂ | Ayrshire | Highlands | Kenya | Ngong | On Station | | 1.4 | | | | | | 1.03 | | | | | Kimenye, 1978 |
| | | | | | | **Mean** | **1.5** | **2.57** | **2.73** | **3.26** | | **3.35** | **1.17** | **1.23** | **1.32** | **1.25** | | | |
| | | | | | | **STDEV** | | **1.028** | **0.963** | | | **0.42** | **0.16** | **0.16** | **0.15** | | | | |
| 11 | White Fulani | Holstein Friesian | T.wet/dry | Nigeria | Vom | On Station | | 2.05 | 1.97 | | | | | | | | | | Knudsen and Sohael, 1970 |
| 12 | White Fulani | Holstein Friesian | T.wet/dry | Nigeria | Vom | On Station | | 2.02 | | | | | | 1.1 | | | | | Shoael, 1984 |
| 13 | White Fulani | Holstein Friesian | T.wet/dry | Nigeria | Vom | On Station | | 5.3 | | | | | | 1.65 | | | | | Olutogun et al., 2006 |
| 14 | Sahiwal | Holstein Friesian | T.wet/dry | India | Ambala | On Station | | 1.2 | 1.31 | 1.11 | 1.06 | | | 0.9 | 0.92 | 0.97 | 0.98 | | Amble and Jain ,1967 |
| 15 | Sahiwal | Holstein Friesian | T.wet/dry | India | Meerut | On Station | | 1.41 | 1.64 | 1.32 | | | | 1.07 | 1.09 | 1.13 | | | Amble and Jain ,1967 |
| 16 | Sahiwal | B.Swiss | T.wet/dry | India | Karnal OS | On Station | 1.78 | 1.85 | 1.56 | | | 1.51 | 1.05 | 1.16 | 1.02 | | | 1.02 | Bala and Nagarcenkar,1981 |
| 17 | Deshi | Holstein Friesian | T.wet/dry | India | Haringhata | On Station | | 3.9 | | | | | | 1.13 | | | | | Bala and Nagarcenkar,1981 |
| 18 | Deshi | Jersey | T.wet/dry | India | Haringhata | On Station | | 3.8 | | | | | | 1.2 | | | | | Bala and Nagarcenkar,1981 |
| 19 | Hariana | Holstein Friesian | T.wet/dry | india | Haringhata | On Station | | 2.43 | | | | 1.63 | | 1.09 | | | | 1.07 | Bala and Nagarcenkar,1981 |
| 20 | Hariana | B.Swiss | T.wet/dry | India | Haringhata | On Station | | 2.17 | | | | | | 1.07 | | | | | Bala and Nagarcenkar,1981 |
| 21 | Deshi | Jersey | T.wet/dry | Srilanka | Karagoda -Uyan. | On Station | | 2.03 | | | | 1.43 | | 1.05 | | | | 1.03 | B. and M .,1975* |
| 22 | Sinhala | Holstein Friesian | T.wet/dry | Srilanka | Karagoda -Uyan. | On Station | | 2.75 | | | | 1.73 | | 1.45 | | | | 1.34 | B. and M .,1975* |

**Key** **Local B** = Local breed in the study **Exotic B**= Exotic breed in the study **Prod Env** = production environment
**Ayrshire♂**= breed of sire in the study is Ayrshire. **Sahiwal♂** = breed of sire in the study is Sahiwal
**Local*** = Actual breed used in the study no given. local breed **B. and M .,1975* =** Buvanendran and Mahadevan ,1975

## Table 4: continued

| No | Local B | Exotic B | Climatic Z | Country | Location | Prod Env | Milk Yield Per Lactation | | | | | | Lactation Length | | | | | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1/4 | 1/2 | 3/4 | 7/8 | 15 / 16 | F2 | 1/4 | 1/2 | 3/4 | 7/8 | 15 / 16 | F2 | |
| 23 | Sindi | Jersey | T.wet/dry | Srilanka | Undugoda | On Station | | 2.12 | 0.97 | | | 1.22 | | 1.19 | 1.07 | | | 1.07 | B. and M .,1975* |
| 24 | Jenubi | Holstein Friesian | T.wet/dry | Srilanka | Undugoda | On Station | | 1.58 | 1.8 | 1.6 | 1.5 | | | | | | | | B. and M .,1975* |
| 25 | Criollo | Jersey | T.wet/dry | Costa Rica | Turrialba | On Station | 1.1 | 1.5 | 1.4 | | | | 1.07 | 1.38 | 1.3 | | | | Alba & Kennedy, 1985 |
| 26 | Local* | Jersey | T.wet/dry | India | Chalakudy | On Station | 2.02 | 2.46 | 2.48 | 3.13 | | 2.79 | | | | | | | Kaptal ,1977 |
| 27 | Local* | Jersey | T.wet/dry | India | Vikas Nagar | On Station | | 2.3 | 2.2 | | | | | | | | | | Kaptal ,1977 |
| 28 | Local* | Jersey | T.wet/dry | India | Visakhapatnam | On Station | 1.73 | 2.53 | 2.86 | | | | | | | | | | Kaptal, 1977 |
| 29 | Local* | Sahiwal | T.wet/dry | Bangladesh | Comilla | on-farm | | 2.16 | | | | | | 0.99 | | | | | Miazi et al., 2007 |
| 30 | Local* | Holstein Friesian | T.wet/dry | Bangladesh | Comilla | On farm | | 2.65 | | | | | | 1.14 | | | | | Miazi et al., 2007 |
| 31 | Local* | Jersey | T.wet/dry | Bangladesh | Comilla | On farm | | 2.5 | | | | | | 1.16 | | | | | Miazi et al., 2007 |
| 32 | Local* | Holstein Friesian | T.wet/dry | Bangladesh | Khulna | On farm | | 1.7 | | | | | | 1.1 | | | | | Ashraf et al., 2000 |
| 33 | Local* | Holstein Friesian | T.wet/dry | Bangladesh | Dhaka | On Station | | 2.9 | | | | 2.9 | | | | | | | Majid et al., 1996 |
| 34 | Local* | Jersey | T.wet/dry | Bangladesh | Dhaka | On Station | | 2.7 | | | | 2.3 | | | | | | | Majid et al., 1996 |
| 35 | Sahiwal | Holstein Friesian | T.wet/dry | Bangladesh | Dhaka | Onstation | | 1.8 | | | | | | | | | | | Majid et al., 1996 |
| 36 | Local* | Jersey | T.wet/dry | Bangladesh | Dhaka | On Station | | 2.1 | | | | | | 1.2 | | | | | Rahman et al. 2007 |
| 37 | Local* | Holstein Friesian | T.wet/dry | Bangladesh | Dhaka | On Station | | 2.5 | | | | | | 1.2 | | | | | Rahman et al. 2007 |
| 38 | Local* | Holstein Friesian | T.wet/dry | Bangladesh | Barisal/Patuakahli | On Station | | 2.17 | | | | | | 1.5 | | | | | Al-Amin and Nahar, 2007 |
| | | | | | | **Mean** | **1.66** | **2.38** | **1.82** | **1.79** | **1.28** | **1.94** | **1.06** | **1.187** | **1.08** | **1.05** | **0.98** | **1.11** | |
| | | | | | | **STDEV** | **0.39** | **0.84** | **0.57** | **0.92** | **0.31** | **0.64** | **0.01** | **0.18** | **0.14** | **0.11** | | **0.13** | |
| 39 | Sahiwal ♂ | Ayrshire | Semiarid | Kenya | Machakos | On Station | | 2.6 | | | | | | 2.05 | | | | | Kimenye, 1978 |
| 40 | Sahiwal | Ayrshire♂ | Semiarid | Kenya | Machakos | On Station | | 2.4 | | | | | | 2.41 | | | | | Kimenye, 1978 |
| 41 | Sahiwal | Friesian | Semiarid | Pakistan | Bahadurnagar | On Station | 1.1 | 1.80 | 1.5 | | | 1.2 | | | | | | | McDowell et al., 1996 |
| 42 | Sahiwal | B.Swiss | T.wet/dry | India | Karnal OS | On Station | 1.78 | 1.85 | 1.56 | | | 1.51 | 1.05 | 1.16 | 1.02 | | | 1.02 | Bala and Nagarcenkar, 1981 |
| | | | | | | **Mean** | **1.44** | **2.16** | **1.53** | | | **1.36** | | **1.873** | | | | | |
| | | | | | | **STDEV** | **0.48** | **0.53** | **0.48** | | | **0.481** | | **0.64** | | | | | |

**Supplementary Table 5:** A summary of relative performance of reproductive traits (of the exotic and crossbred as compared to the indigenous breeds) calculated for the different climatic zones

| No | Local Br | Exotic Br | Climatic Z | Country | Location | Production Env | Calving Interval | | Age at first calving | | | Services /Conception | | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1/2 | F2 | 1/2 | 3/4 | F2 | 1/4 | 1/2 | F2 | |
| 1 | Boran | Friesian | Highlands | Ethiopia | Holeta station | On Station | 0.88 | 0.92 | 0.84 | 0.88 | 0.93 | | 0.87 | 0.94 | Demeke et al., 2004a |
| 2 | Boran | Jersey | Highlands | Ethiopia | Holeta station | On Station | 0.86 | 0.91 | 0.82 | | 0.92 | | 0.77 | 0.84 | Demeke et al., 2004a |
| 3 | Arsi | Friesian | Highlands | Ethiopia | Aresela region | On Station | 0.97 | | 0.98 | 0.90 | | | | | Kiwuwa et al., 1983 |
| 4 | Arsi | Jersey | Highlands | Ethiopia | Aresela region | On Station | 0.90 | | 0.97 | | | | | | Kiwuwa et al., 1983 |
| 5 | Zebu | Friesian | Highlands | Ethiopia | Aresela region | On Station | 1.02 | | | | | | | | Kiwuwa et al ., 1983 |
| 6 | Barca | Friesian | Highlands | Ethiopia | Aresela region | On Station | 0.99 | | | | | | | | Tadesse et al., 2003 |
| 7 | Sahiwal | Ayrshire♂ | Highlands | Kenya | Nanyuki** | On farm | 0.90 | | 0.95 | 0.95 | | | | | Trail and Gregory,1981 |
| 8 | Sahiwal ♂ | Ayrshire | Highlands | Kenya | Nanyuki** | On farm | | | 0.75 | 0.83 | | | | | Trail and Gregory,1981 |
| 9 | Sahiwal | Ayrshire♂ | Highlands | Kenya | Ngong | On Station | | | 0.75 | 0.83 | | | | | Kimenye, 1978 |
| 10 | Sahiwal ♂ | Ayrshire_D | Highlands | Kenya | Ngong | On Station | | | 0.85 | | | | | | Kimenye, 1978 |
| | | | | | | **Mean** | **0.93** | **0.92** | **0.86** | **0.88** | **0.93** | | **0.82** | **0.89** | |
| | | | | | | **STDEV** | **0.06** | **0.01** | **0.09** | **0.05** | **0.01** | | **0.07** | **0.07** | |
| 11 | White Fulani | Friesian | T.wet/dry | Nigeria | Vom | On Station | 0.90 | | 0.68 | | | | | | Soheal, 1984 |
| 12 | Sahiwal | Friesian | T.wet/dry | India | Ambala | On Station | 1.04 | | 1.01 | | | | | | Amble and Jain ,1967 |
| 13 | Sahiwal | Friesian | T.wet/dry | India | Meerut | On Station | 0.94 | | 1.02 | 0.98 | | | | | Amble and Jain ,1967 |
| 14 | Deshi | 1/2 Friesian | T.wet/dry | India | Haringhata | On Station | | | 0.76 | | | | | | Bala and Nagarcenkar, 1981 |
| 15 | Deshi | 1/2 Jesrey | T.wet/dry | India | Haringhata | On Station | 0.80 | | 0.76 | | | | | | Bala and Nagarcenkar, 1981 |
| 16 | Hariana | Friesian | T.wet/dry | india | Haringhata | On Station | 0.82 | | | | | | | | Bala and Nagarcenkar, 1981 |
| 17 | Hariana | B.Swiss | T.wet/dry | India | Haringhata | On Station | 0.78 | | 0.78 | | | | | | Bala and Nagarcenkar, 1981 |
| 18 | Deshi | Jersey | T.wet/dry | Srilanka | Karagoda -Uyan. | On Station | 0.77 | 0.86 | 0.63 | | | | | | Buvanendran and Mahadevan, 1975 |
| 19 | Sinhala | Friesian | T.wet/dry | Srilanka | Karagoda -Uyan. | On Station | 1.00 | 1.14 | 0.82 | | 0.85 | | | | Buvanendran and Mahadevan, 1975 |
| 20 | Sindi | Jersey | T.wet/dry | Srilanka | Undugoda | On Station | 0.86 | 1.08 | | | | | | | Buvanendran and Mahadevan, 1975 |

**Key** **Local B** = Local breed in the study **Exotic B**= Exotic breed in the study **Prod Env** = production environment
**Ayrshire♂**= breed of sire in the study is Ayrshire. **Sahiwal♂** = breed of sire in the study is Sahiwal
**Local*** = Actual breed used in the study no given. local breed

**Table 5: continued**

| No | Local Br | Exotic Br | Climatic Z | Country | Location | Production Env | Calving Interval | | Age at first calving | | | Services /Conception | | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | Jenubi | Friesian | T.wet/dry | Srilanka | Undugoda | On Station | | | 0.81 | 0.76 | | | | | Buvanendran and Mahadevan, 1975 |
| 22 | Local | Sahiwal | T.wet/dry | Bangladesh | Comilla | on-farm | 0.99 | | 0.74 | | | | 1.13 | | Miazi et al., 2007 |
| 23 | Local | Holstein | T.wet/dry | Bangladesh | Comilla | On farm | 0.92 | | 0.86 | | | | 1.21 | | Miazi et al., 2007 |
| 24 | Local | Jersey | T.wet/dry | Bangladesh | Comilla | On farm | 0.91 | | 0.82 | | | | 0.94 | | Miazi et al., 2007 |
| 25 | Local | Friesian | T.wet/dry | Bangladesh | Khulna | On farm | 0.94 | | | | | | | | Ashraf et al., 2000 |
| 26 | Local | Friesian | T.wet/dry | Bangladesh | Dhaka | On Station | | | | | | | | | Majid et al., 1996 |
| 27 | Local | Jersey | T.wet/dry | Bangladesh | Dhaka | On Station | | | | | | | | | Majid et al., 1996 |
| 28 | Sahiwal | Friesian | T.wet/dry | Bangladesh | Dhaka | Onstation | | | | | | | | | Majid et al., 1996 |
| 29 | Local | Jersey | T.wet/dry | Bangladesh | Dhaka | On Station | 1.00 | | | | | | | | Rahman et al., 2007 |
| 30 | Local | Friesian | T.wet/dry | Bangladesh | Dhaka | On Station | 1.04 | | | | | | | | Rahman et al., 2007 |
| 31 | Local | Friesian | T.wet/dry | Bangladesh | Barisal/Patuakahli | On Station | 1.08 | | | | | | 0.83 | | Al-Amin and Nahar, 2007 |
| | | | | | | **Mean** | **0.92** | **1.03** | **0.81** | **0.87** | **0.85** | | **1.03** | | |
| | | | | | | **STDEV** | **0.09** | **0.15** | **0.12** | **0.156** | | | **0.17** | | |
| 32 | Sahiwal ♂ | Ayrshire_D | Semiarid | Kenya | Machkos | On Station | | | 0.85 | | | | | | Kimenye,1978 |
| 33 | Sahiwal | Ayrshire ♂ | Semiarid | Kenya | Machkos | On Station | | | 0.92 | | | | | | Kimenye, 1978 |
| 34 | Sahiwal | Friesian | Semiarid | pakistan | Bahadurnagar | On Station | 0.90 | 1.01 | 0.73 | 0.70 | 0.80 | 2.60 | 1.50 | 1.10 | McDowell et al., 1996 |
| 35 | Sahiwal | B.Swiss | Semiarid | India | Karnal | On Station | 0.89 | 0.90 | 0.77 | 0.75 | 0.84 | | | | Bala and Nagarcenkar, 1981 |
| | | | | | | | **0.90** | **1.01** | **0.83** | **0.70** | **0.80** | **2.60** | **1.50** | | |
| | | | | | | **STDEV** | **0.01** | **0.06** | **0.10** | **0.03** | **0.02** | | | | |

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# Chapter 3

## On-farm Comparison of milk production and growth of purebred Ankole and Crossbred Friesian–Ankole Cattle in South-Western Uganda

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**Abstract**

The study was undertaken to investigate milk yield traits and growth characteristics of pure bred Ankole and crosses of Holstein Friesian (HF) with Ankole on-farm. A total of 18 farms keeping Ankole and Holstein Friesian-Ankole in separate herds on one farm were selected in Kiruhura District of South Western Uganda. On each farm up to 30 animals from each herd covering the complete age and sex range were recruited to the study. The animals were assigned to 3 genetic groups: Ankole, HF50% for the first generation crossbred (F1) animals and HF>50% for animals with exotic inheritance of greater than 50%. During the 29 month study period the selected animals were monitored during which visits a single milk record based morning production, calving and dry off dates were recorded for the milking animals. For all animals in the study live weights estimated by chest circumferences, body condition score and culling dates and reasons were recorded. All animals delivered by the selected cows were also monitored and animals exiting the study due to death or sell were replaced by another similar animal. A total of 1786 animals were recorded in the the study and these generated 18,818 records. Daily milk yields for the three genetic groups were 2.44±0.22, 6.70±0.27 and 7.44±0.08 for the Ankole, HF50% and the HF>50 respectively, while the observed Live weights for cows were 305.4±2.98, 388.6±4.5 and 394.7±1.6 for the Ankole, HF50% and the HF>50 respectively. Body condition score (BCS) for the groups did not differ significantly but varied (P= 0.01) in different months of the year. The HF>50% had lower Age at first calving of 29.1±1.63 months (P<0.0001) as compared to 38.9±1.96 the Ankole. Observed calving intervals for the Ankole and HF>50% were 16.04±0.68 and 15.30±0.47 months respectively.

**Key Words**

Ankole, Holstein Friesian, On-Farm, Crossbreeding, Uganda

## Introduction

The Ankole cattle, a breed known for its large white horns and ability to thrive under stressful climatic and nutritive environment is being kept by pastoralists in the range lands of South Western Uganda on an extensive production system with no supplements, minimal drug inputs and with irregular supply of water (Okello *et al.*, 2005).

According to official estimates (MAAIF, 2009) the cattle breed accounts for 30% of the 11.4 million cattle in Uganda and has been traditionally kept to supply milk to the owners and for sale of animals (Grimaud, 2007). Increasing pressure on land due to the rapidly growing population, growing demand for livestock products in urban centres and new land policies in Uganda are changing the life styles of the hitherto extensive Ankole cattle grazers (Kisamba-Mugerwa, 2001). Large tracts of what used to be communal grazing land have now been individualized and there is a shift from extensive to intensive production systems with farmers practicing crop production along side livestock keeping (Wurzinger *et al.*,2006). To obtain animals with higher milk production, crossbreeding of Ankole with exotic breeds mainly the Holstein Friesian has begun and is taking place at a very fast rate without well established breeding programs (Petersen *et al.*, 2004; Wurzinger *et al.*,2006; Peloschek, 2009). There is however a group of farmers who wish to retain pure Ankole cattle. To facilitate this these farmers have initiated a new production system in which two separate herds, a pure Ankole herd and a herd of Holstein Friesian - Ankole crosses are kept on one farm. The Holstein Friesian-Ankole crosses are kept mainly for commercial milk production, while the Ankole are kept for multiple reasons namely: cultural (this includes dowry payments and prestige), a buffer against shock in case of prolonged drought and disease outbreak and for income through sale of live animals.

Studies from other tropical countries have shown that under good management conditions crossbreds can perform well in the harsh tropical environment (Sottie *et al.*,2009; Demeke *et al*; 2004, Gaur *et al.*, 2005). The rangelands of South Western Uganda where this new production system is developing are typified by bimodal rainfall patterns with a long dry season between June and September (Figure 1) and a shorter one between December and January. Rainfall usually occurs between March and May and also between September to November. This weather pattern creates variations in the availability and quality of pasture and also on the amount of water available to the animals at established water points, with a great effect on livestock productivity (Okello *et al.* 2005, Rugumayo and Mwebaze 2002).

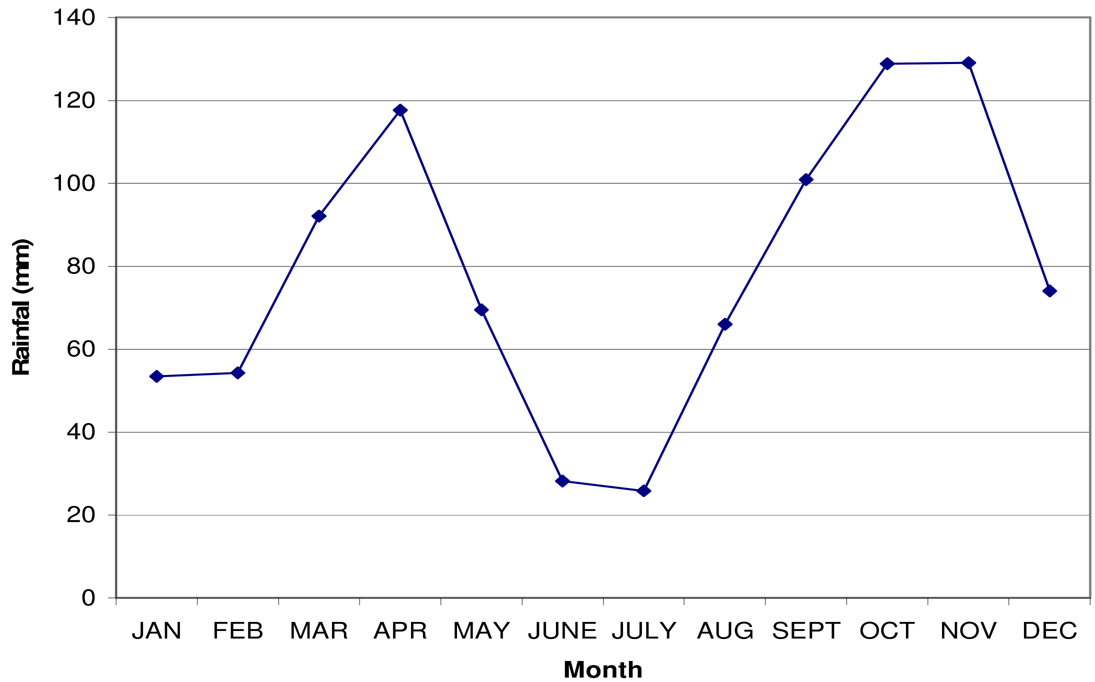


**Figure 1.** Monthly rainfall distribution for 46 year period (1961 -2007) at Mbarara weather station South Western Uganda

Success of the new production system will therefore depend on striking the right balance of all the variables involved; weather conditions, pasture availability, health and productivity of animals of different genotype, herd size, management and socio-economic issues. Such information can not be easily be determined because of absence or incompleteness of on-farm recording systems. Most research work on crossbreeding (e.g. Demeke *et al*., 2004; Kahi *et al*., 2000) has been carried out on research stations , on state owned farms or on well developed commercial entities and as such does not reflect the farming situation of pastoralists. The objective of the study was to determine and compare the performance of different levels of crossbreds of Holstein Friesian with Ankole with that of pure bred Ankole on-farm on natural pasture without feed supplementation so as to generate information on the knowledge gap that exists in this area and to propose appropriate intervention practices.

## Materials and methods

### The study area

The study was conducted in Kiruhura district of South Western Uganda (Figure 2) between April 2007 and September 2009. This district lies within an area referred to as the cattle corridor that stretches from the South Western to the North Eastern parts of Uganda. Livestock farming comprising of cattle, goats and sheep form the most important economic activity. Topography of the area is dominated by undulating hills with an elevation of about 1,100 to 1,525m above sea level (Gregory *et al.*, 1985). Grazing lands in the area are variable. In some parts grazing of cattle takes place among dense Acacia thorny thickets and in others the thickets are more sparsely distributed. Common grass species in the area include *Themeda triandra*, *Bracheria decumbens*, *Digitaria Spps*., *Hyparrhenia fipipendula* and *Chloris gayana* (Gregory *et al.,* 1985; Petersen *et al.,* 2004).

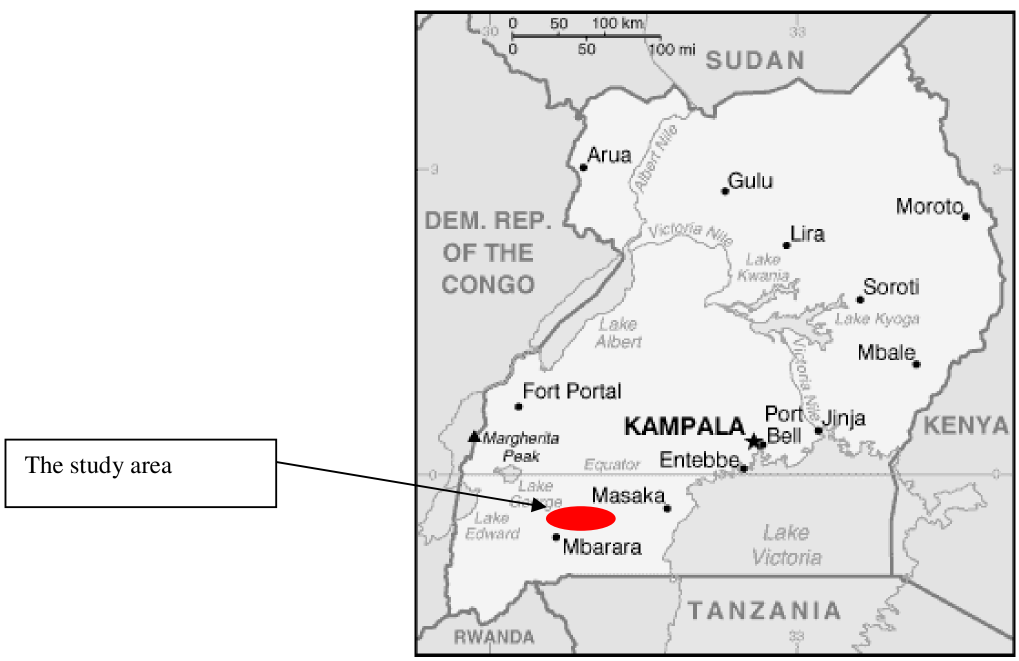


**Figure 2:** The study area

## Selection of the farmers

In the initial phase farmers keeping two or more separate herds comprising of pure Ankole and Holstein Friesian-Ankole crosses on their farms were identified. Farms that were not easily accessible were dropped and 18 farms whose owners were willing to participate in the study were selected randomly from three sub counties of Kikatsi, Rubaya and Kenshunga. A preparatory workshop was held with participating farmers during which aims of the study and methods to be used for data collection were explained. On each of the farms up to 30 animals were selected from each herd covering the complete age and sex range (bulls , cows, heifers and calves) of the herd and were assigned into 3 genotypes namely, Ankole, first generation crossbreds of Holstein Friesian and Ankole (HF50%) and crosses of Holstein Friesian inheritance greater than 50% (HF >50%). Crossbred animals were assigned to their respective genetic groups based on progeny history provided, mainly based on memory, by farmers and on phenotype. Since hardly any form of recording took place on the farms, age of the animals, lactation numbers and stage of lactation at the start of the study were estimated using a number of methods which included information provided by farmers, dentition of the animals and size of the young animals. The selected animals were ear-tagged and monitored by an enumerator at an average interval of four weeks (interval between visits varied in some cases to periods of up to 8 weeks). Selected study animals that were either transferred, sold or that died during the study were replaced by a similar animal from that herd. All calves born to the selected animals were tagged and monitored as well.

## Management on the selected farms

The farms were managed according to the normal practices. No changes were introduced by the research team.

On all the farms natural mating was used and at least one bull was assigned per herd. In the Ankole herd pure Ankole bulls were used, while in the crosses there was continuous upgrading with either pure Holstein Friesian or crossbred bulls (Holstein Friesian X Ankole) of exotic inheritance of 75% or more. Bulls were grazed alongside the cows and were maintained in the herds throughout the year.

On all farms the different genotypes were grazed and kraaled separately to avoid inter-mating. Animals were grazed extensively on natural pastures with no supplementation apart from rock salt (mined from a nearby salt lake) which in most cases was provided *adlib*. Mulindwa *et al.* (2009) provide details of grazing area in hectares which ranged between 100 and 750 hectares while stocking density ranged between 0.36 and 2.03 hectares per tropical livestock unit (TLU) on 16 of the selected farms. All farms had valley tanks (large water ponds) in which water harvested during the rain season was stored. Drinking water from these tanks was provided to the animals by scooping it into a water trough. This was done once a day at around mid day. Herds were driven to the water point at slightly different times.

With a few exceptions of some crossbreds all animals were milked once. At the start of each milking calves suckled their dams for a few minutes to stimulate milk let down. Marketable milk was then withdrawn and some amount was left in the udder for the calf to suckle. After a period of suckling, calves were separated from the dams.

All animals irrespective of genotype were either sprayed once a week with acaricides or dipped in a plunge dip with acaricide solution to control external parasites (mainly ticks). On most farms animals were drenched with antihelminthics for control on internal parasites at least two times a year.

**Data collection**

During each visit milk yield (a record of single morning milk) was recorded for cows in milk. Between March 2007 and December 2008 this was based on farmer's records/statements and from January 2009 to September 2009 it was measured by graduated buckets in the presence of the enumerator. Dry off and calving dates were also recorded. For all animals live weights (estimated by chest circumference) were recorded and body condition score (BCS) based on a score of 1(lean) to 5 (fat) in accordance with Wildman *et al.,* (1982) were assigned to the animals. Additional information collected included the following: Feeding status (whether or not animal is receiving supplementary feed stuff), tick count, If animal had left the herd (when? Why? where to? ) disease outbreak (which? when? and treatments undertaken) Disease control information (dates of spraying/dipping , de-worming dates, vaccinations and costs of the activity) was also recorded.

**Data analysis**

A total of 1786 animals (bulls, cows, heifers and calves) entered the study and they generated 18,818 records. However as discussed in the concluding sections of this paper, most of these records were not included in the final analysis because the data capture and entry process was affected by a number of challenges which affected the quality of collected data. During the editing phase records on calves with missing birth dates, sex and genotype were eliminated. Animals with an age range between 1 day and 548 days were considered in this category. For milk records animals with missing lactation numbers, calving dates and genotype were dropped. In addition animals with stage of lactation of above 300 days were dropped and those above the 6$^{th}$ lactation were also dropped. At the end of the editing 3328 growth records for calves, 1965 milk records and 1971 records on live weights and BCS for animals in milk were retained.

Data were analyzed using the generalized Linear Model (GLM) procedure of SAS 9.2 (2008).

The regression equations developed to estimate weights in kg (Y) from heart girth measurements in cm (X) for both the Ankole and crossbred animals were as follows:

(i) calves (both Ankole and crossbreds combined)

$Y = 130 - 3.28(X) + 0.027 (X^2)$ $R^2 = 0.91$
Number of calves =189

(ii) Cows

Ankole: $Y = -536.2 + 5.2 (X)$ $R^2 = 0.61$
Number of cows = 52

Crossbreds: $Y = -505.1 + 5.1 (X)$ $R^2 = 0.70$
Number of cows = 55

For Body Condition Scores (BCS) and live weights (LW) the following linear model was used:

$Y_{ijkl}$= $\mu + B_i + N_j + P_k + B(S)_{il} + BP_{ik} + b\,(age) + e_{ijkl}$

$Y_{ijkl}$ = BCS/ LW of an individual cow

Where:

$\mu$ = mean
$B_i$ = the effect of the $_i$th genotype of cattle ($_i$ = 1..3)
$N_j$ the effect of the $_j$th year of sampling ($_j$ = 1..3)
$P_k$ = the effect of the $_k$th month of sampling ($_k$ = 1...12)
$S_l$= the effect of the $_l$th farm ($_l$= 1…18)
$B(S)_{il}$ = the effect of genotypes nested in farms
$BP_{ik}$ = the effect of interaction of breed and month of sampling
b = Covariate (age) was used to adjust differences in ages

Estimation of milk yield using milk buckets was only carried in the final year of the study and only a small amount of data was generated by this method. Therefore for analysis of daily milk yield (DMY) data generated by use of milk buckets and that based on farmer's reports were combined and the following linear model below fitted. variation due to method of estimation was controlled by fitting the effect of year of sampling.

$Y_{ijklmn} = \mu + B_i + N_j + P_k + T_m + L_n + B(S)_{il} + BP_{ik} + BT_{im} + BL_{in} + BN_{ij} + e_{ijklmn}$

$Y_{ijKlm}$ = DMY

Where:

$\mu$ = mean
$B_i$ = the effect of the $_i$th genotype of cattle ($_i$ = 1..3)
$N_j$= the effect of the $_j$th year of sampling ($_j$ = 1..3)
$P_k$ = the effect of the $_k$th month of sampling ($_k$ = 1...12)
$S_l$= the effect of the $_l$th farm ($_l$= 1…18)
$T_m$ = the effect of the $_m$th class of days in milk ($_m$= 1..5)
$L_n$ = the effect of the $_n$th parity of dam ($_n$= 1..6)
$B(S)_{il}$ = the effect of genotypes nested in farms
$BP_{ik}$ = the effect of interaction of genotype and month of sampling
$BT_{im}$ = the effect of interaction of genotype and class of days in milk
$BL_{in}$= the effect of interaction of genotype and parity of dam
$BN_{ij}$= the effect of interaction of genotype and year of sampling

For comparison of DMY obtained in each of the two milk yield estimation methods the following linear model was used

$Y_{ijklm} = \mu + B_i + P_j + T_k + L_l + S + B(S)_{ik} + e_{ijklm}$

$Y_{ijKlm}$ = DMY

Where:

$\mu$ = mean

$B_i$ = the effect of the $_i$th genotype of cattle ($_i$ = 1..3)
$P_j$ = the effect of the $_j$th month of sampling ($_j$ = 1...12)
$S_{k=}$ the effect of the $_K$th farm (k= 1….18)
$T_l$ = the effect of the $_l$th class of days in milk ($_m$= 1..5)
$L_m$ = the effect of the $_m$th parity of dam ($_n$ = 1..6)
$B(S)_{ik}$ = the effect of genotypes nested in farms

For analysis of Calving Interval (CI) factors included in the model were genotype, genotypes nested in farms, season of previous calving and interaction of breed x season of previous calving. For Age at first calving (AFC) factors included in the model were genotype, season of birth and farm.

## Results and discussion

### Growth of calves

Live weight (LW) of the calves over time (in days) was obtained by the following equations: $Y= 36.3 +0.34(X) + 0.000072 (X^2)$ for the crossbreds and $Y= 38.8 +0.45(x) - 0.00028 (X^2)$ for the Ankole (Figure 3). Where Y= LW in Kg and X = Age in days. Due to limited number of records results for only two genotypes (the Ankole and HF>50%) were derived. Both the Ankole and HF>50% had similar growth rates up to 350 days of age after which the rate of growth in the HF>75% increased at a much higher rate. At 450 days of age the HF>50% had significantly ($P < 0.01$) higher LW than the Ankole (210 kg for Ankole vs. 230 kg for crossbreds). Live weights observed in the Ankole at 365 days and at 540 days are comparable to those reported by Gregory *et al.,* (1985) who observed weights of 164.2 kg and 228.1 kg at these ages.

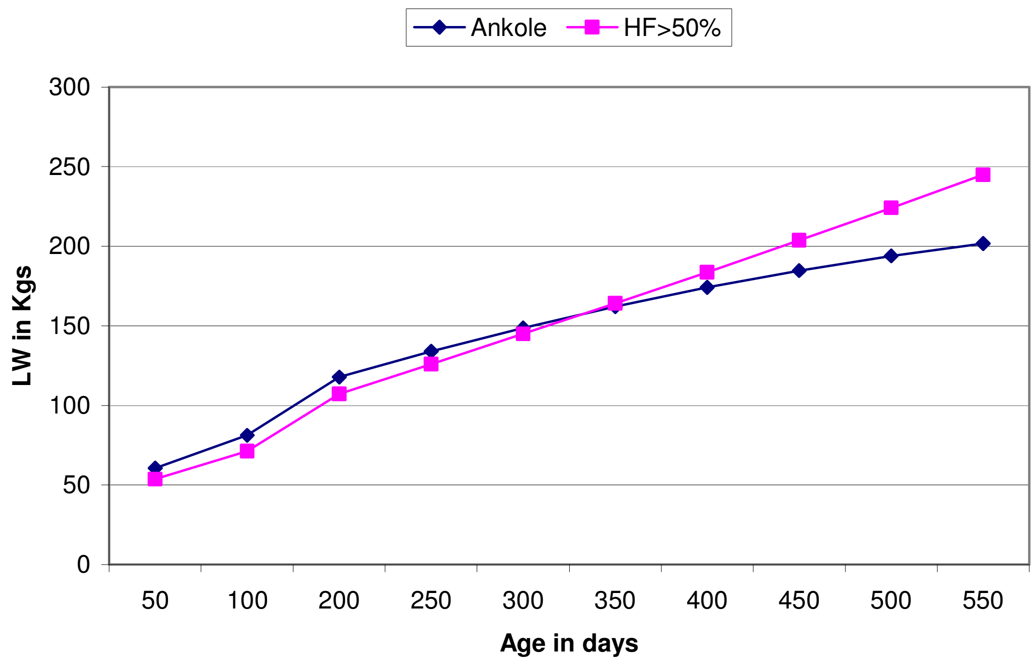


**Figure 3 :** Growth curves of calves

Comparison of growth rates of the HF>50% with results from other studies was not done because literature on growth rates of Ankole-Holstein Friesian crosses was not available.

**Weights and body condition scores of the cows**

The LSM for LW and BCS for cows in are given in Table1. Both the HF50% and HF>50% had similar LW but the two had significantly higher (P<0.0001) live weights than the Ankole. Weights of Ankole cows in this study were comparable to those obtained on other on-farm studies involving 37 farms (Petersen *et al.,* 2004) but lighter than those observed in an earlier study under experimental conditions at a government ranch in South West Uganda (Gregory *et al.*, 1985).

**Table 1**: Least Square means ( LSM ) and standard errors (SE) for weight and Body Condition Score of mature cows

| Genotype | Weight (Kg) | | | Body Condition Score | | |
|---|---|---|---|---|---|---|
| | N | LSM | SE | N | LSM | SE |
| Ankole | 432 | 305.4[a] | 2.98 | 412 | 3.44 | 0.12 |
| HF50% | 226 | 388.6[b] | 4.50 | 216 | 3.35 | 0.12 |
| HF>50% | 1313 | 394.7[b] | 1.60 | 1251 | 3.35 | 0.11 |

[a b] Means in a column different superscripts differ significantly (P<0.0001), N- number of observations

Slight increments in live weights during the rain seasons and a drop in the same during the dry seasons were observed in all the genotypes (Figure 2). These changes were however not significant. Highest/lowest weights observed were 405.03±5.9 vs. 386.9±3.37, 403.9±11.6vs. 372.6±15.2 and 319.4±9.05 vs. 292±7.87 for the HF>50%, HF50% and the Ankole respectively.

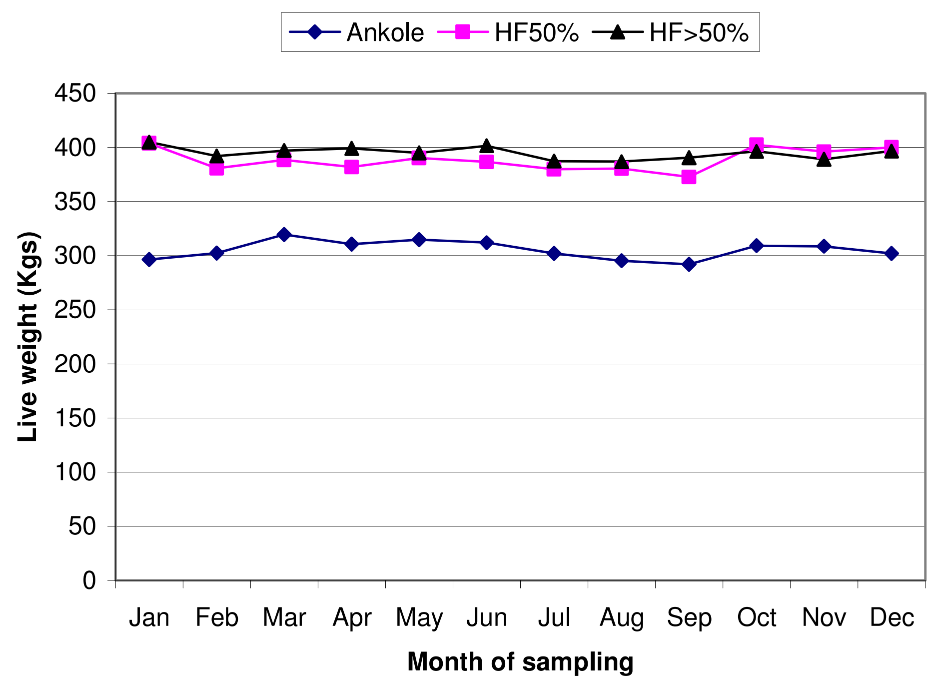


**Figure 2**: Monthly variations on LW

Month of sampling however had a significant effect (P=0.01) on BCS. In all the breeds the highest scores were during the rain seasons, while the lowest scores were observed during the long dry season. Since BCS are an indicator of nutritional adequacy (Msangi *et al*., 2005), the increase in BCS is linked to increased availability of pasture during the rain seasons. Similar variations in BCS have been reported by Okello *et al*., (2005) who observed a drop in BCS during the dry seasons in response to reduced feed resources and reduction in quality of pasture in Ankole cattle grazed on natural range pastures.

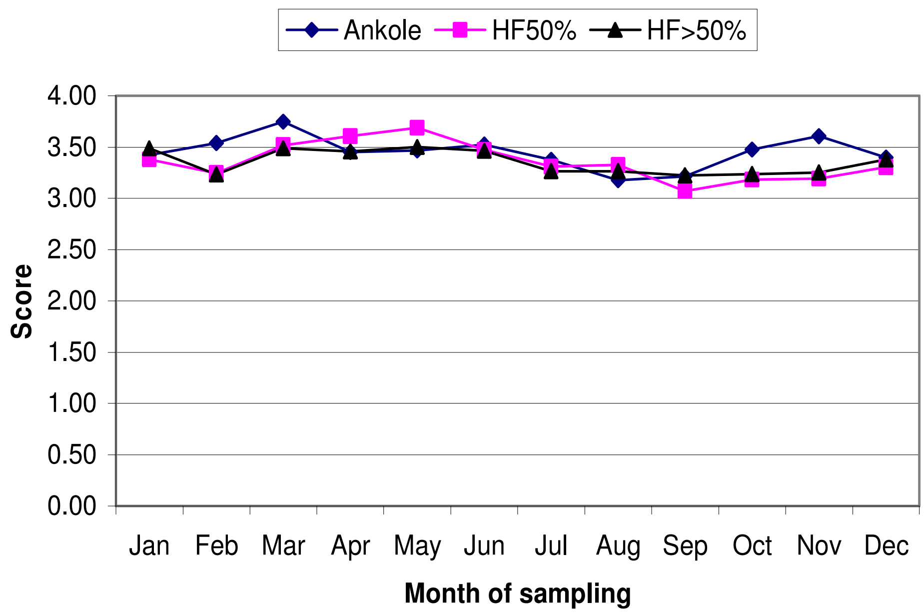


**Figure 3**: Monthly variations in BCS

**Milk production**

Daily milk yield (DMY) obtained for each of the two methods used to estimate milk production is shown in Table 2.

**Table 2**: Least square means (LSM) and standard errors (SE) of DMY in Litres obtained from the two methods used to estimate milk production

| Method used | Farmer´s reports | | | Graduated bucket | | |
|---|---|---|---|---|---|---|
| Genotype | N | LSM | SE | N | LSM | SE |
| Ankole | 344 | 3.00[a] | 0.20 | 81 | 1.70[a] | 0.36 |
| HF50% | 174 | 7.62[b] | 0.26 | 40 | 5.60[b] | 0.47 |
| HF>50% | 1045 | 7.96[b] | 1.57 | 282 | 5.74[b] | 0.22 |

[a b] Means in a column different superscripts differ significantly (P<0.0001), N- number of observations

Slightly higher DMY were obtained from results based on farmer's memory as opposed to that obtained when a graduated milk bucket was used. The differences could be due to the fact in some cases farmers provided figures based on an average production of their cows over certain period as opposed to actual milk yield obtained during the sampling day when graduated buckets were used. DMY obtained from a combination of the two estimation methods is given in Table 3.

**Table 3:** Least square means (LSM) for DMY obtained by combining methods of estimation

| Genotype | DMY (litres) | | |
|---|---|---|---|
| | N | LSM | SE |
| Ankole | 425 | 2.44[a] | 0,22 |
| HF50% | 214 | 6.70 [b] | 0,27 |
| HF>50% | 1326 | 7.44[b] | 0,08 |

[a b] Means in a column different superscripts differ significantly (P<0.0001), SE-Standard error, N-number of observations

Both HF50% and HF>50% had significantly higher daily milk yields (DMY) than the Ankole. The DMY observed in Ankole was higher than that obtained by Grimaund *et al.* (2007) during a study of 24 farms involving Ankole in four agro ecological zones (1.8l /day) but are comparable with those obtained by Hatungumukama *et al.*, (2007) at Mahawa research station in Burundi ( 2.75±0.05 l/day). The differences between results obtained by Grimaud *et al.,* 2007 (based on a study carried out between 1999 and 2000) and our study could be due to improvement in management practices on the selected farms over time. As farmers become more sedentary bush clearing is being carried out to open up more grazing land. Studies have shown that this practice improves livestock productivity because it results in higher herbage yields (Mugasi *et al*., 2000).

The relatively higher milk yields observed in the HF50% and the HF>50% as compared to the Ankole is confirmation that introducing exotic inheritance of dairy breeds in Ankole results in animals with higher DMY. This observation is in line with several studies (e.g., Syrstad O. 1988; Rege 1998; Demke *et al.,* 2004; Hatungumukama 2007 and Darfour-Oduro *et al.,* 2009 ) that have demonstrated that milk production in indigenous animals is generally lower than that of their crosses with exotic dairy breeds especially in the F1 generation. The DMY of the HF50 and HF>50% did not differ significantly. Further studies on economic performance and life time milk yields should be undertaken to determine which of the two genotypes is most suited to the production environment. Studies are also required to establish if the crossbreds are more profitable than the Ankole by virtue of the higher DMY.

DMY was significantly influenced ($P < 0.05$) by month of sampling, stage of lactation and lactation number (figures 4, 5 and &6). With regards to month of sampling a similar pattern to that of BCS, was observed. The highest DMY for all genotypes was observed during the rain seasons while the lowest DMY occurred during the dry seasons. Reasons for these seasonal fluctuations are similar to those of BCS. HF50% and HF>50% showed the largest fluctuations in DMY over the months. The Ankole on the other hand show minimal fluctuations through out the year this could be linked to the fact that the breed has lower milk yields than the HF50% and HF>50%.It has also been suggested that Ankole can change their grazing behaviour and are able to mobilise body reserves during the dry periods (Okello et al., 2005). Correlations of DMY and BCS were however lower than expected in all the three genotypes. Results from pair wise correlations revealed that variations in DMY were correlated ($P< 0.001$) with BCS ($r= 0.28$, $r= 0.22$ and $r= 0.21$) for the Ankole, HF50% and HF >50% respectively. BCS are therefore a poor predictor of DMY in this study.

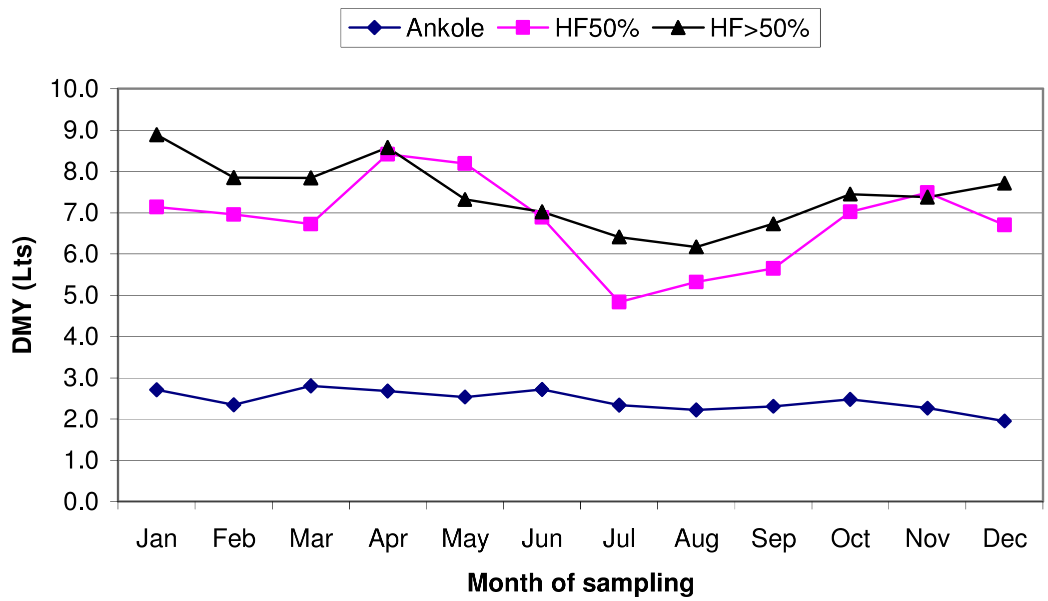


**Figure 4**: Monthly variations in DMY

The highest DMY (Figure 5) for all the genotypes was observed during the first 2 months of lactation. This observation is consistent with results of Hatungumkama *et al*. (2007) who reported peak lactation in the in the first month of lactation while studying milk production of crossbreds of Ayrshire X Sahiwal x Ankole at a research station in Burundi. Both the HF50% and HF>50% showed a gradual decline in DMY with advancement in days in milk with a steep drop after 100 days in milk. The Ankole on the other hand only showed slight changes in DMY over the 300 days period. The highest/lowest DMY observed for this breed was 2.6 ± 0.30 vs. 2.4 ± 0.5 at around 50 days and 300 days in milk respectively.

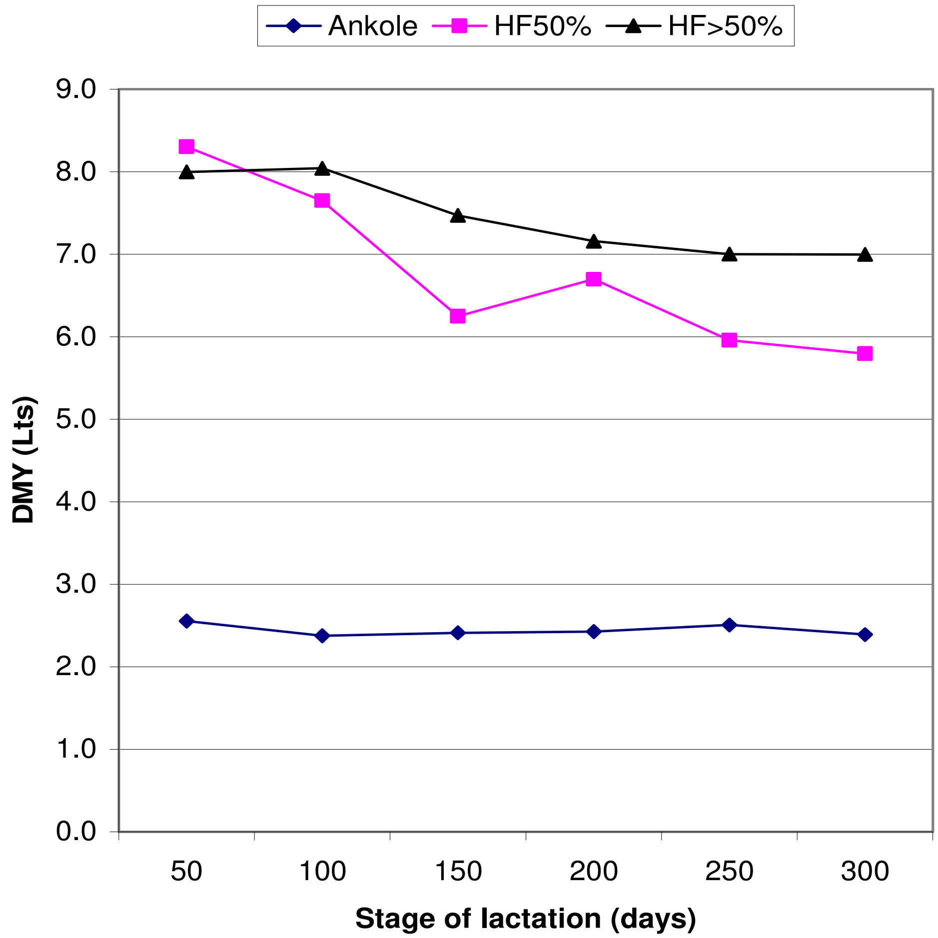


**Figure 5**: Variation in DMY with stage of lactation

For all the genotypes there was an increment in the DMY from first parity up to a certain level then this dropped (Figure 6). The low production in the first two parities could be attributed to the fact that development of the animals was still taking place and as a result nutrients were partitioned to both body building and milk production. The highest DMY in HF50% was observed in cows in $4^{th}$ parity while in HF>50% and the Ankole this was observed in the $5^{th}$ parity. The results are in contrast with those from a study by Darfour-Oduro *et al.* (2009) on milk yields of Ghana Sanga and it crosses who observed that Friesian-Sanga cows of second parity had the highest DMY and that highest milk yields in Sanga cows occurred at the third parity. The differences could be partly due the fact that wrong (higher) parity numbers were assigned to some of cows at the beginning of our study.

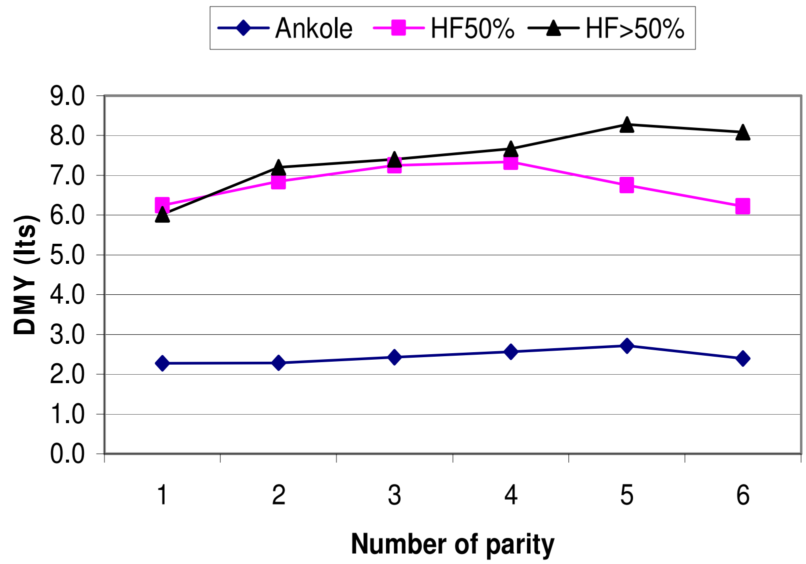


**Figure 6:** Variations in milk yields with increasing parity

**Reproductive performance**

LSM for Age at First Calving (AFC) and Calving Interval (CI) could only be calculated for Ankole and HF>50% (Table 3)

**Table 3:** Least square means (LSM) and standard errors (SE) for reproductive performance

| Genotype | AFC | | | CI | | |
|---|---|---|---|---|---|---|
| | N | LSM | SE | N | LSM | SE |
| Ankole | 50 | 38.90[a] | 1.96 | 33 | 16.04 | 0,68 |
| HF50% | | | | | | |
| HF>50% | 70 | 29.10[b] | 1.63 | 82 | 15.30 | 0,47 |

AFC – Age at First calving in months, CI- Calving interval in months [a b] Means in a column different superscripts differ significantly (P<0.0001), N- number of observations

There was a significant difference in AFC between the genotypes. Literature on AFC and CI of Ankole and of Crosses of Ankole with exotic cattle is scarce. Results from earlier studies (Sacker and Trail 1966) estimate AFC in Ankole to be 51.3 months and CI

(Furnemont, 1981) at between 13.5 – 17.1 months. Whereas the CI observed in our study is in agreement with earlier publications, the observed AFC is in contrast. This difference could be as a result of improved management of the Ankole as the cattle keepers become more sedentary. The AFC and CI observed in the HF>50 support findings of various studies (Kimenye 1978; Kiwuwa et al. 1983; Demke et al. 2004 and Miazi *et al.*2007) in which crossbreds of indigenous tropical cattle with exotic dairy breeds have been shown to have earlier AFC and a shorter CI. Calving patterns of the cows based on 545 records comprising 166 Ankole, 55 HF50% and 324 HF>75% are shown in Figure 7.

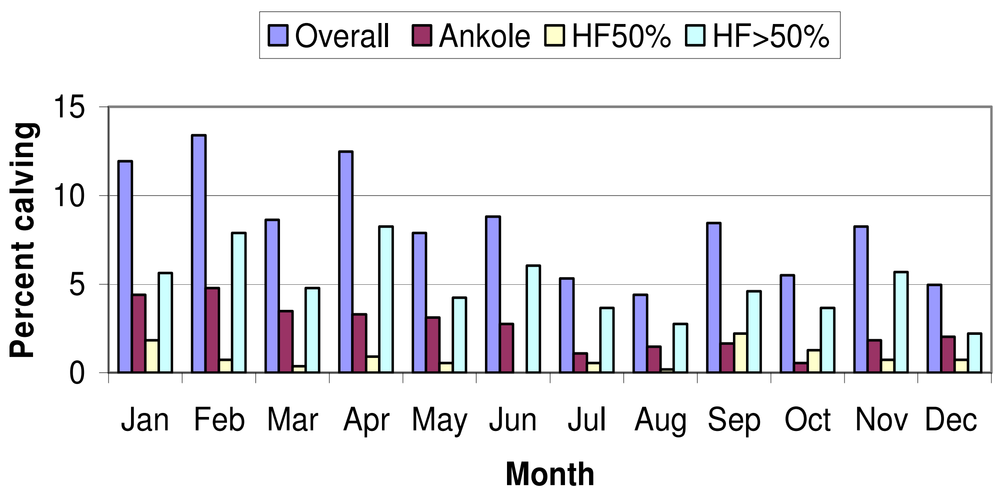


**Figure 7**: Calving pattern of cows through out the year

Cows calved throughout the year but the largest proportion of the calving occurred between January and April with a peak in February. Given that the gestation period of cows is 9 months, It appears that the highest number of conception occurs between April and June, a period that lies mostly within the long wet season. Since bulls are maintained in the herds throughout the year, it can be concluded that the rain seasons have an effect on the calving patterns. Slightly different calving patterns were observed in the HF50% from the other two genotypes (Ankole and HF>50%) this difference could be due to the small number of records (55) used for this genotype as compared to the other two.

**The future**

Crossbreeding of Ankole with Holstein Friesians has for the time being provided farmers of South Western Uganda with genotypes with increased DMY, lower AFC and reduced CI under a low input production system (minimal supplementation). However the unplanned breeding currently taking place could easily result in reversing these achievements.

The increased volumes of marketable milk currently obtained from the crossbreds translate into increased house hold incomes. It is therefore likely that crossbreeding will continue at a fast rate in response to increasing demand for milk in the urban centres. To ensure sustainability of the production system, the appropriate level of Holstein Friesian inheritance in the Ankole needs to be determined and a well organized breeding program needs to be in place to ensure continuous production of the appropriate genotype. The breeding program should not be restricted to production and selection with-in crossbreds but a program to improve Ankole needs to be developed as well. The benefits of this are three fold (i) Farmers who wish to retain the Ankole will benefit from its improved productivity (ii) An improved Ankole will be attractive to farmers and will not be regarded as an inferior breed (Mbuza, 1995) (iii) An improved Ankole will produce higher performing crossbred offspring because dams of known genetic worth will be used (Cunningham, 1981).

Establishment of a breeding program in the study area is however bound to face some challenges because of the absence of a recording system. However, a simplified recording system as discussed in the previous chapter can be developed and introduced and a breeding program for the area developed. These issues are discussed in the following chapter on Breeding objectives and strategies of cattle keepers in south Western Uganda.

Efforts to improve productivity of the animals should not only focus on breeding. It is possible that with improved nutrition management higher DMY in all the three genotypes could be obtained. For example the loss in production during the dry seasons (Figure 4) could be bridged if strategies are developed to ensure adequate nutrition of the animals through out the year. Studies are therefore required to establish the suitable stocking rates under the new management systems and to identify or develop economically viable techniques of forage conservation or distribution of agro-industrial by–products for supplementing the milking animals during the dry seasons.

## Conclusion

The high demand for milk in the urban centres and improved productivity of the crossbred animals shall remain a major reason for farmers in South Western Uganda to crossbreed Ankole with Holstein Friesian. The haphazard crossbreeding methods employed at the moment are not sustainable and could easily result in an animal population that is not well adapted to the production environment. To avert this appropriate level of exotic inheritance needs to be determined and a breeding program backed up by a good livestock recording system should be established. Improvement in livestock productivity should not only be restricted to crossbreeding with exotic animals but other aspects like improved nutrition should also be considered.

## Problems encountered during the study

The results presented in the previous section have been obtained from data collected between March 2007 and September 2009. Throughout the study period there have been many irregularities in the data capture process, transmission of data capture sheets from the field to ILRI (Nairobi) and final transmission of the keyed-in data to the graduate fellow in BOKU. As a result of this much of the important information has not been captured and there have been considerable delays in the transfer of information. For example, the complete final merged data set for analysis was obtained in BOKU in late November 2009. There has therefore been limited time to clean and internalize the data and to carry out analysis.

In this section possible causes of the above irregularities, lessons learnt and recommendations for future on- farm studies are discussed.

**The start-up phase**

The major activities involved at this stage which included identification and recruitment of farmers, recruitment of an enumerator, a kick–off workshop and purchase of a motor cycle for the enumerator took much longer than anticipated as a result of the following:

- The Graduate fellow was assigned a lot of administrative work by his employer (NAGRC & DB) which interfered with Ankole II project time. This was in spite of the written commitment of his employer that he would be granted study leave.
- Funds for field expenses that were transferred by ILRI to the collaborating partner (NAGRC & DB) were never released on time. This continued through out the study as a result fuel for the enumerator's travel and salaries were always late.
- Procurement of the motor cycle for the enumerator had to be done through the lengthy government procedure.

All the above resulted in irregular farm visits (longer than the originally planned 4 week interval), poor or inadequate orientation of the enumerator on techniques of data capture and affected negatively the working morale of the enumerator.

**Failure to deliver on promises made to the farmers**

Several promises made to the participating farmers were never fulfilled. This included support "in-kind" for the construction of cattle inspection crushes, availing an earth excavator at a cost for construction valley tanks and delivery of feed back livestock performance reports to the farmers. This dampened keenness of the farmers and towards the end of the project many were not as co-operative as they had been at the start. It was at times difficult for the enumerator to make visit appointments and to obtain all the required information like important events on the farm, calving dates or reasons for culling.

**Lack of supervision of the data collection process by NAGRC & DB**

There was no proper coordination of field activities and a check on data quality by NAGRC & DB. Arrangements to have someone at NAGRC &DB to do this did not work out. As a result of this failure data sent to ILRI was at times incomplete and was in most instances sent late to enable feed back and corrections.

**Recommendations**

Factors that have affected the study are mainly due to a lack of full commitment by NAGRC & DB to the project, the lengthy bureaucratic government procedures which NAGRC & DB must adhere to, lack of proper training in field data collection skills of the enumerator, poor reporting of outstanding issues in the field by enumerator and the long route used to get data from the field to the graduate fellow. To minimize the above, the following are recommended:

- The start up phase should be given adequate time. Major bureaucratic procedures that could affect the activities of a program should be understood and methods to overcome them with-in the law devised.
- The enumerators should receive training on data collection procedures and should also be given an insight on how the collected data would be utilized.
- Captured data should be keyed locally as close to the field as possible, preferably by the enumerator. A lengthy process involving many people should be avoided.
- A standard reporting format on important concerns by farmers should be developed for the enumerator so that outstanding issues are thought through before feed-back workshops with the farmers are held.
- In some institutions it may be required to appoint staff member for co-ordination of activities. Part of the remuneration for the officer should come from project funds.

**Acknowledgement**

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# Chapter 4

## Breeding objectives and strategies of cattle keepers in South Western Uganda: Possibilities of a community based breeding program

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**Abstract**

The study was conducted to investigate the possibility of setting up a community based breeding program in South Western Uganda. Thirty four cattle keepers were selected from the area and individual interviews focusing on breeding objectives and strategies and on socio-economic background were conducted amongst them. Majority of the cattle keepers (88%) kept pure bred Ankole and Ankole Holstein-Friesian crosses in separate herds. Crossbred cattle were mainly kept for marketable milk while Ankole were kept for cultural reasons, as security and store of wealth. The cattle keepers had an established system through which breeding activities were controlled. Exchange of bulls was acceptable or practiced by 66% of the farmers while 34% were totally against it. No bulls were shared between the livestock keepers. Each livestock keeper owned at least one bull per herd. More than half of the interviewees stated that they kept mental records of the progeny history of their herds and 71% stated that they shared breeding information with family members and friends. Community based breeding programs are a viable avenue for cattle improvement in the area plus they will bring about numerous benefits to the communities like organized market channels for milk and livestock. Success of programs will however depend on a number of factors which include interest of the cattle keepers in the program, long term commitment and involvement of the cattle keepers while designing the breeding program.

**Key words**

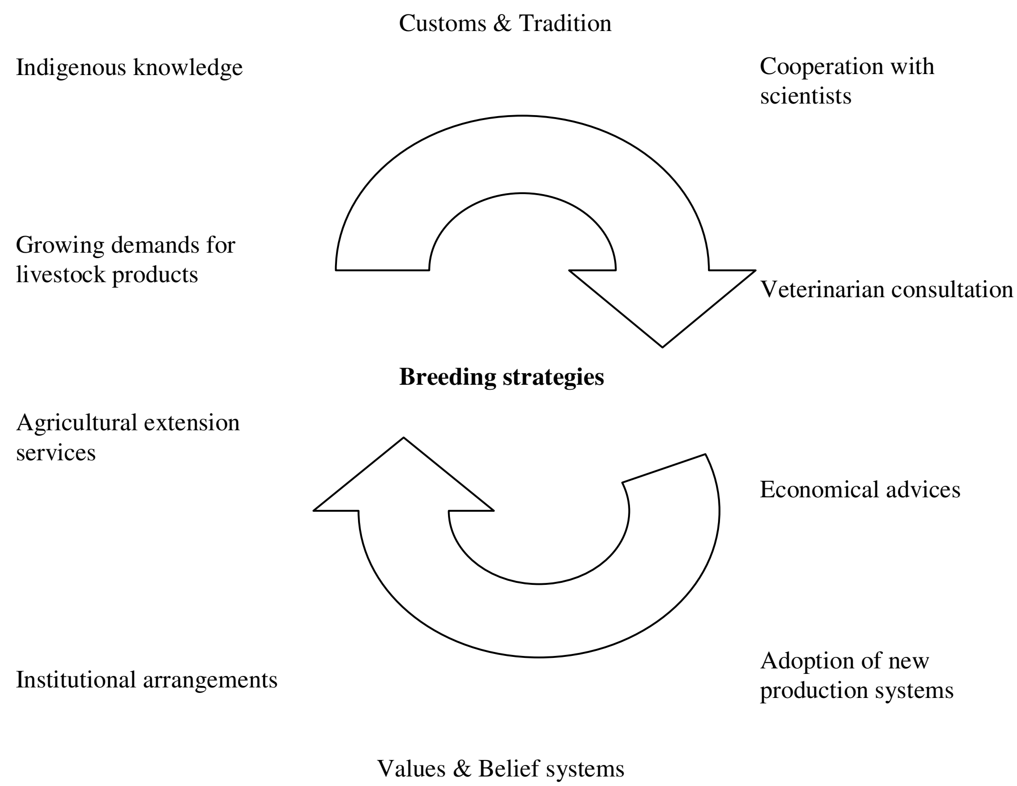
Ankole, community based breeding program, breeding objectives, breeding strategies, Uganda

## Introduction

In response to increasing pressure on land due to the rapidly growing population as well as growing demand for livestock products in urban centres new land policies have been enacted in Uganda that encourage individual land ownership (Nakimbugwe and Muchunguzi, 2003; Petersen, 2004). As a result of this, pastoralists keeping the long horned Ankole cattle are abandoning their nomadic life style to a sedentary one and are resorting to increased milk production to support the new life style largely through the sale of milk. To obtain animals with higher milk yields, crossbreeding of Ankole with exotic breeds, mainly Holstein Friesian has begun and is taking place at a very fast rate without any defined breeding program. This could result in a cattle population that is not economically viable for the production environment (Kahi, 2002). Results from various studies (Goshu, 2005; Kahi, 2002; Kahi *et al.,* 2000; Alexander ,1986) however indicate that if crossbreeding programs are planned well they can result into profitable and well adapted dairy cattle populations. There are many constraints to successful design and operation of breeding programs in developing countries. These include; i) Lack of well developed recoding systems, ii) Lack of strategies and policies to utilize advantages of the crosses (Rege, 1998) iii) knowledge gaps as to appropriate levels of crossbreeding for a particular production system (Kahi, 2002) and iv) lack of an in depth analysis of the socio-economic and cultural values of livestock in the different production systems or production environment thereby leading to wrong breeding objectives (Chagunda, 2002).

Involvement of rural communities and a clear understanding of their breeding practices while planning the programs by relevant authorities could be a key in obtaining successful results (Sölkner *et al*. 1998). Kahi *et al.* (2005) propose that participation of the local communities and other stake holders can be best achieved through Community Based Organizations for General Improvement of Livestock (CBOGIL). The authors define CBOGIL as organizations owned by farmers in a community with the objective of improving livestock production through use of animal genetic resources. Other authors (Sölkner *et al.* 1998; Wurzinger *et al.*2008) refer to this livestock improvement approach as village breeding programs. Before a CBOGIL can be established some back ground studies on a particular community are required to establish a number of factors which will guide its design and implementation. The study was therefore undertaken to generate knowledge on cattle breeding practices of the livestock keepers in South Western Uganda, their breed preferences, their decision making process with regards to breeding and the existing institutional breeding arrangements. Institutional arrangements are regarded as the complex laws, customs, markets, norms and associated organisations that inhibit or encourage certain activities in a community. These could be (a) gazetted laws and regulations, (b) commonly accepted but not legally binding rules and guidelines, and (c) organisations established by the culture. (Wenger, 2000, as cited in: Macadam *et al.*, 2003). Institutional arrangements are both stable and dynamic and in the case of this group of cattle keepers could be affected by a number of factors (Figure 1).

**Figure 1: Influences on institutional arrangements among the cattle keepers**




Source: Peloschek, 2009

## Materials and methods

### Description of the study area

The study was carried out in Kiruhura District, South Western Uganda between March and May 2009. The district lies within an area referred to as the cattle corridor that stretches from the South Western part of Uganda to the North East of the country. The district is divided administratively into counties and sub-counties. The area receives 939mm of rainfall per annum in two rainfall seasons with peaks from March to May and from September to November (Mulindwa *et al*., 2009). Topography of the area is dominated by undulating hills with an elevation of about 1,100 to 1,525m above sea level (Gregory *et al.,* 1985). Cattle which are reared on extensive production systems are an important economic activity in this area (Ocaido *et al*. ,2009). In some parts grazing of cattle takes place among dense Acacia thorny thickets and in others the thickets are sparsely distributed. Common grass species include *Themeda triandra*, *Bracheria decumbens*, *Digitaria Spps*. *Hyparrhenia fipipendula* and *Chloris gayana*. In some parts *Cymbopogon afronardus* , a grass of low nutritive value and palatability has encroached the natural grazing fields (Gregory *et al.,* 1985; Petersen *et al*., 2004). Some of the farms in the area are fenced off with either barbed wire, live fence or a combination of the two.

### Data collection

Open-ended interviews were conducted individually with 34 cattle keepers selected from 6 sub-counties in Kiruhura district namely, Kikatsi, Kenshunga, Masha, Rubaya, Nyakashashara and Sanga. Selection was based on geographical distribution and genotypes kept. The selected farmers either kept only pure Ankole cattle (4) or Ankole and crosses of Ankole with Holstein-Friesian (30). Three farmers kept Boran – Ankole crosses, Brown Swiss-Ankole crosses, Ayrshire-Ankole crosses and Simmental-Ankole crosses in addition to pure Ankole and Holstein-Friesian Ankole crosses. The interviews were divided into two parts. Part one comprised of questions on herd size, breed preferences, breeding strategies and on progeny history. Questions on progeny history were conducted in accordance with recommendations on progeny history analysis as outlined by FAO (2000). This included gathering information on calves produced by a selected animal that the farmer considered being favourite. This section of the study was designed to obtain information on the type of records farmers kept or stored about the animals, off takes, herd mortality and on special incidents on the farms. Part two of the interviews focused on socio-economic issues of the house holds which included household sizes, succession plans and education levels of the household heads. With exception of few cases where the interview was done in English all interviews were carried out in Runyankore, the local language of the region, and later translated into English.

**Data analysis**

Recorded interviews were transcribed with software program f4', version 2.1, 2004 version and qualitative data was analyzed using Atlas.ti, version 5.2 (Muhr, 2004). This program allows the user to systematically analyse qualitative data with codes and quotations to sort the collected information. Frequency counts and means were calculated for some data sets using SAS 9.2 (2008).

## Results

**Household information**

General household information is given in Table 1. Majority (85.3%) of the cattle owners interviewed were male and were in most cases the household heads. Most (64.7%) of the cattle keepers had received formal education at varying levels and all of the households had dependants attending school, including children or siblings of the household head. Some of the cattle keepers interviewed had children who had graduated from University or other tertiary institutions and were living in the capital city. Cattle rearing were the most important source of livelihood for the households and the interviewees indicated that they started rearing cattle at a very young age. Other important enterprises included banana cultivation, goat rearing and formal employment elsewhere.

**Table 1:** General house hold information

| Category | Mean | Min. | Max. | S.E | Range/level | Percent |
|---|---|---|---|---|---|---|
| **Age of owners (years)** | 49.39 | 29 | 71 | 1.81 | 31 - 40 | 22.6 |
| | | | | | 41 -50 | 38.7 |
| | | | | | 51 - 60 | 22.5 |
| | | | | | > 60 | 16.1 |
| **Household members** | 8 | 1 | 25 | 1.07 | 1 - 10 | 73.3 |
| | | | | | 11 - 20 | 23.3 |
| | | | | | > 21 | 3.3 |
| **Level of Education** | | | | | | |
| No education | | | | | | 35.2 |
| Primary education | | | | | | 20.6 |
| Secondary education | | | | | | 35.3 |
| Tertiary education | | | | | | 8.8 |
| **Main source of livelihood** | | | | | | |
| Cattle | | | | | | 73.5 |
| Cattle and banana plantation | | | | | | 8.8 |
| Cattle and employment elsewhere | | | | | | 11.8 |
| Cattle and goats | | | | | | 5.9 |

**Succession**

Commenting on succession, 57.1 % of the cattle keepers indicated that they would pass on their herds to their children before they died, while 32.1 % said their herds would only be passed on after they have passed away. Irrespective of the succession plans the heirs all had particular responsibilities assigned to them in the herds while the family head was overall in charge of the management. There were cases on some of the farms where the highly educated children had migrated to the cities and were not living on the farms anymore. This was of concern to the affected families. One farmer faced with this situation commented *“my children all live in the city if they come back then they can inherit the herds”.* It was not clear if by staying away from home these children would forfeit their inheritance.

### Herd size and structure

Mean herd size for the Ankole was 89 $\pm$ 11.6 and number of animals in this group ranged between 16 to 306 while mean herd sizes for the crossbreds was 96 $\pm$ 14.6 with a range of 4 to 306. Majority of the cattle keepers (64%) reared their animals in two herds, separating pure Ankole and the crossbred animals, the rest either had one herd (6), three herds (3), 4 herds (2) and five herds (1). Some farmers with single herds had plans of splitting their herds according to genotypes when their cattle population increased and after acquiring more land. All farmers kept at least one bull in each of their herds.

### Choice of breed

Four cattle keepers kept only Ankole cattle. The rest kept Ankole and crosses of Ankole with different breeds. 56% of the interviewees stated that that they still kept Ankole for cultural reasons like payment of dowry and prestige. The other reason advanced for rearing Ankole by 38.2% of the interviewees was hardiness of the breed. Farmers mentioned resistance to diseases, ability to withstand draughts and ability to cope with harsh environments. In addition beauty of the animals and superior milk and beef quality as compared to the crossbred were given as positive attributes of the Ankole cattle. All cattle keepers keeping crossbreds of either Ankole with Holstein-Friesian, Brown Swiss or Simmental did so because they provided more marketable milk. Crossbred cattle were also attractive to cattle keepers because their off spring sold for breeding were in high demand and fetched a good market price as compared to Ankole. Furthermore culled animals sold for slaughter fetched a higher price than the Ankole due to their relatively larger body size. The cattle keepers were asked to state the cattle breeds they would like to keep in the future, 87 % stated that they would like to continue keeping both the Ankole and crossbreeds animals. The rest (13%) preferred to keep only Ankole. This included farmers that had crossbreds, but wanted to revert back to Ankole.

**Source of the crossbred cows/heifers in the herd**

Although some farmers started crossbreeding as early as 1979, most (93%) started crossbreeding after 1990. Majority of the farmers (80%) stated that they obtained information about crossbreeding from other farmers, while the others obtained the information from government extension programs and Non-government organizations (NGO's). Some of the farmers (46%) stated that they established their crossbred herd by buying in Holstein Friesian or crossbred bulls and mating them to selected Ankole cows. Another group 54% stated that they bought a herd of crossbred heifers along with a crossbred bull. Majority of the interviewees (66%) stated that they no longer buy crossbred heifers or cows from outside their herds for replacement or expanding the herd. Two farmers advanced reasons for this; one stated that they were expensive and another farmer stated that heifers raised on other farms were too delicate and he feared they could die on his farm. The rest (34%) stated that they need to buy in more crossbred cows or heifers to expand their herds. With regards to disposal 73 % stated that they sell or give away cows/heifers while 27% retain all their stock. Pastoralists that sell their stock do so for several reasons which include raising of money for specific needs and getting rid of unproductive animals. Although cattle markets exist in Kiruhura, the study was carried out at a time when local authorities of the area had closed all markets as a disease control measure. Cattle traders were buying animals directly from the farms, a situation cattle keepers did not like because they were offered very low prices.

**Source and criteria for selection of bulls**

With the exception of two farmers that used artificial insemination in some of their herds, all the other farmers used natural mating. The number of bulls per herd ranged between 1 and 3 depending on the herd size and preference of the farmer. Bulls on the farms during the study had been obtained from 5 sources (Table 2).

**Table 2:** Source of bulls in the different herds

| | Ankole | Crosses |
|---|---|---|
| Source of Bull | Frequency | Frequency |
| Raised on farm | 29% | |
| Bought in | 45.2% | 75.8% |
| Exchanged | 3.23% | |
| Gift | 9.7% | 13.8 |
| Combination* | 12.9% | 10.3 |

Combination* some farmers had more than one each bull each obtained from a different source. For example one could have been was bought in and the other raised on the farm

Few bulls had been obtained through exchange and all were Ankole. According to one farmer, it was conducted like a long term loan i.e. the reciprocal return was not immediate and was not necessarily a bull. All interviewees were aware of the negative effects of inbreeding and had some “in built controls” to avoid mating of closely related animals. Firstly, bulls were removed from the herd when the daughters had matured. Secondly, for bulls that were retained for long periods in the herd, special care was taken to ensure that it never mated the daughters. According to some farmers it was culturally wrong to mate a bull to its daughter. Exchange of bulls with strangers was discouraged as a measure to control disease.

The cattle keepers were asked to state their views on bull exchange. 66% of the interviewees found this acceptable or had done it at one stage. According to the pastoralists exchange of bulls fostered close relationships among the livestock keepers and also helped reduce on the rates of inbreeding in the herds. Some respondents (21%) further explained that they were open to the exchange of both Ankole and crossbred bulls and that regardless of the genotype the traditional rules of animal exchange will be followed; i) Exchange would only take place with close friends or relatives to avoid spreading of diseases ii) A cattle keeper giving out an exchange animal would not be repaid immediately but an animal of similar quality would be repaid at a later date. There was however a group (34%) that was strongly against exchange of animals. This group stated that they would rather buy in a bull and sell off their old bull for slaughter to avoid spread of disease.

None of the cattle keepers interviewed advocated for bull sharing (use of one bull concurrently with another cattle keeper). All the herds represented in the study had at least one bull assigned to them. One farmer strongly opposed to bull sharing stated, *"A bull is like a wife and can therefore not be shared".*

Criteria used in selecting a bull varied but most import was size, the bigger the better, overall appearance of the bull, appearance of animals in the herd from which the bull is to be selected and milk production of the dam. A distinction between genotypes was made by 41% of the farmers, who stated that general appearance , size and colour of horns and coat colour where very important for Ankole bulls while for the crosses ability to produce female calves and animals with high milk yields was most important.

**Progeny history and transfer of the knowledge with in the household and society**

All the cattle keepers a had favourite animal in each of their herds. Majority (82.3%) of the favourite cows mentioned by the farmers had been born with in their herds and the rest had been purchased from an external source. The interviewees could easily recall offspring from a favourite cow and it was common to retain female offspring from these cows for breeding within their herd or to be given as gift to friends or as dowry. The following reasons were advanced for favouring a cow *"i) It produces a lot of milk ii) It is beautiful iii) I raised it up".* In most cases sires of favourite cows were also remembered. One farmer narrated 3 characteristics of one such sire *" i) It produced very good offspring 2) It never strayed away from the herd but grazed near to all animals 3) The bull defended the entire herd and no other bull dared to come my herd"* Negative performance of sires of favourite dams were also remembered as stated by one farmer " *I removed the sire of my favourite cow because he produced only male offspring*".

Memory of progeny history is not restricted to favourite animals. 53 % of the interviewees stated that they know their cattle well to provide detailed information about their progeny. This was demonstrated by their ability to give the number of offspring they had received from a given animal, the sires used, all based on memory. One farmer indicated that he could tell backwards up to the 10$^{th}$ generation in his herd. Information on pedigree of the cattle was passed on to the families especially to children. Some farmers (15%) were however concerned that there was a growing lack of interest with regards rearing cattle among their children. It was therefore becoming more difficult pass on pedigree

information to their children. One farmer stated *"with my death this information would be lost because there was a lack of interest among them"*.
Sharing information, discussing breeding matters and exchange of knowledge was common amongst the cattle keepers. 71% stated that they discuss breeding matters with family and friends. At family level decisions were made on various issues like selecting animals to sell from the herd. Up to 73% explained that they share experiences with in their farming community and 55% mentioned that they shared experiences with farmers outside their community.

## Discussion

Results from the study provide an insight into the current practices and aspirations of the cattle keepers in South Western Uganda. There are a number of factors that may support the establishment of a CBOGIL. Firstly, it is evident from our results that cattle are the major source of livelihood for the pastoralists emphasized by the fact that in all the farms household, members of appropriate age participated in rearing of the cattle and other farm activities. The importance of cattle as a major source of livelihood in the same study area has also been reported by Ocaido *et al.,* (2009) who observed that cattle contributed up to 78.4% of incomes in pastoral households. Milk and cattle sales were the major outputs from the enterprises. It can therefore be argued that improvements in cattle will translate to increased incomes through increased productivity, a development that would be readily accepted by farmers.

Secondly, genetic improvement of cattle is customary to the cattle keepers. It has been taking place for many years guided by a set of rules. This is evident from the following observations. i) There already exists cooperation amongst the farmers and systems exist through which cultural beliefs with regards to breeding are shared with in the community and also passed on to subsequent generations with in a house hold. ii) Particular traits are considered when selecting breeding bulls and cows. Selected traits listed by farmers in this study are in agreement with findings by Ndumu *et al.,* (2008) who also observed that among the pastoralists community keeping Ankole cattle, cows were selected for milk production while bulls were selected for growth, physique and beauty traits. iii) Long term livestock loans and gifts are practiced. This not only strengthens social ties but can also aid in reducing levels of in-breeding within the herds and also facilitates transfer of genes between herds. iv) Traditional rules on avoiding inbreeding are strictly followed v) pedigree information is mentally stored and passed on to the next generation. Similar observations have been made in other studies (Köhler-Rollefsson, 1995; Kugonza *et al* 2005) and have shown this information to be reliable in some cases. Although the above mentioned existing institutional arrangements for breeding among the cattle keepers have yielded some results like the distinctive appearance of the Ankole breed, they also have some weaknesses. For example some farmers stated that it was becoming difficult to pass on pedigree information to their children because they are not always available because of the time spent at school or due to declining interest of the younger generation in livestock keeping. Further more production data is not recorded thus making progeny testing impossible. In spite of their weaknesses, the existing breeding arrangements provide a starting point from which important indigenous knowledge may be bridged with scientifically accepted principles of breeding thereby giving a reliable recording system from which information can easily be retrieved.

Thirdly, the high demand for milk and breeding cattle from other regions in Uganda and the neighbouring countries is a big motivator for cattle keepers to engage in a sustainable breeding program. CBOGIL will be attractive to the farmers because it will result in a pool of herds in which recording is taking place. This will allow for greater genetic improvement than is currently possible in single herds, since it will enable farmers to make decisions on which breeding animals to use after their genetic worth has been established. Furthermore with records cattle keepers with crossbred animals will be able to compare performance of the different grades of crosses of Ankole with Holstein Friesians on-farm and decide on appropriate levels to maintain. This is important because many livestock keepers and policy makers are still unclear about appropriate levels of crossbreeding for the different farming systems in the tropics (Kahi, 2002).

Fourthly, CBOGIL provides an opportunity for the cattle keepers to operate as a group and take advantage of the benefits of economies of scale. This could be achieved in a number ways, like bulk procurement of inputs, access to market and other information of interest and negotiation of favourable market prices and arrangements.

Finally, majority of the farmers have received some formal education and in all households children of school age attended school. This is an indication that education is valued among the cattle keepers. It will be easy to carry out recording among a literate community and interpretation of results from evaluations will be easy.

## Conclusions

The Ankole pastoralists have a strong attachment to their animals (both Ankole and the crossbreds), share information amongst themselves and follow a strict set of rules. It is therefore expected that the establishment of a CBOGIL will be embraced if its benefits are well understood and if the breeding program to be followed does not violate important cultural beliefs. The direct benefits of such an establishment include i) Ability for farmers to make informed decision on which breeding animals to use based on performance. ii) Improved price of breeding stock because animals will have authentic records and due to group bargaining power. iii) Overall improvements in performance of cattle due to genetic improvement and increased access to a wide range of information. Farmers should however be aware that results from breeding can not be immediate and that success will depend on having a good number of committed members.

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# Chapter 5

## General discussion

Crossbreeding of Ankole with exotic dairy breeds will continue and possibly at a faster rate than is currently happening because of the following: i) Continuous improvement in rural infrastructure thus opening up access to more markets ii) Increasing pressure for intensive and more efficient production systems due to reduction in available farming land (MAAIF 2008) and iii) increased awareness among the pastoralist community about the benefits of crossbreeding like the higher daily milk yields and lower calving intervals observed in our study. As a result of the above forces it is possible that farmers keeping two genotypes in separate herds may eventually switch to keeping crossbreeds only.

The current livestock improvement method being employed by the farmers of continuous upgrading is of concern. It is likely to result in a population of animals with a level of exotic inheritance that are not suitable for the production environment in South Western Uganda (Kahi 2002). This could be happening already. There have been concerns by one of the farmers that participated in the study (Elia Kyamanyanga, personal communication) who also happens to be one of the pioneers of crossbreeding in the district, that there were increased incidences of tick borne diseases in his crossbred herd.

The absence of recording on most farms makes it impossible to have an organized breeding program because animals of high performance can not be easily identified. In addition the level of exotic inheritance of bulls purchased from other can not be easily established.

The factors mentioned in the two preceding paragraphs and also elsewhere in this document emphasize the fact that farmers crossbreeding Ankole with exotic dairy breeds need urgent technical solutions/intervention so that the new production system becomes sustainable. Some of the existing bottle necks could be addressed through a Community Based Organization for Genetic Improvement of livestock (CBOGIL) described in chapter 3. In the following sections some practical steps and factors that should be considered in establishment of a community based breeding program are discussed in relation to the farming system in South Western Uganda. Reference has been made to experiences in South Africa reported by Bester et al., (2001), Banga (2002) where a community improvement program for Nguni cattle has been established and a recording system among small holders is being implemented. Reference has also been made to recommendations by Kahi *et al*. (2005) and Köhler-Rollefson (2001)

**Back ground studies**

These are necessary to understand the production systems, the limiting factors that exist, breeding institutions that exist and the roles of the different genotypes and enterprises that exist in the selected area. Studies could be in form of surveys, or medium to long term data collection and analysis. Several studies which include those presented in Chapter 2 and 3, Mulindwa *et al.,* (2009); Wurzinger *et al.* (2007) and Ndumu (2008) conducted among the Ankole/Bahima pastoral farmers have generated vital information which can be used while establishing CBOGIL.

**Awareness creation**

Pastoralists need to be informed about possible avenues of improving their livestock and the working principles of a CBOGIL. This could be done through many channels so that many members of the community are reached. Farmers participating in the study (Chapter 3) were informed about the working principles of a GBOGIL during one of the routine workshops. The idea was well received following which farmers agreed to form a CBOGIL. Follow up and support by the relevant authorities and technical personnel on this matter will be necessary so that the program is successfully established.

**Formation of a CBOGIL and its composition**

The breeding group should an independent group with legal status with an appropriate name. The primary objective of the organization will be to improve and conserve cattle using scientifically sound principles. Membership should largely comprise of the farmers but should be flexible to accommodate development partners or related associations in the area and technical personnel from with in the area. For this particular group under discussion organizations like the National Animal genetic Resources Centre and Data Bank (NAGRC & DB) a body corporate under Uganda's Ministry of Agriculture, Animal Industry and Fisheries whose mandate is to establish a comprehensive breeding program for the country and operates 3 ranches in the area could be a member. Other technical personnel that could be considered include extension staff or community members with special skills of strategic importance, like artificial insemination or computer literacy. Although membership should be open to all farmers, it is important that members that join from the farming community understand the benefits of such a group, are able to articulate their needs, are willing to be organized in a group, willing to meet some of the start up costs like tagging of stock and to keep records.

The group should at all times maintain a link with technical support providers like NAGRC & DB and research organizations to provide technical support in development of breeding programs and training of farmers. Links should also be made with development agencies responsible for the development of infrastructure capacity. This includes roads, market links, credit facilities and communication networks all of which are essential for successful implementation of improvement programs

**The Breeding Committee**

A breeding committee to guide farmers on breeding issues and comprising of few members that meets on a regular basis should be established.

**The administrative committee of CBOGIL**

An administrative committee to co-ordinate and manage function should be elected early enough. Its functions should extend from day to day management to i) building up membership by encouraging community members in -its set area of operation to join. ii) Forging links and seeking support from development partners. This could either be in kind or financial. For example the study was conducted in Kiruhura district where cattle are the main source of revenue. District authorities could be lobbied to fund some of the activities or for construction and maintenance of strategic roads for easy access to markets. iii) negotiating reasonable prices for the farm produce with traders and farmers interested in buying breeding stock. iv) Maintaining links with development partners. Figure 1 shows possible relationships between different stake holders of a CBOGIL.

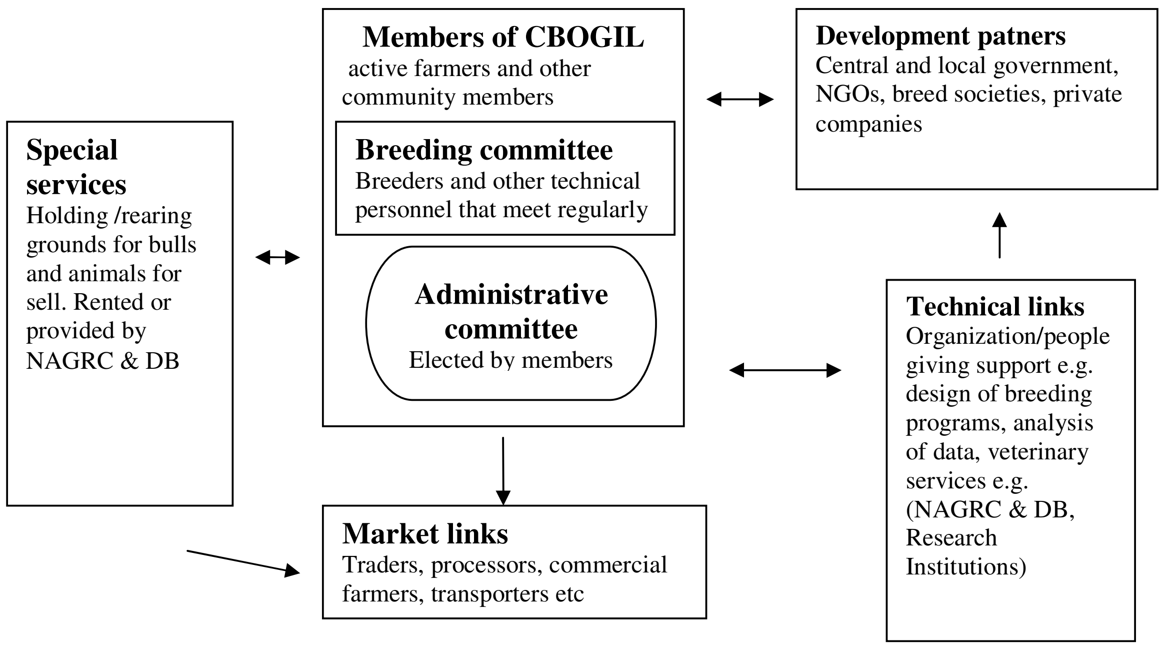


**Figure 1**: Possible relationships between farmers and other stakeholders on the CBOGIL

**Challenges envisaged**

Formation and functioning CBOGIL will be complex and may face some challenges, examples of these are discussed below.

Removal or castration of unwanted bulls may not be easily acceptable by all farmers especially when they have a strong attachment to a particular bull. Similarly it may be difficult for farmers to remove other non productive animals from the herd because of the traditional practice of maintaining the cattle as form of security. Artificial insemination services are still very poor in the area and farmers will have to rely heavily on natural mating. This may necessitate establishment of a bull exchange or sharing program. For some farmers this is totally unacceptable and this could be a source of conflict and have a negative effect on the rate at which good genes are disseminated in the herds.

There is a variation in herd sizes and in management, nutrition and disease control standards among the farmers. These differences will mask performance of potentially high yielding animals if reared in poorly managed farms. The above variation in management standard may affect the readiness of farmers to accept a bull from a particular farmer whose farm or animals may be considered to be inferior.

Continuous sensitization and capacity building of the farmers will therefore be necessary to overcome some of the mentioned challenges. One of the farmers with a large piece of land or alternatively one of the NAGRC & DB farms could be used as a rearing ground or holding station for young males or bulls before they are transferred to another farm or finally sold off. This will control unwanted mating and also temptation of the farmers selling off potentially superior genetic animals for slaughter when in need of money.

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# Chapter 6

## Summary

This thesis presents findings which are part of a study that aims to investigate the economic and ecological sustainability of a new livestock farming system emerging in South Western Uganda. In this new system farmers are keeping separate herds one of pure bred Ankole and the other of Holstein Friesian-Ankole crosses on one farm. The results are presented in three studies. The first is a review on crossbreeding for milk production in the tropics. The second reports findings of an on-farm study in which performance of the Ankole is compared to that of Holstein Friesian-Ankole crosses on a low input system. In the third study results from a study carried out to investigate breeding objectives and strategies for farmers in South Western Uganda are presented.

The review discuses experiences with crossbreeding for milk production in the tropics. Data from 50 separate studies in which performance of the different grades of crossbreeds had been evaluated along with the local breeds were compiled and analysed jointly. Relative performance of the indigenous breeds compared to the different grades of crossbreeds in 3 climatic zones in the tropics was calculated. Traits considered were milk yield per lactation, age at first calving, services per conception, life time milk yield and total lactations completed. At 50% *Bos taurus* level lactation milk yields were 2.6, 2.3 and 2.3 times higher than those of local cattle in Highland, Tropical Wet and Dry and in Semi Arid Climatic zones respectively. Lactation length increased by 1.2 to 2.3 times and calving interval reduced by 0.8 to 1 times. In spite of the fact that quick results can be obtained through crossbreeding it faces a number of challenges which include poor design of crossbreeding programs and absence of livestock recording systems (Kumar et al., 2003; Kahi, 2002; Syrstad and Ruane, 1998). Recent advances in genomic technology and in assisted reproductive technologies (Dekkers, 2007; Wheeler et al., 2006) plus a number of other factors provide opportunities for its wider use in the future.

The on-farm study was conducted over a period of 29 months in 3 sub counties in Kiruhura District of South Western Uganda. The aims of the study were to evaluate milk yield traits and growth characteristics of pure bred Ankole and Holstein Friesian -Ankole

crosses. A total of 18 farms keeping the Ankole and Holstein Friesian-Ankole crosses in separate herds on one farm were selected. On each of the farms up to 30 animals from each herd covering the complete age and sex range were recruited on to the study. The animals were assigned to 3 genetic groups namely: Ankole, HF50% for the F1s and HF>50% for animals with exotic inheritance of greater than 50% and animals were monitored on a 4 week basis. During each visit morning milk yield calving and dry off dates were recorded for the milking animals. For all animals in the study live weights estimated by chest circumferences, body condition score (BCS) and culling dates and reasons were recorded. All animals delivered by the selected cows were also recruited on to the study and animals that died or left the farm during the study were replaced by another similar animal.

All together 1786 animals were entered into the study. Daily milk yields for the three genetic groups were 2.44±0.22, 6.7±0.27 and 7.44±0.08 for the Ankole, HF50% and the HF>50% respectively, while the observed Live weights were 305.4±2.98, 388.6±4.5 and 394.7±1.6 Ankole, HF50% and the HF>50% respectively. BCS) for the groups did not differ significantly but varied (P= 0.01) in different months of the year. The HF>50% had lower age at first calving of 29.1±1.63 months (P<0.0001) of as compared to 38.9±1.96 months in the Ankole. Observed calving intervals for the Ankole and HF>50% were 16.04±0.68 months and 15.3±0.47 months respectively.

The above results show that the crosses perform better. They have higher milk yields and lower calving intervals. It is likely that crossbreeding of Ankole with Holstein Friesians will continue at a much faster rate than is currently taking place. There are however signs that this program can run into problems: There is no defined breeding program. It was observed that continuous upgrading of cattle without or little recording taking place. This could result in the generation of a crossbred population with high levels of exotic inheritance that are not well adapted to the production environment (Kahi, 2002). Technical interventions that will enable farmers establish a simple but effective recording system and breeding program are therefore necessary. Community Based Organizations for General Improvement of Livestock (CBOGIL) have been proposed (Sölkner *et al*. 1998; Kahi *et al.* 2005) as possible avenues through which proper planning and implementation of breeding programs can be achieved. Results from a study conducted to investigate the possibility of setting up such a program in South

Western Uganda are reported in chapter 4. Thirty four cattle keepers were selected from the area and individual interviews focusing on breeding objectives and strategies and on socio-economic background were conducted amongst them. The majority of the cattle keepers (88%) kept pure bred Ankole and Ankole Holstein-Friesian crosses in separate herds. Crossbred cattle were mainly kept for marketable milk while Ankole were kept for cultural reasons, as security and store of wealth.

The cattle keepers had an established system through which breeding activities were controlled. Exchange of bulls was acceptable or practiced by 66% of the farmers while 34% were totally against it. No bulls were shared between the livestock keepers. Each livestock keeper owned at least one bull per herd. More than half of the interviewees stated that they kept mental records of the progeny history of their herds and 71% stated that they shared breeding information with family members and friends.

It was concluded that CBOGIL are a viable avenue improvement for the in South Western Uganda. The programs can ensure sustainable production of suitable genotype for the farmers plus they can bring about numerous benefits to the communities like organized market channels for milk and livestock. Success of programs will however depend on a number of factors which include interest of the cattle keepers, long term commitment and involvement of the cattle keepers and their partners while designing the breeding programs.

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# Appendix

## Selected photographs taken during the study

A group of Ankole calves at one of the study farms

Ankole cows on one of the study farms

Data collection on one of the farms

A crossbred cow with its calf on one of the farms


A valley tank on one of the study farms