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COMPARISON OF LANDIM AND AFRICANDER CATTLE IN SOUTHERN MOZAMBIQUE FOR GROWTH REPRODUCTION AND TOTAL PERFORMANCE

JULIO G. V. CARVALHEIRA

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COMPARISON OF LANDIM AND AFRICANDER CATTLE IN SOUTHERN MOZAMBIQUE FOR GROWTH, REPRODUCTION AND TOTAL PERFORMANCE

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Julio Gil Vale Carvalheira

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Robert D. Blackburn

ABSTRACT

Objectives were to compare the growth and female reproductive performance of Landim and Africander breeds and to estimate the genetic and phenotypic variance components for growth and reproductive traits using data collected from 1968 to 1981 at the Chobela Research Station in Mozambique. Breeds were managed together and grouped by age and sex, except when separated for breeding.

Growth traits were body weights at birth, weaning at 7 mo (WW), 18 mo (W18), first calving (WFC), and pre- and post-weaning daily growth rates. Reproductive traits were age at first calving (AFC), first calving interval (FCI), and 2nd and subsequent calving intervals (CI). Growth traits were analyzed using a fixed least squares model, containing breed (B), year-season of birth (YS), sex, YS x B interaction, parity/B, and linear regression on dam's age/B. The model for reproductive traits included B, YS, and conception group/B. The model for the genetic analyses also included the random effect due to sire for each trait (sire model).

Africander exceeded Landim in all early body weights being about 15 ± 3 kg heavier at 18 mo than Landim which averaged 238 kg. The Africander calves were 15%, 11% and 6% heavier than the Landim for birth, weaning and 18 mo adjusted weights ($P<.01$), but no difference was detected for age-adjusted WFC and post-weaning daily growth ($P>.5$).

In contrast, Landim females were 4% younger at first calving and had 47 ± 7 d (or 10%) shorter FCI than the Africander average of 480 d. The mechanism for this superior reproductive performance was the greater probabilities of conception for Landim females at first breeding exposure as heifers and as cows ($P<.04$).

Weaner and yearling productivity indices containing WW or W18, WFC and rates of survival and calving showed that the Landim were 21% to 25% superior to the Africander in terms of weaner ($P<.01$) and yearling ($P<.01$) calf offtake per kg of cow weight per year.

In a restrictive environment like the Chobela Research Station, where the expression of genetic variances should be expected to be compressed, larger components of genetic variance for early body weights and reproduction were estimated for the Landim breed, which may signal one mechanism (i.e., additive genetic) of greater adaptation, especially in reproduction, of this breed to conditions of the local environment.

Africander was widely disseminated in the tropics based on large mature size. However, the indigenous Landim was more productive in the Chobela environment partly due to diminishing weight differences with advancing age, and especially because they were more likely to conceive at first exposure as heifers and as cows. As a result Landim gained advantage by being younger at first calving and having shorter calving intervals.

BIOGRAPHICAL SKETCH

Julio Gil Vale Carvalheira was born in Nampula, Mozambique on April 19, 1955. He graduated from the Agriculture Technical School in Manica in 1973 and got his DVM degree from the Eduardo Mondlane University at Maputo, Mozambique in 1977. Following graduation from the Veterinary School, Julio was assigned to the Chobela Research Station to work as a research assistant until 1979. From 1980 to 1982 he worked in the Veterinary Extension Department at Maputo Province. He was then appointed as the head of the technical staff in a Parastatal Dairy Company up to 1988 after which he joined the Department of Animal Production at the Faculty of Agronomy and Forestry Engineering at the Eduardo Mondlane University. In January 1990, he began his M.Sc. program at Cornell University in the field of Animal Breeding.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The most numerous livestock species on the African continent is cattle, which accounts for more than 70% of all domestic livestock animal units (1 AU = 450 kg live weight, Scholtz, 1988). The array of tropical conditions in African territories results in a variety of difficult environments. Animals in these environments face high temperatures, humid climates, lengthy and pronounced dry seasons, and extensive exposure to diseases. Consequently, it is important to utilize well-adapted livestock, first ensuring their survival, and then to produce supplies of animal products.

Breeds of native African cattle are arguably well-adapted to their various environments from thousands of years of natural selection. Most stock are kept under simple management conditions and receive little supplementary feed or health care. Specialized beef and dairy industries are uncommon, except around urban centers (Trail, 1986). There is need to know more about these native breeds to design appropriate breeding programs because of nutritional and disease limitations in most African environments, which has resulted in a diverse array of cattle breeds.

The limited genetic potential of indigenous cattle has often been cited as a major constraint for beef and milk production in Africa and other regions in the tropics (Scholtz, 1988). However, characteristics like mothering and walking abilities, survival on poor feeds, climate and disease tolerance, and water economy are fitness qualities that also contribute to animal performance through survivability, which may be what is indicated by the term adaptability. As Trail (1986) pointed out, it should not be surprising that livestock from Africa's environments are slow growing, late maturing and modest milk producers. The primary performance criterion in these difficult environments is survivability.

Consequently, a major constraint in designing breeding programs in tropical regions is the lack of information about local breeds that survive (are adapted) in nutrient-limiting and disease challenged environments. Knowledge about the characteristics of these breeds is essential for deciding breeding programs, particularly in the tropics. If this information had been available it might have dramatically influenced the decision making leading to earlier programs (Trail, 1986; Scholtz, 1988).

In Mozambique, like other tropical countries, the lack of information about the performance of indigenous cattle in several instances led to wrong decisions in regard to cattle breeding, which jeopardized the conservation of useful germplasm. The loss of useful livestock germplasm should be an important concern of cattle breeders in tropical environments like it is in other areas of natural resource conservation and biodiversity.

Besides their use in resource poor environments, potential benefits from evaluating indigenous breeds may be from their use in crossbreeding and in forming synthetic or composite breeds. There are major differences in terms of production between Bos taurus and Bos indicus breeds. An objective of cattle crossbreeding systems is to capitalize on some of the breed differences in additive genetic merit for economically important traits. Performance characteristics of specialized Bos taurus breeds then may be synchronized with the adaptability of Bos indicus breeds to a given environment and with market requirements. Heterosis effects can be simultaneously exploited to increase economic returns from genetic management (Trail and Gregory, 1981). Forming synthetic or composite breeds is a potentially attractive alternative or supplement to continued crossbreeding. This approach avoids the management complexity of maintaining rotational crossbreeding systems and has the potential advantage of eliciting a greater response to selection from a larger pool of genetic variation (Trail and Gregory, 1981).

Mozambique and the other countries on the southeast coast of Africa have particularly difficult environments for cattle production in terms of climate and disease (Scholtz, 1988). In order to manage breeding programs (crossbreeding and/or formation of synthetic or composite breeds), it is necessary to have accurate information about the environment and the breeds that are to be used. Indigenous breeds are the obvious first choice to found such breeding programs because of the need for adaptability in livestock populations in African environments. A necessary step for making objective decisions about the genetic improvement of livestock, is to quantify differences between breeds to determine preferred choices and breeding system(s). In this context breed comparisons yield the major source of information to assess the potential breed resources to utilize.

Consequently, and in accord with the existing data resources, this study contains a description of the Mozambican environment with regard to livestock production, and a quantitative comparison in growth and reproductive performance of Africander and Landim, which is the main local breed. This chapter describes the general aspects of climate, the types of pasture natural resources for cattle production, the prevailing cattle production systems and populations, and the specific research objectives addressed in this thesis.

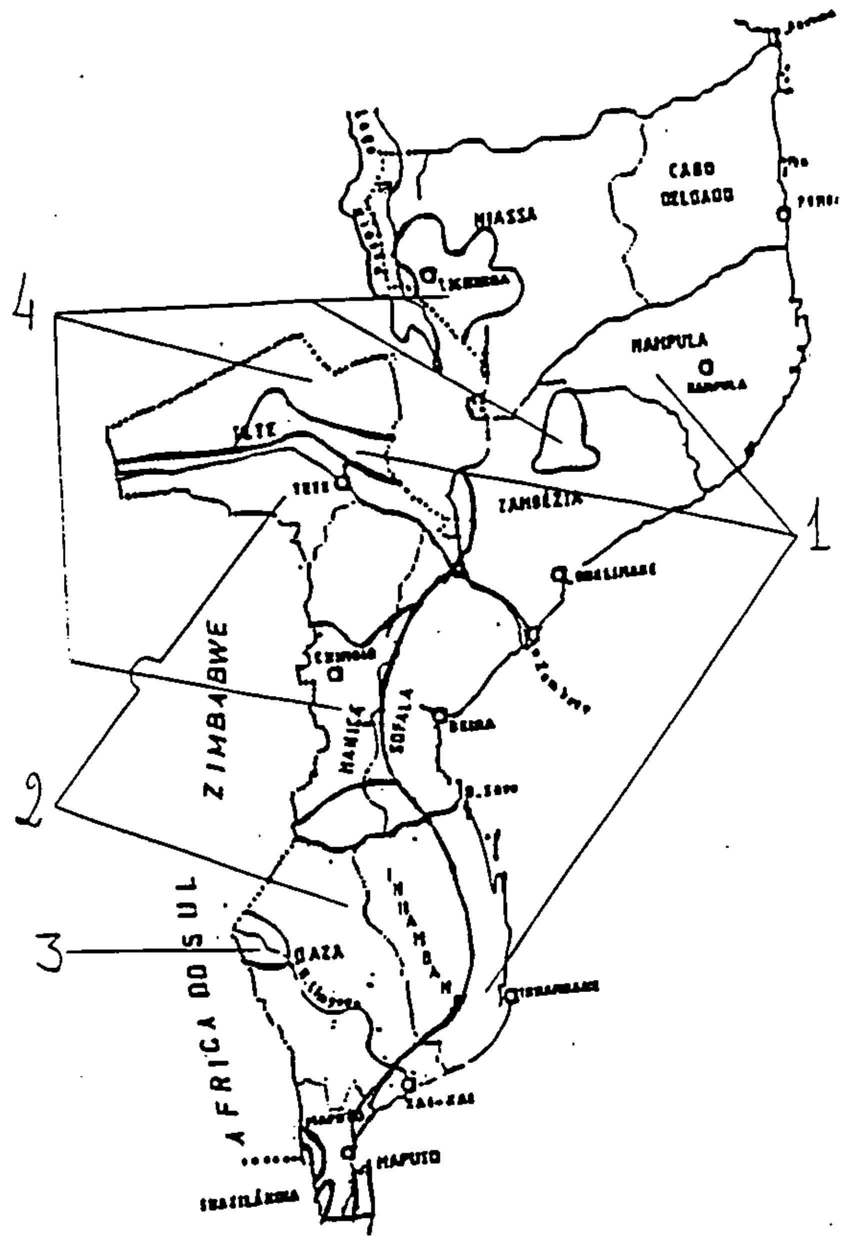
1.2 MOZAMBIQUE'S ENVIRONMENT

1.2.1 GEOGRAPHY AND CLIMATE

Mozambique is located in southeastern Africa along the Indian Ocean with 2,500 km of coast line between latitude 30° and 40° E and longitude 10° to 28° S. Mozambique covers almost 800,000 Km^2 and has borders with Tanzania, Malawi and Zambia in the north, and Zimbabwe, South Africa and Swaziland in the west and south (Map 1).

Mozambique comprises a variety of ecozones and ecosystems. The characteristic unimodal rain distribution defines the two main seasons -- the wet, hot season and the dry, cool season. The duration and amount of rainfall varies from north to south. The rainy season in the north is shorter (~4 mo) but has more annual precipitation (~1200 mm) than in the south, which receives ~600 mm of rainfall in a 6 mo period. The rains typically begin in October or November.

Zones of "mixed" and "sour veld" natural pastures, are found throughout the country. Sweet, mixed and sour veld are designations widely used in the region to describe the palatability and nutritive value of natural pastures during the dry season. Sweet veld refers to pastures in low rainfall regions where grasses retain some palatability and nutritive value. Sour veld refers to intermediate to high rainfall



ECOZONES	ALTITUDE Range (m)	RAINFALL Range (mm)	TEMPERATURE Range (°C)
1	0-500	600-1,200	22-26
2	100-500	400-800	› 26
3	200	0-400	› 26
4	› 500	› 1,200	18-22

Map 1. Climate and Geography of Mozambique.

regions where nutritive quality is high in a short growing season, but with a sharp decline in nutritive value in the dry season. Mixed veld, as the name implies, corresponds to pasturelands that are intermediate between sweet and sour veld from the previous ones. Sweet veld is the most sensitive to overstocking, especially during the growing season, generally supporting not more than .25 AU per ha. The carrying capacity usually increases to .3 or .5 AU per ha in the mixed and sour velds, but body weight losses in cattle are greatest in the dry season.

There are four main climatic zones (Map 1) ranging from humid to semi-arid and arid regions including zones where climate is modified by altitude. The annual rainfall ranges from 600 mm to 1200 mm with an average temperature of 24° C which includes most of the northern part of the country in the coastal belt. This is generally characterized as the wet region.

The southern and northwestern parts of the country make up the second zone. This area experiences lower rainfall (400-800 mm) and higher temperatures (26°C), typical of a dry region. Because of the low rainfall, the natural pastures are classified as sweet veld. The grasses maintain some of their nutritive value during the dry season as standing hay. They are sensitive to overgrazing, especially during the growing season, easily giving way to brush encroachment.

The west and north of the country contain high plateaus of more than 500 meters in elevation. The climate in this region is modified by variations in altitude, which is characterized by high rainfall (more than 1200 mm per year), and mild temperatures ranging from 18° to 22° C. The natural pastures are classified as sour veld.

Finally, there is a well-defined region in the southwestern part of the country, bordering on Zimbabwe and South Africa, which is predominantly sweet veld. This region is characterized by an arid to semi-arid climate, very low rainfall (less than 400 mm), and temperatures averaging more than 26° C.

1.2.2 LIVESTOCK PRODUCTION

The Mozambican economy is based on agriculture, which accounts for 45% of the Gross National Product (GNP) and employing over three-quarters of the population. Agricultural products contribute about 75% (Relatório Nacional de Estatistica, 1988) of the total income from exported goods. Although there exists potential for larger contributions, the livestock industry has historically played a minor commercial economic role in agriculture, accounting for about 5% of the 45% of the GNP that comes from agriculture.

Mozambique is the south African country with the smallest ratio of cattle to human inhabitants (.07 head per capita).

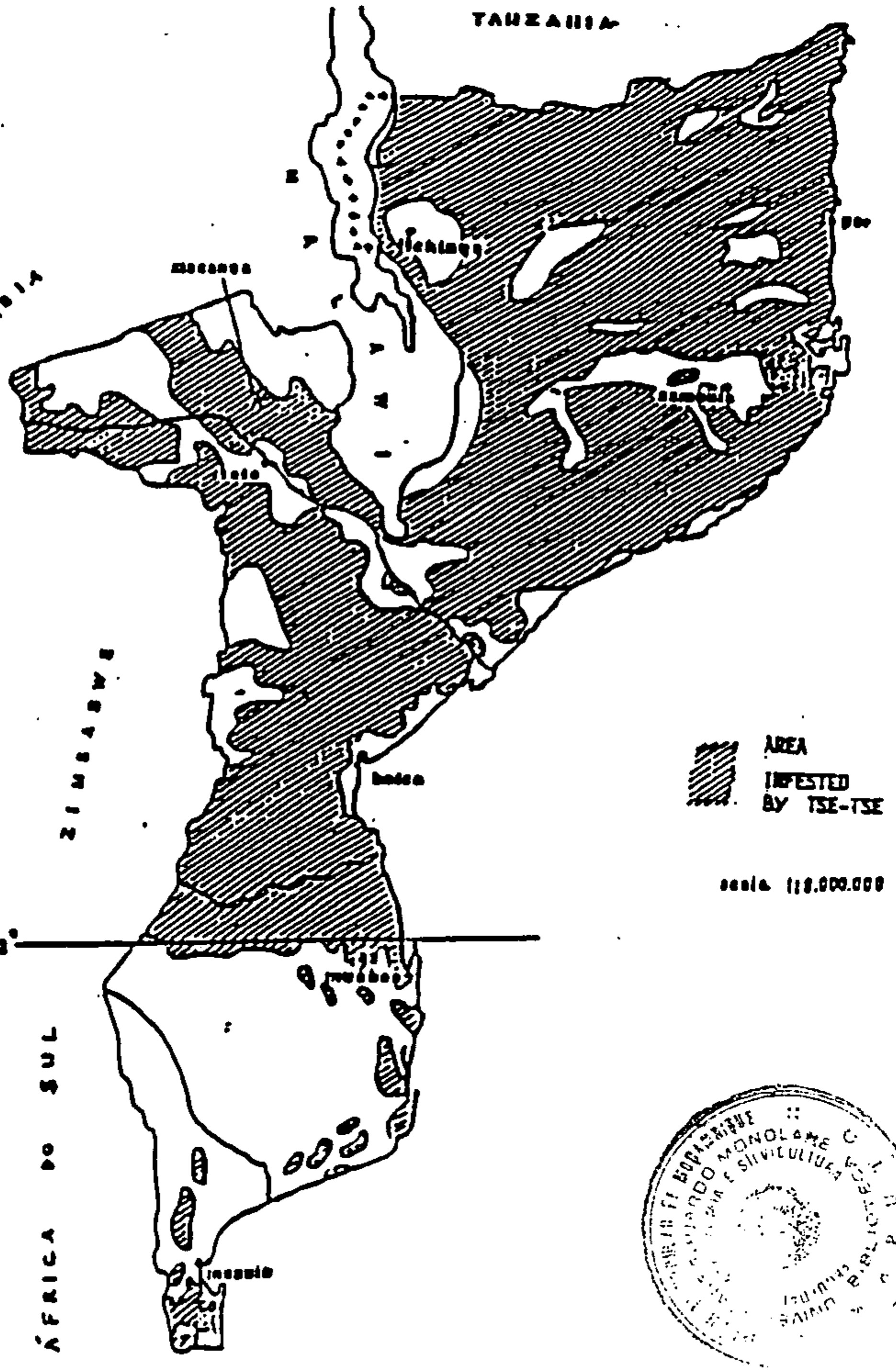
This is perhaps a result of the harsh environment for cattle production that prevails in most of the nation. All neighboring countries have more cattle than humans. The 1988 statistics indicate that the total annual registered meat production per hectare (all domestic species), was only 78 grams, which was considerably less than in previous years (e.g., .25 kg in 1975). In Latin America this index was about 20 kg per year per hectare of cattle land (Dionisio, 1985). Another indicator of cattle productivity is the amount of meat produced (from cattle sold in official markets), divided by the cattle population. In 1988, this index was only 6 kg compared with 11.3 kg attained in 1971.

Cattle account for the most important form of livestock production in Mozambique. The first statistics were recorded in 1930 with the first national census. These statistics have been subsequently updated annually by the Livestock Department of the Ministry of Agriculture. Several factors contribute to the low cattle productivity and population. One reason is that few Mozambicans are natural cattlemen like the Maasai pastoralists of Tanzania or the Swazis of Swaziland (Campion, 1978). However, the most important constraint is that two thirds of Mozambique is infested with tsetse fly (Pinto, 1989), the main vector for trypanosomiasis. This disease causes high morbidity and mortality in ruminants. The central and northern regions are the ones most affected (Map 2) and, because of their climatic and soil conditions, are also the areas with most potential for cattle production. This partly accounts for more than 75% of the cattle in this area belonging to the commercial sector. This sector has the greatest financial resources to cover expenses for curative drugs. On the other hand, the absence of tsetse fly in the south explains the high cattle density in these provinces (70% of the total -- Map 3).

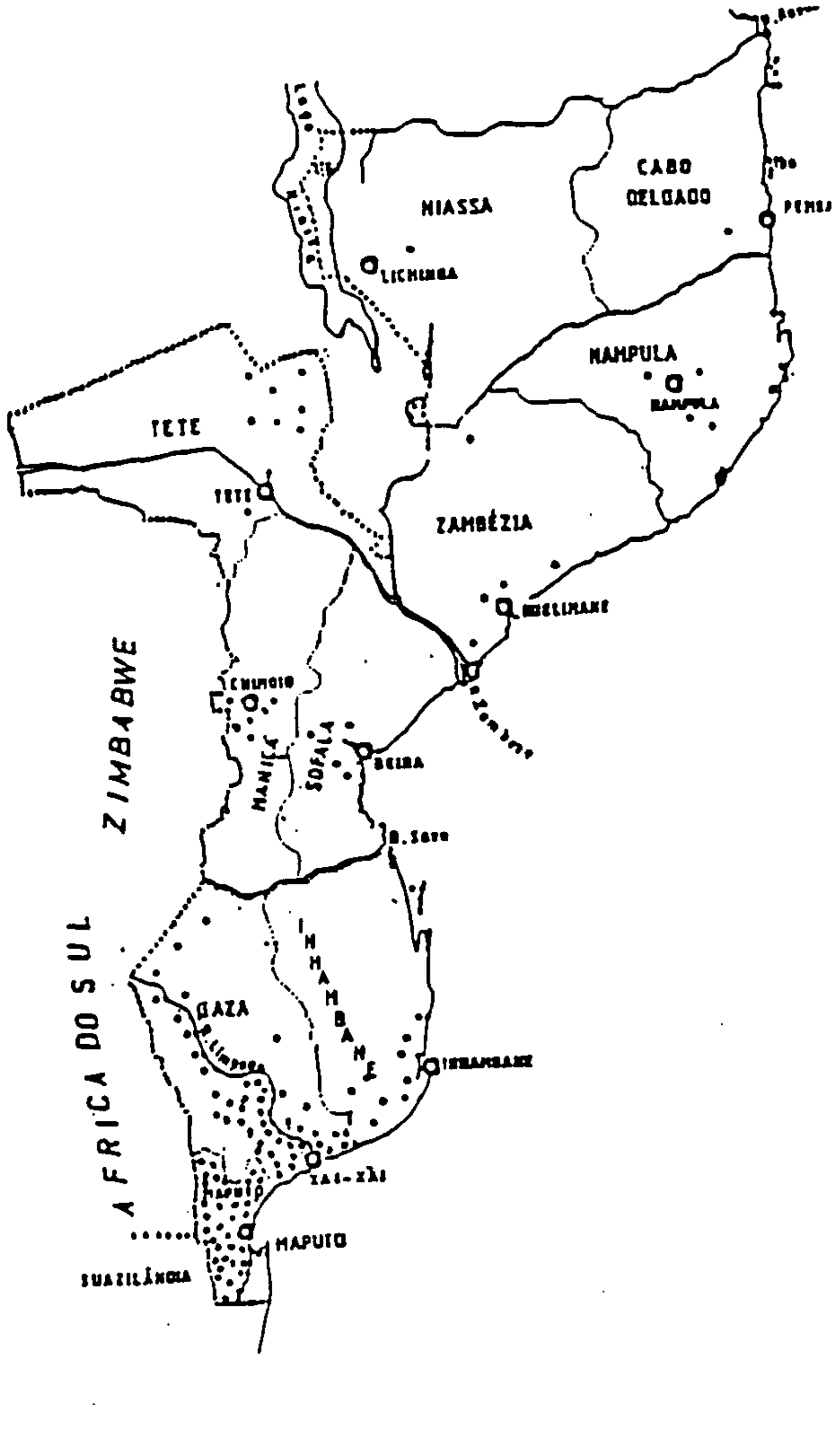
Cattle ownership in Mozambique is divided into three main sectors -- the peasant, the private and the parastatal sectors. The last two are essentially composed of farms forming the commercial sector, while the peasant sector is primarily a subsistence system. Tables 1.1 and 1.2 show the temporal and sectorial distributions of cattle in various regions of Mozambique, and the proportions of cattle in the commercial and family farming sectors. The southern provinces south of the Save River (Table 1.2) are almost free of the tsetse fly or the incidence is low enough to permit cattle production. Also, the tsetse fly does not survive in the highlands or in deforested areas in the west and north of the country.

The national cattle population almost doubled between 1950 and 1975 despite a severe drought in the early 1970's (Table 1.1). Average annual growth between 1930 and 1974 was 2.7%, and the largest cattle population was 1.45 million head in 1974. Historically, the dairy herd has been small, the largest population was registered in 1970 with about 13,000 cows.

The cattle population has decreased dramatically since Mozambique gained independence from Portugal in 1975. This decrease was relatively small in the first seven years after independence (-1.4% per yr from 1975 to 1982). However, since 1983 cattle numbers have decreased about 14% per year. There are now probably less than one-third as many cattle in Mozambique as there were in 1974 (Table 1.1).



Map 2. Tsese fly infestation in Mozambique.



Map 3. Geographical distribution of cattle in Mozambique in 1988. (• ~ 5000 head).

Table 1.1. Cattle population of Mozambique 1950-1988[1].

Year	Total cattle[2]	Percent of 1974 pop.	Ownership		Annual growth	
			Family	Commercial[3]	1 or 5 yr	1950=0
		%				
1950	738	50.8	77	23	...	...
1955	835	57.5	73	27	2.6	13.1
1960	1088	74.9	72	28	6.1	47.4
1965	1134	78.0	67	33	.8	53.7
1970	1338	92.1	59	41	3.6	81.3
1971	1262	86.9	53	47	-5.7	71.0
1972	1356	93.3	53	47	7.4	83.7
1973	1407	96.8	52	48	3.8	90.7
1974	1453	100.0	52	48	3.3	96.9
1975	1422	97.9	58	42	-2.1	92.7
1976	1326	91.3	70	30	-6.8	79.7
1977	1282	88.2	64	36	-3.3	73.7
1978	1271	87.5	71	29	-0.9	72.2
1979	1306	89.9	70	30	2.8	77.0
1980	1306	89.9	78	22	0.0	77.0
1981	1305	89.8	78	22	-0.1	76.8
1982	1292	88.9	79	21	-1.0	75.1
1983	1126	77.5	81	19	-12.8	52.6
1984	977	67.2	82	18	-13.2	32.4
1985	620	42.7	82	18	-36.5	-16.0
1986	692	47.6	81	19	11.6	-6.2
1987	592	40.7	84	16	-14.5	-19.8
1988	486	33.4	82	18	-17.9	-34.1

[1]Compiled from Bol.Dinap Moç., (1976); Campion, (1978); Pinto, (1989).
[2]In thousands.
[3]Private and state farms.

Table 1.2. Cattle distribution by region of Mozambique from 1950 to 1988[1].

Year	South		Central		North	
	N[2]	%	N[2]	%	N[2]	%
1950	544	74	188	25	6	1
1955	600	72	223	27	12	1
1960	784	72	285	26	19	2
1965	765	68	342	30	27	2
1970	847	63	432	32	59	5
1971	771	61	420	33	71	6
1972	832	61	439	32	85	6
1973	859	61	453	32	95	7
1974	926	64	436	30	91	6
1975	907	64	424	30	91	6
1976	886	68	364	27	76	5
1988	345	71	114	24	27	5

[1]Compiled from: Bol.Dinap Moç., 1976; Campion, 1978; Pinto, 1989.
[2]In thousands.

There are several reasons to explain this dramatic decrease in the cattle population. First, there was a large exodus of management personnel in 1975-76, especially technicians and administrators. The national herd decreased by 10% in these two years, almost entirely in the commercial sector. With a worsening civil war in 1982, all sectors suffered production losses, especially the family sector. Then there was mass exodus of peasants and their families from rural areas to the cities, the impossibility of adequate veterinary and other extension services, and destruction of the majority of the productive infrastructure contributed to almost 15 years of socio-economic instability.

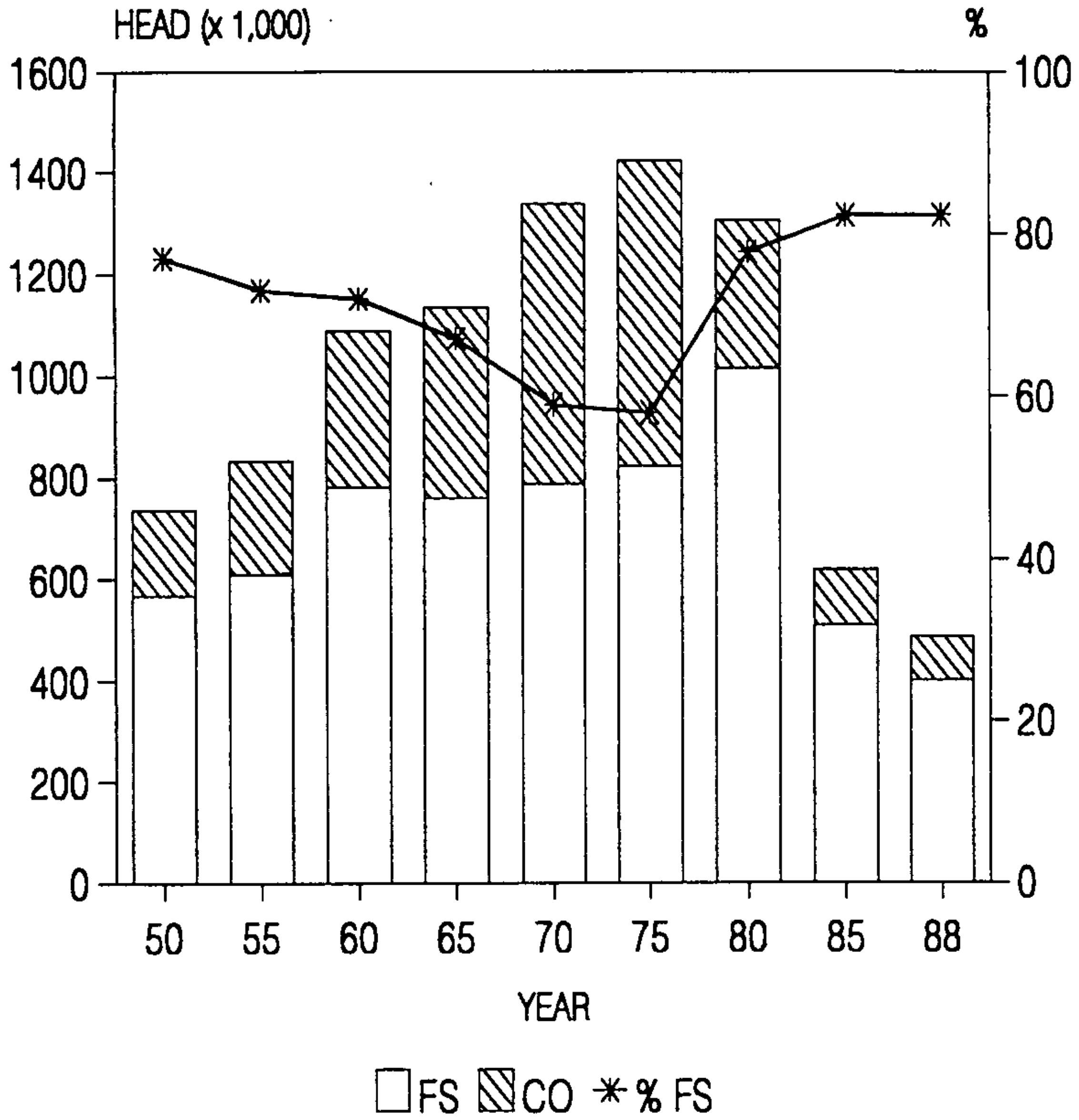


Figure 1.1. Change by sector of production in the cattle population in Mozambique from 1950 to 1988. FS=family sector; CO=commercial sector; %FS=proportion of cattle in the family sector.

1.2.3 PRODUCTION SYSTEMS

1.2.3.1 THE FAMILY SECTOR

The largest unexploited asset of the livestock industry in Mozambique is peasant-owned cattle, which now represents more than 82% of the national herd (403,380 head). The importance of this sector is not restricted to the potential output in animal products. Many commercial farms were established based on cattle purchased from the family sector and perspectives for the future are the same for new commercial farms. There are no reliable records to show how many cattle moved from this sector directly into the commercial sector. In 1970, about 13,000 head were purchased through organized sales, and it is likely that more came to the commercial sector by other means (Campion, 1978). Mozambique's family sector also works as a reservoir of livestock, especially cattle. The family sector is the most feasible source of livestock to feed the needs of expansion in the commercial sector in a post-war era.

The family sector owns almost exclusively indigenous livestock. There are three indigenous cattle breeds in Mozambique of which two are Sanga breeds. The term Sanga was generalized by Mason and Maule (1960) to refer to all eastern and southern Africa cattle with small cervico-thoracic humps. Morgado (1954) supported the hypothesis that the Sanga breeds evolved from crosses between the Longhorn cattle (Bos primigenius) native to the Nile valley and the shorthorn Zebu (Bos brachyceros) introduced in this region around 3000 BC during invasions of the Semitic tribes from Asia. The Sanga cattle were then spread into southern Africa through migrations of the Bantu tribes. The East African Shorthorn Zebu is believed to be of more recent origin as a result of the influence of cattle brought by Arab and Indian traders (Morgado, 1954).

The Landim, which is the most numerous Sanga breed in Mozambique, occupies the south and central regions. The Tete cattle is a distinct type which is localized in the south of Tete Province near to the Zimbabwe border. The Tete is a small (about 20 thousand head) nucleus of animals and perhaps is better classified as intermediate probably resulting from crosses between the Sanga and Zebu (Mason and Maule, 1960). The Angone breed, is a type of small East African Shorthorn Zebu, originating from the Angonia plateau in the north of the Tete Province.

Households in the family sector usually practice a sedentary agro-pastoral system. About 40 to 80% of the livestock are in mixed (crop/livestock) farming systems in the tropics (McDowell, 1986); and Mozambique is no exception, where more than 90% of cattle owners manage mixed systems (Pinto, 1989). The cattle graze communal lands surrounding the family households and in crop (mostly maize) fields after harvest. At night, animals are kept in small corrals without feed. Animals of both sexes and all ages are managed in one herd. There is a well-defined calving season that coincides with the beginning of the rainy season. This system receives very little input except for managing health, which is provided gratis by government extension specialists. Weekly dipping is used to control ticks, and annual vaccination clinics are provided to control the major diseases of anthrax (*Bacillus anthracis*) and blackleg (*Clostridium chauvoei*).

Milk, manure, draught power, meat, cash reserve (savings), and cash income are the main uses for cattle in the family sector. Several studies (Rocha, 1985; Rocha *et al.*, 1988; Dionisio, 1989; Valadares, 1989), showed that at least 90% of smallholders milked their cows daily during the wet season. The general practice is to separate calves and cows (usually at night), and allow the calves to suckle until milk let down. The calf is then moved within view of the cow, and the remainder of the milk is extracted by hand for human consumption. After milking, all animals go to graze and calves are free to nurse. Manure is almost exclusively utilized as fertilizer, whether directly when the animals are feeding on crop residues in fields or by spreading manure collected from the night corral.

Draught power is a very important aspect in the family household economy. Pinto (1989) observed a direct relationship between herd size and cultivated area in this sector (Table

1.3) where wealthy families own more cattle and more land. Considering that the average herd size in the family sector is 10 head per owner, this may be an indication of the importance that cattle have in agricultural production for this sector.

Table 1.3. Relationship between herd size (head) and cultivated area in the family sector.

Herd size per family	Cultivated area (ha)
1.2	1.1
3.5	1.9
6.9	3.6
> 9.0	7.6

Beef production is perhaps the most important commercial output from the family sector. The only official data concerning meat production in this sector is based on the number of the animals sold for urban consumption through official retailers. These sales are about 1% of the national beef offtake. This figure is very low even for a system based on subsistence. A recent study (Pinto, 1989) shows that the offtake in this sector was much higher when considering all uses that cattle have in the household economy. For example, exchanging animals directly for cereals and other products, and home consumption contributed substantially to the total offtake (Table 1.4).

Table 1.4. Major uses of cattle in the family sector of Mozambique (output of cattle per year expressed as a percentage of the national herd)[1].

Use	Offtake
	%
Official retailers	.4
Exchange for cereals	4.0
Direct sale	2.3
Home consumption	.8
Ceremony	.4
Payment for services	.5
Exchange for other products	.2
Total offtake	8.6

[1]Source: Pinto (1988).

1.2.3.2 THE COMMERCIAL SECTOR

The commercial sector was dominated by private owners until 1975. After independence, many cattle owners, mostly expatriates, left the country and their farms were taken over by the government. Now, the commercial sector consists of state and private farms that have a high level of management and specific economic objectives.

Until the end of the 1950's there was little difference in management between the private and family sectors (Dionisio, 1985). Since then, improvements in infrastructure, such as fences, water holes, dipping tanks for tick control, and adoption of management practices (e.g., breeding season and pasture rotation) have differentiated these two sectors. Also, it was during this period that the first specialized dairy farms came into operation using Holstein crossbreds.

There are no intensive systems of production in the country. All cattle graze on natural pastures with few exceptions. However, during the dry season some supplements, mostly molasses and urea, and hay from natural grasses are fed. In addition, dairy farmers usually supplement lactating cows with wheat bran (obtained from milling imported wheat) and other by-product concentrates (also from the food industry).

In general, farms in the commercial sector separate animals by age and sex. There is a defined mating season usually from February to April. A preventive health program for the major diseases is also common including vaccination against brucellosis and in some cases immunization against heartwater disease (rickettsiosis).

Starting in 1941, several *Bos taurus* and *Bos indicus* breeds were introduced and utilized by this sector to improve the local cattle or, in a few cases, were maintained as purebreds. Table 1.5 shows the primary breeds imported into Mozambique between 1941 and 1975.

Table 1.5. Imported breeds in the period 1941 to 1975 (percent of the total of 8820 head)[1].

Breeds	(%)
Africander	34
Holstein Friesian	22
Hereford	14
Simmental	8
Brahman	6
Charolais	5
Jersey	2
Sussex	2

[1]Source: Dionisio (1985).

The management practices used in general by the commercial sector resulted in higher productivity for this sector in terms of reproduction, survivability, and in meat and milk yields. Table 1.6 show some productivity parameters achieved by the commercial sector in Mozambique by region.

Table 1.6. Productivity in the commercial sector of Mozambique by region[1].

Parameters	South	Central	North
Calving rate (%)[2]	62	61	61
Mortality (%)[3]	7	10	10
Off-take (%)[4]	17	10	12
Carcass weight (kg)[5]	189	125	143
Milk/cow/year (kg)[6]	2194	1545	1105

[1]Compiled from: Bol.Dinap Moç. (1976); Dionisio (1985); Carvalheira and Vaz (1989); and Pinto (1989).
[2]Expressed as the percentage of calves born from the total number of breeding females. Average for the period 1967-74.
[3]Expressed as the percentage of animals that died from the total cattle in the commercial herd. Average for the period 1967-74.
[4]Expressed as the percentage of animals sold from total cattle in the commercial herd. Average for the period 1967-74.
[5]Average dressing weight for the period 1967-74.
[6]Average for 1988. Dairy cows only (Holstein crossbreds).

1.3 SUMMARY AND OBJECTIVES

Mozambique is a developing country with grave social and economic difficulties. The rural social structure has collapsed. Rebuilding and sustaining Mozambique's framework requires overcoming a series of challenging constraints. The lack of knowledge and experience to solve important problems in several areas of the animal sciences, makes research necessary to meet the immediate needs and to provide solutions to problems which are likely to arise during the next 20 years and more.

The major role for livestock production lies within the family sector. With proper incentives, the family sector can increase livestock productivity. In doing so, it could become the major supplier of meat, milk, and other animal products in the marketplace.

In the commercial sector, it is likely that private ownership will evolve to a dominant system of production. The likely goal will be to strive for a dual purpose cattle system instead of a highly specialized breed or system of production. This approach takes advantage of natural pasturelands, one of Mozambique's major natural resources (Silva, 1966).

In socio-political situations like in Mozambique, where there is high priority to rebuild lost productive capacity, all information on cattle breeds, especially the predominant ones like the Landim and the Africander, are of critical importance to effectively guide the national welfare. The economic situation in Mozambique will force more intensive use of local resources in all areas including animal production. Landim, the most numerous cattle breed in the country, and the Africander (which is well represented in the commercial sector), merit evaluation before deciding on critical programs to repopulate the country. In this context, comparisons between these breeds in the traits influencing beef production is essential for deciding future breeding and management systems. Consequently, the objectives of this study were 1) to compare growth and reproduction performance of Landim and Africander breeds, and 2) to estimate the genetic and phenotypic variance components for growth and reproductive traits of Landim and Africander breeds in Mozambique.

CHAPTER 2

LITERATURE REVIEW

2.1 TROPICAL ENVIRONMENTS

The tropics geographically encompass the earth's surface between latitudes 23° 30'N and 23° 30'S, but which is typically expanded to include the area demarked by latitudes 30° N and 30° S. Within these parallels are a great variety of climates, terrains, soil types and ecosystems, varying from the high altitude temperate climates, such as the highlands of Kenya and South America, to the rain forests of central Africa, South America and Asia, to the true deserts, of the Arabian Peninsula and the north of Africa. Varying combinations of altitude, precipitation, humidity, solar radiation, wind velocities and soil types result in a variety of diverse habitats, which, coupled with disease and social factors, pose a formidable task to those attempting to genetically manage cattle because each habitat presents its own problems and requirements (Ansell, 1985).

The countries of the developing world (Latin America, Africa and Asia) have 80% of the world's human population and more than 68% of all cattle stocks, but they yield less than one-fifth of the total milk and contribute less than one-third of the total beef from world's cattle (FAO, 1989). Cattle are important in the tropical areas of the world (Table 2.1). In addition to the fact that nearly half of the world's cattle are reared in tropical areas, this population is growing, both in absolute terms and as a proportion of the world cattle population. However, this growth in cattle numbers does not match growth in the human population, which means that improved productivity per head is required merely to maintain the relative contributions from cattle to the standards of living of people in tropical countries.

Table 2.1. World distribution of cattle in 1989[1].

Continent	Region	Millions	%
Africa	Tropics	177	14
	Other	8	0.7
Americas	Tropics	317	25
	Other	111	9
Asia	Tropics	306	24
	Other	85	6
Europe		126	10
Former USSR		120	9
Oceania	Tropics	23	2
	Other	8	0.6
Totals			
World	Tropics	824	64
	Other	458	36
Developing Countries[2]		878	68
Developed Countries[3]		404	32

[1]Source: FAO (1989).
[2]Defined as countries with less than US$1000 per capita in terms of GNP.
[3]Countries with more than US$1000 per capita in terms of GNP.

The rate of growth in cattle numbers in the tropics is the most rapid in Latin America, also rapid in Africa in spite of droughts and disease, and slowest in Asia (FAO, 1989).

Increasing the productivity of domestic livestock, especially the cattle owned by smallholders, is an important challenge for developing countries wanting to increase supplies of animal products.

2.2 ROLES OF CATTLE IN TROPICAL AFRICA

The reasons differ for utilizing cattle in agricultural systems in Africa compared to systems in western societies. Indigenous cattle are mostly used for multiple purposes to produce meat, milk, draught, and dung as fuel (when it can be dried) and fertilizer. Cattle are frequently maintained in subsistence (traditional) production systems in the tropics, where they are found in large nomadic herds across Africa and in sedentary smallholder farms in Latin America and Asia (Bondoc et al., 1989). Consequently, cattle in Africa cannot be separated into distinct classes by commodity or service (e.g., beef, dairy, draught). In many situations, the same animals are milked, used for draught and then slaughtered (Trail, 1981). Well defined beef or dairy industries are rare, although there are schemes to collect milk from smallholder producers around many of the large population centers.

McDowell (1978) described the smallholder farmer as being especially dependent on livestock with little or no use of outside labor, and with returns that provide little more than subsistence. The husbandry and management practices and the attitudes of owners towards their cattle are such that productivity is generally low and with little or no change resulting from the introduction of breeds that are more productive in less input-limiting environments (Hofmeyr, 1974; Trail, 1981; Payne, 1981; Ansell, 1985; Bondoc et al., 1989).

2.3 CATTLE BREEDS IN THE TROPICS

Most developing countries are in the tropical belt in ecological zones ranging from desert to tropical forests. Cattle breeds native to these areas have a relatively low potential for production, but as a result of artificial and natural selection are adapted to local environments and tolerant to various stressors. Important factors affecting animal productivity are: high ambient temperatures, seasonal and erratic or inadequate rainfall, inadequate feed supplies, serious diseases, low-input animal management practices among stock owners, inadequate capital, and low genetic potentials in the typical production traits (Ansell, 1985).

Most cattle indigenous to the tropics are Bos indicus, which generally exhibit low milk production, low weight gains and late maturity (Ansell, 1985; Trail, 1986; Bondoc et al., 1989), even under good dietary and management regimes. On the other hand, indigenous cattle often exhibit remarkable tolerance to environmental stressors (e.g., the ability to maintain themselves on poor quality feedstuffs, some resistance to local diseases).

Hofmeyr (1974) pointed out that reproductive fitness is a useful measure of adaptability. High reproductive rate implies that a genotype (i.e., a population) is in equilibrium with its environment (Hofmeyr, 1974). Nonetheless, indigenous livestock are often regarded as inferior from a production point of view when compared with exotic breeds from temperate zones. This widely held opinion is based not only on the generally slow growth and low milk yield of indigenous livestock under nutrient limiting conditions, but also due to their modest responses to more favorable conditions. A logical argument is that indigenous animals (populations) survive in harsh environments by natural selection (i.e., humans are also natural predators) for fitness traits (e.g., reproductive rate, resistance to disease) and against excessive (i.e., obtaining diminishing returns in) yields in growth and milk.

Considerable efforts have been and are being made to increase output through breeding programs in many African countries (Trail, 1981). These efforts include introduction of European and Zebu breeds. Early reports of the importation of <u>Bos taurus</u> cattle to tropical countries generally showed unsatisfactory results. The performance of European breeds often has been disastrous with retarded growth, high mortality and low fertility (Vacarro, 1973 and 1974). Taneja and Bhat (1986) summarized that milk yield performance of temperate genotypes in tropical environments is usually 30 to 40% lower than in the countries of their origin. In a recent review on the losses of cattle of European dairy breeds in the tropics, Vacarro (1990) concluded that these cattle may not offer a viable option for milk production in the tropics because of their poor survival rates which, in most cases, were translated in an inability to generate their own replacements.

Many tropical cattle are now crossbreds. This situation is, perhaps, responsible for the following statement by the FAO/UNEP (Food and Agriculture Organization and United Nations Environment Program) Technical Consultation on Animal Genetic Resources (after Ansell, 1985) that, "There is now widespread realization that breed importation is not necessarily the quickest route to increased animal production. Indigenous adapted breeds should be examined more closely and where necessary steps should be taken to ensure conservation of at least some of them. Crossing with imports may sometimes be useful but crosses should be evaluated against the indigenous breeds in the local environment; indiscriminate crossing without evaluation should be discontinued".

Some synthetic (composite) breeds have been developed from crossbred foundations. Examples of these breeds are the Bonsmara in southern Africa, Australian Milking Zebu, Kenyan Sahiwal, Karan Swiss, Karan Fries, and Jamaica Hope. The major breeding objectives were hardiness, tick and/or disease resistance, heat tolerance and improved milk yield (Maule, 1973; Mason, 1974; Vacarro, 1974; McDowell, 1985; Taneja and Bhat, 1986; Nagarcenkar, 1982).

2.4 BREEDING FOR THE TROPICS

Breeding animals that are suitable for the developing countries is a complex problem involving many disciplines (Maule, 1973; McDowell, 1985; Ansell, 1985; Trail, 1986; Buck et al., 1982; Bondoc et al., 1989; Kebede, 1992). Even when animal production is a priority, the role of animal breeding for improving animal productivity in subsistence (traditional) production systems is not clearly understood. Nevertheless, attempts have been made to improve indigenous cattle and exotic stocks under existing management systems (McDowell, 1985; Bondoc et al., 1989). The ability to cope with dietary inadequacies is a certain factor that interacts with breeding decisions for the tropics. Therefore, it is probably useless to increase genetic potentials in production traits unless there will be improvements in nutrition and management.

Information about breed differences is important to decisions about the genetic improvement of livestock. Information on combining ability is also essential to permit increased productivity through utilization of both additive and non-additive variation (Tawonezvi et al., 1988). McDowell (1972) suggested that the large coefficient of variation in the indigenous stocks indicated an opportunity for selection, but the potential may be difficult to exploit because of the small numbers of animals available, fluctuations in the environmental conditions, and the high costs of systems for identifying superior genotypes. He added that estimates of repeatability and heritability for most dairy characteristics of indigenous stocks fell within the same range as those for the European breeds. Nagarcenkar (1982) also concluded that adequate genetic variation exists among local tropical breeds for many economic traits. In designing future crossbreeding systems, estimates of additive genetic differences between local and temperate breeds, the relative value of heterosis in crosses between them, and their interactions with different environment and management levels are needed (Cunningham and Syrstad, 1987).

Production from purebred European cattle is not feasible under traditional systems. Crossbreeding with European or tropical dairy breeds will combine adaptability (reproductive capacity, disease resistance) of native cattle with the high milk yield of European or tropical dairy breeds (Bondoc et al., 1989; Kebede, 1992). From a long-term crossbreeding experiment between European (Friesian, Jersey, Simmental) and indigenous Zebu breeds in Ethiopia, Kebede (1992) reported important heterozygosity effects in all crosses (F_1, F_2, and 3/4) for all traits studied (growth, milk and reproductive performance) except for calving interval. However, the optimal proportions of genes from European or tropical dairy breeds may differ among production systems. In Ethiopia, Kebede (1992) indicated an increase in calving interval in crosses with ≥75% of European genes. A smaller proportion of exotic genes may be required to match the limited feed resources in traditional production systems (McDowell, 1985). The optimal range in composition of Bos indicus and Bos taurus genes then could be maintained by rotational crossbreeding or by forming a composite breed (Trail et al., 1981; Gregory et al., 1982). However, the amount of heterozygosity retained with *inter se* matings in a composite breed is not clearly understood (Trail, 1986).

A problem that generally concerns farmers and animal breeders is how best to maintain the herd at a given genetic composition. Ansell, (1985) stated this question in the following manner, "If, for instance, experience has shown that in a given environment no more than 50% exotic blood can be tolerated, what should be done with the first-cross heifers? Put to an exotic bull, the indigenous percentage will be too low; put to an indigenous bull, the indigenous percentage will be too high". One possibility is to put the F_1 generation to any bull and dispose of the progeny, meanwhile keeping a small herd of purebreds to produce F_1 replacements, or to purchase F_1's on the market. This is not usually a practical solution for smallholder farmers. An alternative is to use crossbred bulls to maintain the desired gene proportion in future generations. Although use of crossbred bulls is not common because of a certain aversion in their use, the policy of using crossbred bulls is a satisfactory management decision that does not result in unacceptably high rates of culling (Ansell, 1985).

Genotype by environment interactions are difficult to detect because of the diverse environmental conditions, management practices, and disease control factors (Bondoc et al., 1989). In a crossbreeding study in Ethiopia, Kebede (1992) did not find evidence of interaction between genotype and environment for growth and milk yield. Evidence (Trail and Gregory, 1981; Barlow, 1981; Cunningham, 1981; Trail, 1986; Madalena, 1990) indicates that heterosis by environment interactions are common. Heterosis for most traits (except growth) appears to be relatively greater in suboptimal environments (Barlow, 1981). Cunningham (1981) suggested that genotype by environment interactions with a substantial difference between the F_1 and the local strain is largely due to heterosis in the poor environment and to the additive genetic difference between the strains in the good environment. Madalena (1990) came to the same conclusion when comparing differences between first lactation milk yields and length of mean calving intervals between breed groups with different proportions of Holstein genes in high and low management environments in Brazil. Studying the length of calving intervals of crossbreds (local Zebu and European breeds) in two different environments in Ethiopia, Kebede

(1992) found that heterozygosity effects were only important in the more difficult environment.

Therefore, in order to raise production, the breeder has two alternatives; either selecting within the existing genetic material of the indigenous cattle or crossbreeding with high-yielding *Bos taurus* animals from the temperate zones, or alternatively, make use of specialized *Bos indicus* breeds. Although there are some authorities who maintain that selection from within the indigenous *Bos indicus* is preferable, Ansell (1985) indicated that the consensus now is that this method is too slow for the urgent and growing need for increased production and that crossing is preferable. It has been estimated that the most one can expect from selection within a *Bos indicus* population is a 2% increase in milk yield per generation (Ansell, 1985). However, there are certain circumstances where crossbreeding may be undesirable, for example when dealing with trypanotolerant cattle in which trypanotolerance can be markedly reduced by crossing with non-trypanotolerant breeds or when the environment (physical, social and economical) is too harsh for crosses with exotic breeds.

2.5 INDIGENOUS CATTLE FROM SOUTHERN AFRICA

Mason and Maule (1960) have described indigenous cattle of East and Southern Africa in three main groups: Sanga, Zebu and an intermediate type that possibly originated from interbreeding of the two latter groups. These groups are primarily distinguished by the position and size of the hump. The hump is large and positioned thoracically in Zebu cattle, and small and positioned cervico-thoracically in Sanga cattle. Mason and Maule (1960), further subdivided these groups according to horn size. Table 2.2 summarizes these breed distinctions.

Table 2.2. Criterion used for the classification of cattle types in Eastern and Southern Africa[1].

Horn size	Size and position of Hump		
	Large thoracic	Intermediate	Small cervico-thoracic
Long			Longhorned Sanga
Medium	Madagascar Zebu	Aradó, Jiddu, Alur, Nganda	Shorthorned Sanga
Short	East African Shorthorned Zebu	North Sudan Zebu	

[1]Source: Mason and Maule (1960).

From their relative geographic locations -- Zebu along the coast and Sanga further inland -- and from the similarities between East African Zebus and those of India and southwest Asia, it is possible that the Sanga breeds were in eastern and southern Africa first and the Zebus arrived more recently from the east (Mason and Maule, 1960). Morgado (1954) acknowledges the possibility of the East African Zebu originating with the appearance of the Arab and Indian traders.

Along the boundaries of the area of distribution of the two types of cattle (Zebu along the coast and Sanga further inland) there is considerable intermixture, and in several places specific breed types, intermediate between Zebu and Sanga, have emerged. In Zimbabwe and Mozambique the Sanga and Zebu areas are separated by tsetse belts (Mason and Maule, 1960). One possible exception is a small area south of Tete Province (Mozambique) bordering the northwest region of Zimbabwe, that is relatively free of tsetse fly and that connects this country with the Angonia district where the Mozambican Angone (a Zebu type of cattle), is found. It is in this region that the Tete breed, an intermediate type of cattle, is found. The Tete breed possibly resulted from interbreeding between the Sangas from the south and the Angone in the north. This hypothesis was advanced by Morgado (1985). These intermediate types have humps of moderate size that are located between the thoracic and cervico-thoracic positions. The origin and subsequent evolution of the Sanga breeds are probably explained by crosses between the longhorn cattle (Bos primigenius) native to the Nile valley and the shorthorn Zebu (Bos brachyceros) introduced in this region around 3000 BC during the invasions from Asia of the Semitic tribes (Morgado, 1954; Mason and Maule, 1960).

Maule (1973) identified 19 indigenous cattle breeds in southern Africa. Table 2.3 shows the names and countries of those breeds.

Table 2.3. The indigenous breeds of cattle in southern Africa[1].

Breed	Country	Breed	Country
Africander	South Africa	Malawi Zebu	Malawi
Angone	Mozambique	Mashona	Zimbabwe
Angoni	Zambia	Zulu (Nguni)	South Africa
Bapedi	South Africa	Nkone	Zimbabwe
Barotse	Zambia	Ovambo	Namibia
Basuto	Lesotho	Swazi (Nguni)	Swaziland
Bonsmara	South Africa	Tonga	Zambia
Damara	Namibia	Tswana	Botswana
Drakensberger	South Africa	Tuli	Zimbabwe
Landim (Nguni)	Mozambique		

[1]Adapted from Maule, (1973).

Except for the Angoni, the Malawi Zebu and the Mozambican Angone, all of these breeds belong to the Sanga group. Cattle from northeastern South Africa (Zulu) and Swaziland (Swazi) are similar. The general name Nguni is frequently used to refer to these breeds (Mason and Maule, 1960). Cattle from southern Mozambique are called Landim but, because of the similarities with the Nguni either in conformation or performance, is sometimes also referred by that name. The primarily use of these breeds is for beef production although milk is also extracted in the traditional sector for self consumption.

2.6 SANGA CATTLE IN MOZAMBIQUE

There are two cattle breeds belonging to the Sanga group in Mozambique: the Landim, which is indigenous to the region, and the Africander, which was imported from South Africa. Maule (1973) indicated that the Africander is the numerically dominant Sanga breed being distributed throughout southern Africa. The Africander, generally assumed to be descended from the cattle of the Hottentots, the first people known to inhabit southern Africa, is an improved indigenous breed that underwent selection by European immigrants in South Africa. Selection criteria were for draught power and later for body weight (Mason and Maule, 1960; Scholtz, 1988). The coat color is red, varying in shade from dark red to pale red and often with white marks on the underline.

Because the Africander is heavier than the other Sanga breeds in South Africa, it was believed, therefore, to be more productive (Trail, 1986), which probably explains its wide dissemination throughout southern Africa. However, Buck et al. (1982) found that the Tuli and the Tswana outperformed the Africander in a productivity index (expressed as weight of 18 mo old calf per cow per year) combining reproductive performance, calf and cow viability (annual percentage of animals that survived), and growth in a comparative study in Botswana. The Tuli and Tswana had advantages (227 kg and 213 kg respectively vs 163 kg for the Africander) because of exceptional reproductive performance and low mortality. Also, data from Chobela Station in southern Mozambique, revealed greater productivity for the Landim cattle (2.3 kg vs 2 kg expressed as weight of 18 mo calf per unit metabolic weight of cow per year) than for Africander cattle (Dionisio and Syrstad, 1990).

There are no official records indicating when the Africander was first introduced into Mozambique. Silva (1966), indicates that this breed has existed in the south since 1920. Based on the South African official records for the breed, Mason and Maule (1960) gave the desirable weight of the mature Africander bull (6 years) as 745 kg and 525 kg for mature cows (8 years). At the same time, they refered to a great variability on these weights, having found a range from 750 kg to 850 kg for bulls and 450 kg to 525 kg for mature cows in South Africa. As for milk production (estimates of total production -- calf plus milking), and citing Bonsma (1955), Mason and Maule (1960) reported an average yield for ten summer-calving cows of 875 kg in 180 days while for ten winter-calving cows the average was 1180 kg in 210 days.

The Landim is a breed of medium size with mature cows ranging in weight from 300 kg to 475 kg (average of 350 kg at

5 years) and mature bulls (5 years) averaging 600 kg (Paiva, 1970). Landim are predominantly horned but polled animals are not uncommon with a deep body, fairly short legs, and a tendency towards the angularity of dairy breeds. Coat color varies from black to red and white in either solid or spotted patterns. The skin color is dark. Scholtz (1988) indicates that the Landim/Nguni is tick-resistant, with acquired tolerance to tick-borne diseases, with usually high calving rate (87%), and acceptable milk yield based on birth-to-weaning growth rates.

There has been limited research on Landim cattle in Mozambique (Morgado, 1954; Rosinha, 1963; Silva, 1966; Paiva, 1970; Fonseca, 1970; Silva, 1975; Rocha, 1985; Dionisio and Syrstad, 1990). Two of these studies refer to estimates of genetic variances and heritabilities (Fonseca, 1970; and Silva, 1975).

There are few reports about milk yields of Landim cows (Morgado, 1954; Rosinha, 1963; Silva, 1966). All milking records are from the Chobela Research Station, which probably provided better management and nutrition (in terms of quality and quantity of roughage, health care and hygiene), than in the family sector herds. All cows were milked in absence of the calf, which may have negatively affected expression of this character because of impaired milk let down. Morgado (1954) reported an average milk yield for 13 cows of 572 ± 6 kg in 139 days. Rosinha (1963) found a range in milk yield from 573 to 1793 kg per lactation, and Silva (1966) reported an average yield of 1055 kg for 5 primiparous cows completing 300 days of lactation.

2.7 BREED COMPARISONS IN SOUTHERN AFRICA

Maule (1973) emphasized the need to compare cattle breeds in southern Africa. He said that much of the research and development work in this region in the last 20 or 30 years has been aimed at evaluating indigenous breeds for milk yield and less has been aimed at the reproductive performance and growth of indigenous breeds. Much of the information on the productivity and performance of these indigenous breeds comes from studies of single herds of one breed (Maule, 1973). However, other researchers have since compared two or more of those breeds in the same environment (Buck et al., 1976; Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio, 1989; Dionisio and Syrstad, 1990).

2.7.1 GROWTH TRAITS

Trail et al. (1977) found heavier (P<.05) birth weights for Tswana and Africander calves in Botswana than for Tuli. Tuli is a selected line of Tswana cattle (indigenous Sanga type from Botswana) that was developed in southwestern Zimbabwe and with high fertility performance (Buck et al., 1982). Buck et al. (1982) did not find important birth weight differences between Tswana and Bonsmara breeds in Botswana. Bonsmara is a synthetic breed developed in South Africa (5/8 Africander and 3/8 Bos taurus -- Shorthorn and Hereford) for beef production. Tawonezvi et al. (1988) evaluated seven beef breeds in Zimbabwe -- three indigenous Sanga breeds -- Mashona, Nkone and Tuli, one exotic Sanga breed -- Africander -- one Zebu breed -- Brahman -- and two Bos taurus breeds -- Sussex and Charolais. Mashona calves were the lightest at birth (29 ± .5 kg); and birth weights of other breeds were near to 33 kg. Dionisio (1989) found that the Africander calves in Mozambique were heavier at birth (38 ± .3 kg) than the Landim calves (35 ± .3 kg). Table 2.4 shows average birth weights of 9 indigenous breeds from various reports throughout southern Africa.

Table 2.4. Mean birth weights for various indigenous breeds from southern Africa[1] (kg).

Breed	Botswana[2]	South Africa[3]	Zimbabwe[4]	Mozambique[5]
Africander	30	32	33	38
Bonsmara	31	35	...	...
Drakensberger	...	36	...	...
Landim/Nguni	...	28	...	35
Mashona	...	...	29	...
Nkone	...	...	32	...
Tswana	31	...	...	...
Tuli	29	...	33	...

[1]Compiled from Trail et al. (1977)[2]; Buck et al. (1982)[2]; Scholtz (1988)[3]; Tawonezvi et al. (1988)[4]; and Dionisio (1989)[5].
[4]Standard errors varied from .5 to .6 kg.
[5]Standard errors were .3 kg.

Trail et al. (1977) found that Tswana calves were heavier at weaning than Tuli and Africander calves (P<.05). However, Buck et al. (1982) did not find important differences in weaning weight between Tswana and Tuli calves but each was lighter than Bonsmara (P<.01). Tawonezvi et al. (1988) found a similar trend in weaning and birth weights, i.e., Mashona calves were lighter (172 ± 2.2 kg) and Brahman calves were heavier (206 ± 3.1 kg) than other breeds. Africander calves were 19 kg heavier (P<.001) at weaning than Landim calves in Mozambique (Dionisio and Syrstad, 1990). Table 2.5 shows the weaning weights reported in these studies.

Table 2.5. Mean weaning weights for various indigenous breeds from southern Africa[1] (kg).

Breed	Botswana[2]	South Africa[3]	Zimbabwe[4]	Mozambique[5]
Africander	166	173	194	164
Bonsmara	197	197	...	...
Drakensberger	...	200	...	...
Landim/Nguni	...	164	...	145
Mashona	...	...	172	...
Nkone	...	...	187	...
Tswana	177	...	...	...
Tuli	175	...	184	...

[1]Compiled from Trail et al. (1977)[2]; Buck et al. (1982)[2]; Scholtz (1988)[3]; Tawonezvi et al. (1988)[4]; and Dionisio and Syrstad (1990)[5].
[4]Standard errors varied from 2.1 to 2.6 kg.
[5]Standard errors varied from 1.1 to 1.4 kg.

Weight at 18 mo is an important trait because it is a major criterion for selecting female replacements and bulls for breeding. Table 2.6 shows average 18-mo weights for the Africander, Bonsmara, Landim, Tswana and Tuli breeds from studies in Botswana and Mozambique. Note the differences in the 18-mo weights between the two countries. Trail <u>et al.</u> (1977) and Buck <u>et al.</u> (1982) found the Africander to be lighter ($P<.05$) than the other breeds under comparison in Botswana (Table 2.6). In contrast Dionisio and Syrstad (1990) found the Africander (254 ± 1.9 kg) to be 8% heavier ($P<.001$) than the Landim (235 ± 1.7 kg) in Mozambique.

Table 2.6. Average weight for calves at 18 mo for various indigenous breeds from southern Africa[1] (kg).

Breed	Botswana[2]	Mozambique[3]
Africander	277	254
Bonsmara	322	...
Landim	...	235
Tswana	295	...
Tuli	287	...

[1]Compiled from Trail <u>et al.</u> (1977)[2]; Buck <u>et al.</u> (1982)[2]; and Dionisio and Syrstad (1990)[3].
[3]Standard errors varied from 1.7 to 1.9 kg.

2.7.2 REPRODUCTIVE PERFORMANCE

Calving percentages from a study in Botswana (Trail <u>et al.</u>, 1977) differed ($P<.05$) from 65% to 85% between

Africander, Tswana and Tuli breeds. The Africander was the least fertile and Tuli was the most fertile with 85% of all Tuli breeding females calving per year (Table 2.7). In the studies reviewed from this region (Botswana, Zambia, South Africa, and Zimbabwe), the Africander consistently had the lowest calving rate (Rakha et al., 1971; Scholtz, 1988; Tawonezvi et al., 1988), even when compared to Charolais and Sussex *Bos taurus* breeds. Tawonezvi et al. (1988) concluded that low reproductive performance (measured in terms of calving rate) seems to be characteristic of the Africander breed.

Table 2.7. Average calving rate for various indigenous breeds from southern Africa[1] (%).

Breed	Zambia[2]	Botswana[3]	South Africa[4]	Zimbabwe[5]
	%			
Africander	65	65	72	56
Bonsmara	...	...	81	...
Drakensberger	...	...	72	...
Mashona	83	...	...	76
Nguni	...	...	87	...
Nkone	...	...	...	63
Tswana	...	71	...	...
Tuli	...	85	...	70

[1]Compiled from Rakha et al., (1971)[2]; Trail et al., (1977)[3]; Scholtz, (1988)[4]; Tawonezvi et al., (1988)[5].
[5]Standard errors varied from 3.0 % to 4.5 %.

A similar pattern was observed in length of the calving interval (Table 2.8). Rakha et al., (1971) found that the Africander in Zambia had a calving interval and gestation period significantly longer (P<.01) than those of the other breeds -- Mashona, Angoni (Zebu type), and Hereford. The studies from South Africa (Scholtz, 1988) and Mozambique (Dionisio and Syrstad, 1990) also indicated that the Africander is less fertile than the other Sanga types.

Table 2.8. Calving intervals for various indigenous breeds from southern Africa[1] (days).

Breed	Zambia[2]	South Africa[3]	Mozambique[4]
Africander	426	469	459
Bonsmara	...	434	...
Drakensberger	...	469	...
Landim/Nguni	...	412	418
Mashona	388	...	...

[1]Compiled from Rakha et al., (1971)[2]; Scholtz, (1988)[3]; and Dionisio and Syrstad, (1990)[4].
[2]Standard deviations varied from 114 to 131 d.
[4]Standard deviations varied from 110 to 157 d.

2.7.3 TOTAL PRODUCTIVE PERFORMANCE

Buck et al. (1976) indicated that low reproductive performance and maternal ability in providing the calf with adequate pre-weaning environment are the main constraints to the productivity of cattle in Botswana. This statement is probably generalizable to the southern Africa region because all studies reviewed reported the same conclusion (Rakha et al., 1971; Buck et al., 1976; Trail et al., 1977; Buck et al., 1982; Trail, 1986; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990).

Several parameters were used to construct a total productivity index in the studies reviewed. Trail et al. (1977) in Botswana combined the effects of calving percentage (expressed as the number of calves produced from the cows exposed to service), pre-weaning growth and mortality rate, thus permitting a comparison on the basis of "weight of weaner calf per cow per year". Another index measuring the "weight of 18 mo old calf per cow per year" was constructed by adding the effect of post-weaning growth to 18 mo. Results showed that the Tuli was 16% more productive (135 kg) than the Tswana (116 kg), which in turn was 18% more productive than the Africander (88 kg) in terms of weight of weaner calf per cow per year (Trail et al., 1977). The same study showed that, in terms of weight of 18 mo old calf per cow per year, the Tuli (223 kg) was 22% superior to the Tswana (182 kg), which was 17% more productive than Africander cows (155 kg). Buck et al. (1982), using the same productivity indices, found the Tuli to be the most productive among five breeds for 18 mo old calf per cow per year in Botswana (227 kg for Tuli, 224 kg for Bonsmara, 213 kg for Tswana, 176 kg for Brahman, and 163 kg for

Africander) because high reproductive performance and low mortality more than compensated for lower weights at 18 mo compared to Tswana and Bonsmara breeds. He added that the Tswana outperformed the Africander breed, which had disappointing performance in all three traits accounted in the index.

In Zimbabwe, Tawonezvi <u>et al.</u> (1988), estimated a productivity index by combining calving rate, cow weight, calf weaning weight and pre-weaning viability. The Mashona breed outperformed the other Sanga breeds (Nkone, Tuli and Africander) with Africander being the least productive. Scholtz (1988) constructed two weaning productivity indices, which were expressed as the ratio of weight of calf (kg) weaned per 100 kg of cow exposed or per unit of metabolic weight of cow exposed. He referred to the advantages of these methods because they account for differences in fertility (measured by the calving rate) and cow maintenance (cow live weight). Using data from the National Beef Cattle Performance and Progeny Testing Scheme of South Africa, he found the Nguni to be the most productive of the indigenous breeds evaluated (Nguni, Africander, Bonsmara and Drakensberger). Dionisio and Syrstad (1990) also found advantage of the Landim over the Africander in an overall productivity comparison using the same productivity ratio approach as Scholtz (1988).

The results reported herein support the claim by Trail (1986) that a different decision may have resulted regarding the widespread dissemination of the Africander breed had information comparing the Africander and other Sanga breeds in southern Africa been available earlier. For example, in Botswana, more productive crossbreds might have been utilized earlier, and Sanga types other than Africander might have been used to develop breeds of greater productivity than the Bonsmara in South Africa and the Belmont Red in Australia (Trail, 1986).

2.8 CONCLUSIONS

Priority in this review of literature was given to information about the performance of the most important indigenous breeds in southern Africa. Although native tropical breeds are typically characterized by low performance in typical productivity traits, they are well adapted to local environments through advantages in fertility and mortality rates that probably have arisen from natural selection. Inadequate nutrition is probably the major factor limiting livestock productivity throughout the tropics (Maule, 1973; Payne, 1981; Trail, 1981; Trail, 1986). In traditional systems where management inputs are low, one reason for malnutrition of cattle is severe overstocking especially in areas prone to periodic droughts. Maintaining unproductive animals (e.g., high proportion of males is normally found in traditional herds) means that available nutrients (natural pastures in this case) are wasted or not used in an efficient way, particularly during the dry season when pastures are scarce. When better management is provided -- culling unproductive animals, introduction of a breeding season coinciding with the rains to provide better nutrition during this critical period, and minimal control of diseases and parasites -- indigenous breeds show substantial increase in reproductive performance (Rakha et al., 1971; Buck et al., 1976; Trail et al., 1977; Buck et al., 1982; Trail, 1986; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990). High fertility is a characteristic of most indigenous breeds in above average environments in southern Africa.

Although exotic breeds exceed indigenous breeds in growth and weight performance, the breeds with the highest reproductive performance were the more productive ones when evaluated with indices combining reproductive performance with growth and survival rate to summarize liveweight offtake per cow per year. This is an indication that fertility is an important parameter to take into account when considering the choice of breeds for specific areas. Only with large improvements in the environment (nutrition, disease) is it possible to exploit breeds with high genetic potential for milk or beef production. In most cases, such modifications are economically infeasible.

Crossbreeding has been widely used in the tropics to combine adaptability (hardiness, disease resistance and heat tolerance) of native cattle with the high potential for milk and growth of the specialized temperate breeds. Kebede (1992) reported an increased performance of crosses of European and the indigenous Zebu breeds in Ethiopia and considered that heterosis and complementarity between the breeds were the major contributing factors. However, the optimum proportion of genes from European breeds may vary for different environments and production systems. Maintaining herds at a given (optimal) proportion of exotic genes is still a major challenge for animal breeders especially because of recombination losses (Trail and Gregory, 1981; Gregory et al., 1982; Ansell, 1985; McDowell, 1985; Trail, 1986; Bondoc et al., 1989).

Comparisons of total productivity between indigenous breeds in southern Africa showed superiority for the local breed indicating a difference in adaptation for specific environments within the region. This may be an indication that possible genotype by environment interactions are important in matching genotypes to particular environments. However, Hofmeyr (1974) professed that although genotype by environment interactions may be present, they probably are not important in relation to breeding plans except possibly, where extreme conditions are experienced.

On the other hand, Trail (1986) suggested that interactions among genotypes and environments are usually found where breeds with different degrees of adaptation to stress are managed together in various African environments.

One example was the case of an experiment in Kenya involving Sahiwal x Ayrshire crossbreeding, where genotype by year interaction effects were manifested in different growth patterns that were associated with seasonal and yearly climatic differences (Trail, 1986).

In general, results from several studies identified the need for more research especially to compare indigenous breeds for reproductive performance and growth traits. Maule (1973) considered the Africander, Drakensberger and Bonsmara to be the largest of the Sanga breeds in the sub-continent. But he emphasized that this does not mean that they are necessarily the most productive ones, especially because the economics of beef production also impinge on reproductive performance, survival and maintenance costs.

CHAPTER 3

MATERIAL AND METHODS

3.1 THE CHOBELA RESEARCH STATION

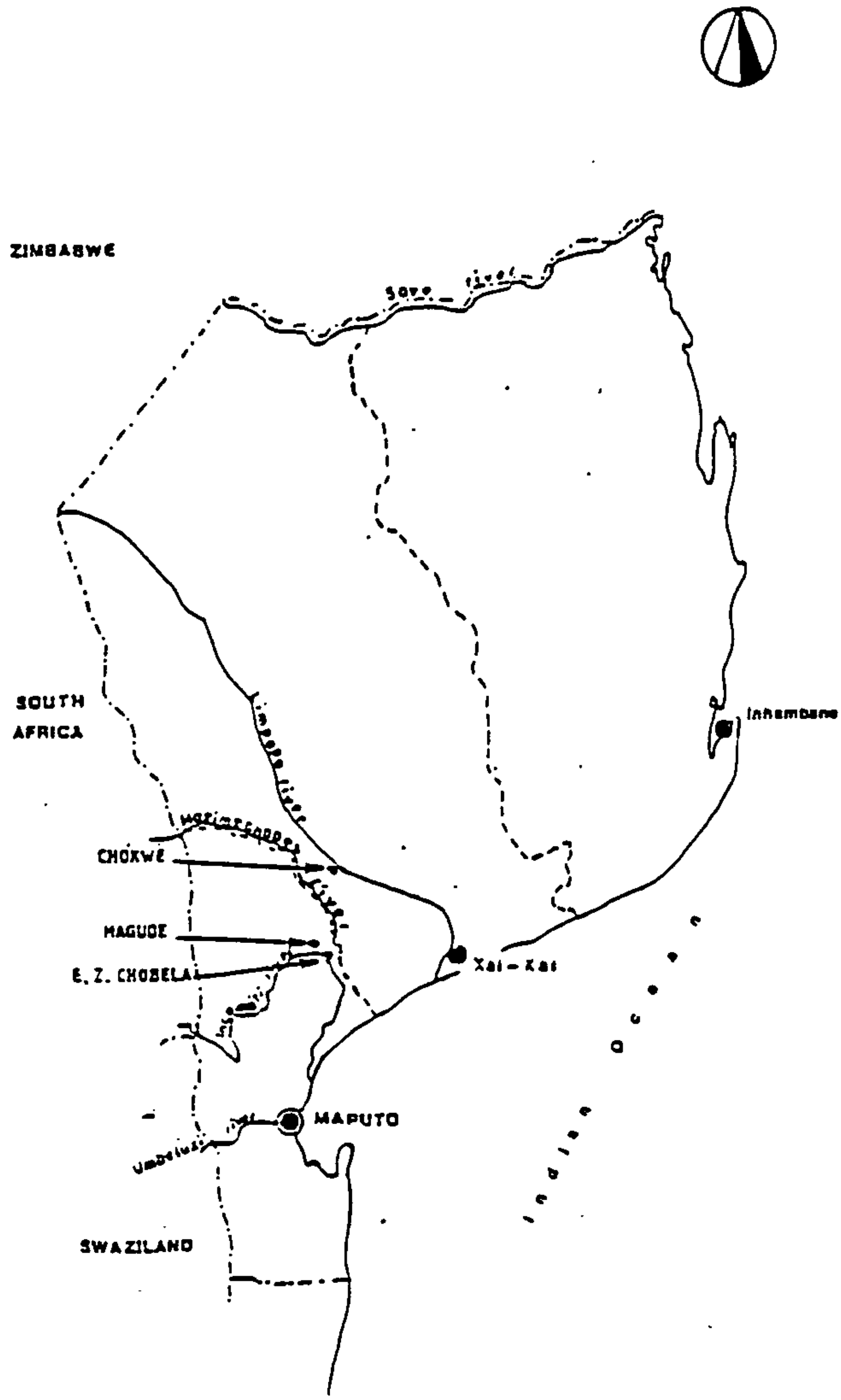
3.1.1 LOCATION AND OBJECTIVES

The data for the present study were collected at the Chobela Central Research Station in southern Mozambique, which is about 150 km north of Maputo, the capital city (Map 4). The Chobela Station was established in 1917, and 88 Landim cows were introduced in 1940. Africander cattle were introduced in 1944 with importations from South Africa, whereafter these two breeds were kept and managed together with the main goal to objectively compare these breeds. Selection criteria were based on fertility, conformation, and growth.

3.1.2 CLIMATE

In tropical areas the rainfall regime is the dominant climatic factor influencing agriculture and vegetation, including natural pastures. As Van Soest (1982), pointed out, vegetative growth in the tropics is more limited by water availability rather than by temperature. However, nutritive value is limited by temperature.

The highly variable climate results in a dry tropical region with an annual average rainfall of 686 mm, average temperature of 23.3°C, and an average relative humidity of 72%. Figure 3.1 shows the average annual rainfall at the Chobela Station in the period 1952 to 1968. The unimodal rainfall pattern results in two main seasons: a rainy, hot season and a dry, relatively cool season. Usually the rainy season starts in October or November and extends to March or April, which is the hottest period of the year. The months with highest and lowest average precipitation were February and August for the 28 year period from 1952 to 1980 (Figure 3.2). For the same period, the highest average maximum temperature occurred in January (32.5°C) and the lowest mean maximum temperature was in July (18.7°C). The temperature (average of the minima) never dropped below 10°C (Figure 3.3).



Map 4. Southern Mozambique. Localization of the Chobela Research Station.

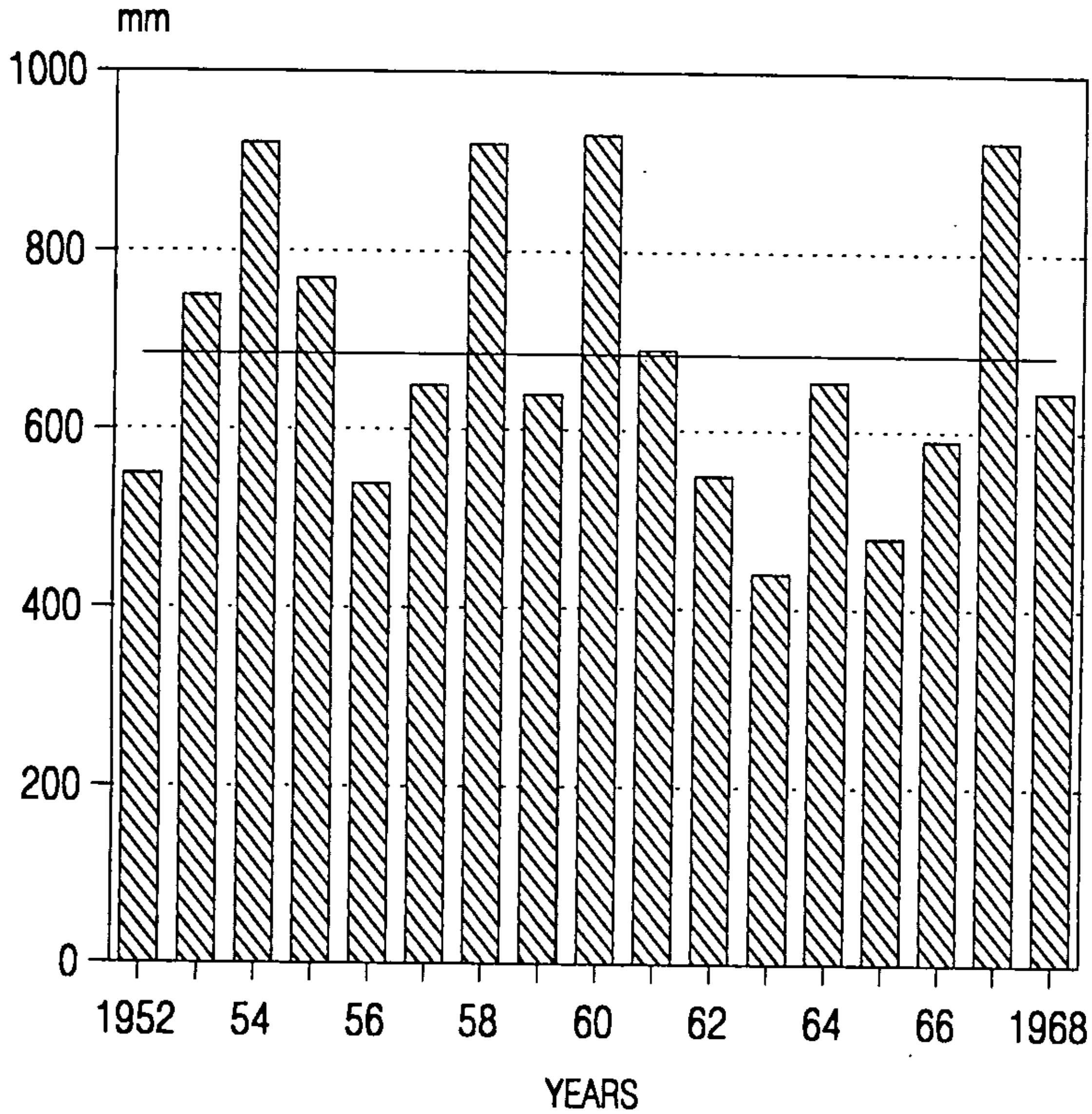


Figure 3.1. Annual average rainfall from 1952 to 1968 at the Chobela Research Station. (— Mean = 686 mm/yr).

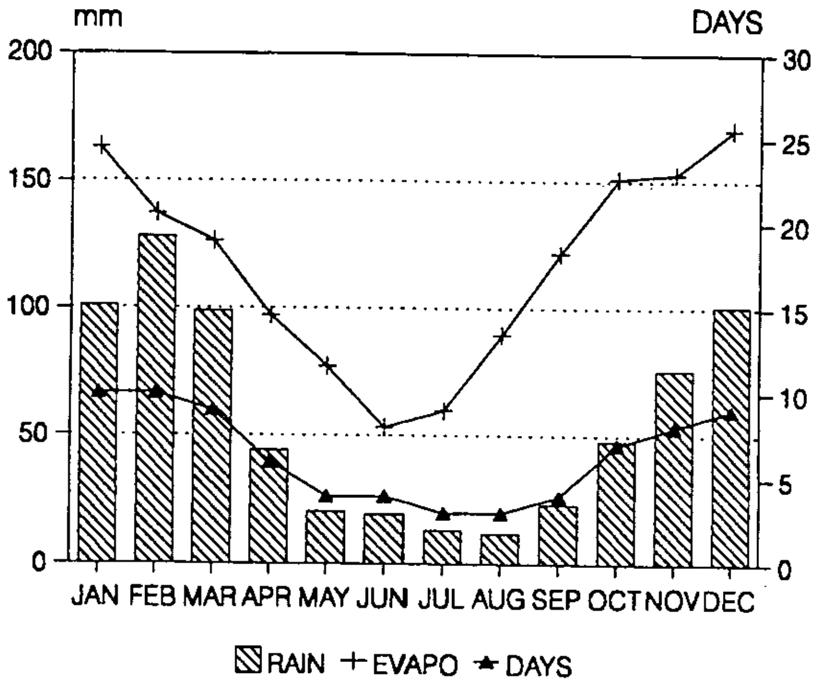


Figure 3.2. Average rainfall (RAIN), potential evapotranspiration (EVAPO), and days of rain per month (DAYS) at the Chobela Research Station from 1952 to 1980.

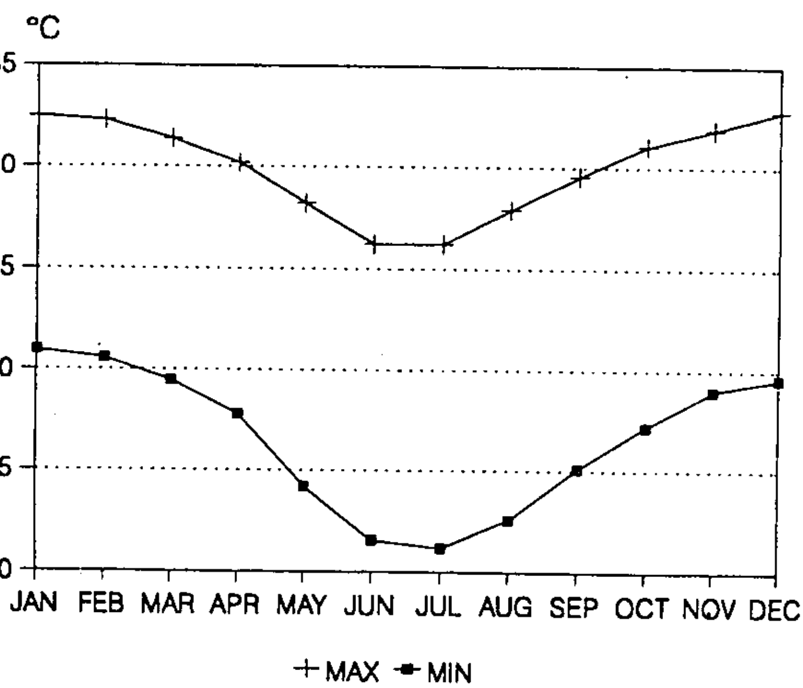


Figure 3.3. Average temperature per month at the Chobela Research Station from 1952 to 1980. MAX = average of the maxima; MIN = average of the minima.

3.1.3 SOILS AND VEGETATION

The Chobela station is located in the Magude district, which has a flat topography with an average altitude of 40 m above sea level. The station is situated on the left bank of the Incomati River which is the source of all drinking water because the subterranean water is very salty.

There are two main soil types. Alluvial soils along the river form part of the river valley and are considered to be of medium fertility. The other soil type, also of sedimentary origin, is referred to as the gray soil of Guijá (Gouveia, 1959). These soils of gray color are highly compact, and have some sub-soil profiles with a cement-like consistency. The surface layers have a sandy texture but a sandy-clay texture is found in deeper layers. All profiles have large particles of quartz. It is very difficult to plough the gray soils in the dry season, especially with draught power.

The grass vegetation comprises <u>Themeda trianda</u> (Red grass), <u>Urochloa pullulans</u>, <u>Urochloa mossambicencis</u>, <u>Panicum maximum</u> (Guinea grass), <u>Digitaria sp.</u>, and <u>Setaria sp.</u> (Paiva, 1968). The most common bush and arboreal species are <u>Acacia nilotica</u>, <u>Acacia nigrescens</u>, <u>Combretum imberbe</u>, <u>Sclerocarya caffra</u>, <u>Ziziphus mucronata</u>, <u>Dicrostachys glomerata</u>, and <u>Pseudocadia zambeziaca</u> (Paiva, 1968). The natural pasture in this region is classified as "sweet veld" (Silva, 1966). A current major concern in pasture management for this region is determining the correct or optimal stocking rate(s) to control brush encroachment, especially Acacia sp., which is considered a major threat for the livestock industry because of their aggressive invasion of pasture lands.

3.2 GENERAL MANAGEMENT

The Chobela Research Station has a total area of approximately 3200 ha. As mentioned earlier, a major task at the Chobela station was to compare the performance of the two most common beef breeds in the region: the Landim and the Africander. The Landim and Africander were reared in natural pastures at a stocking rate of 3 to 4 ha per animal unit (1 AU = 450 kg liveweight). The breeds are managed together but are grouped by age and sex -- females of breeding age (with or without suckling calves), heifers, weanlings (both sexes), and young and mature bulls.

During the breeding season, which is usually from February to April, females of each breed are separated into different paddocks. The ratio of bulls to cows in the breeding herds is 1:25 during the breeding season. Breeding paddocks are smaller (50 ha) than non-breeding paddocks to facilitate management and to accurately record the sire of future calves.

Calves are weaned at 7 mo of age (August and September). All calves were weighed at birth, and then monthly until 18 mo. Subsequent weighings occur twice per year, usually at the beginning (November) and end (April) of the rains (Paiva, 1970). Supplementation is not practiced except in very dry years when some straw (usually from rice) is provided with molasses and urea.

Replacement females and sires are selected based on weight at 18 mo of age. Unselected males are castrated to avoid breeding management problems, and later sold at 3 to 4 years of age weighing approximately 400 kg. Females not selected as replacements are usually sold for breeding purposes unless reproductive problems are detected. Females not pregnant after two consecutive breeding seasons are culled.

Preventive health care is practiced routinely. All animals are vaccinated against anthrax (Bacillus anthracis) and blackleg (Clostridium chauvoei). All calves are immunized against Salmonella spp.. Heifers between 4 and 7 mo of age are vaccinated against brucellosis. Annually, all animals are screened for tuberculosis. Curative treatments (wounds, infections) are provided when needed. All animals are dipped weekly with an acaricide to control external parasites, especially ticks (Amblyomma hebraeum, Rhipicephalus appendiculatus, Boophilus decoloratus, and others).

3.3 DATA AND TRAITS

The data consisted of body weights and dates of birth and calvings of the Landim and Africander cattle at the Chobela Research Station herd from 1968 to 1981. The number of breeding females averaged 250 per year during the period of study, which represented 38% of the entire herd. Each breed accounted for about 50% of the beef herd and were always maintained at this level. Since there were few records prior to 1975, these were pooled with the records from 1975. Only a few records were excluded from the analysis due to evident error in recording (e.g., birth weights ≥ 60 kg). Details about data collection are outlined below.

The traits recorded were body weights at birth, weaning (at about 210 days), 18 mo (~540 days) and first calving. Body weights at weaning and 18 mo of age were adjusted before recording to 210 and 540 days of age based on the average daily gain surrounding these ages. Besides body weights, pre- and post-weaning average daily gains were calculated from birth to weaning and from weaning to 18 mo, respectively. Primary reproductive traits were age at first calving and length of first calving interval. The average lengths of second and subsequent calving intervals were also recorded. Table 3.1 shows the numbers of records available for each trait and breed.

A sub-set of these data (records from 1975 to 1980) was used by Dionisio and Syrstad (1990) to evaluate the Landim and Africander for weights at weaning and 18 mo, average daily growth between weaning and 18 mo, and average calving interval. In their study the data from each breed were analyzed separately and mean differences were tested by Student's t-test.

Table 3.1. Number of observations by trait and breed for growth and reproductive performance.

Trait	Landim	Africander
Weight at		
Birth	459	395
Weaning	367	334
18 months	244	233
First calving	69	66
Daily gain		
Pre-weaning	325	300
Post-weaning	239	226
Reproduction		
Age at first calving	174	124
First calving interval	113	50
≥2nd calving interval	285	225

3.4 STATISTICAL ANALYSIS

3.4.1 BREED COMPARISONS

The statistical analysis of body weight, growth and reproductive traits was by least squares methods using the General Linear Models procedure of the Statistics Analysis System (SAS, 1985). A fixed effects model was used to evaluate differences between breeds after adjusting for identifiable environmental effects.

The calving period is conditioned by management to coincide with the beginning of the rainy season in October/November. The natural pasture regrowth is most highly digestible early in the rainy season and subsequent nutritive value is less as plants mature. Females calving during thisperiod benefit from this higher plane of nutrition, which probably provides a relatively good maternal environment to their calves (i.e., milk production is greater in this period than for cows calving late in the rainy season). Consequently, two seasons of calving were considered: July 1 through December 31 (i.e., early rainy season) and January 1 to June 30 (i.e., late rainy season). Correspondingly, preliminary analysis showed that these seasons had important effects on most traits studied. Figure 3.4 shows the frequency distribution of calvings per month.

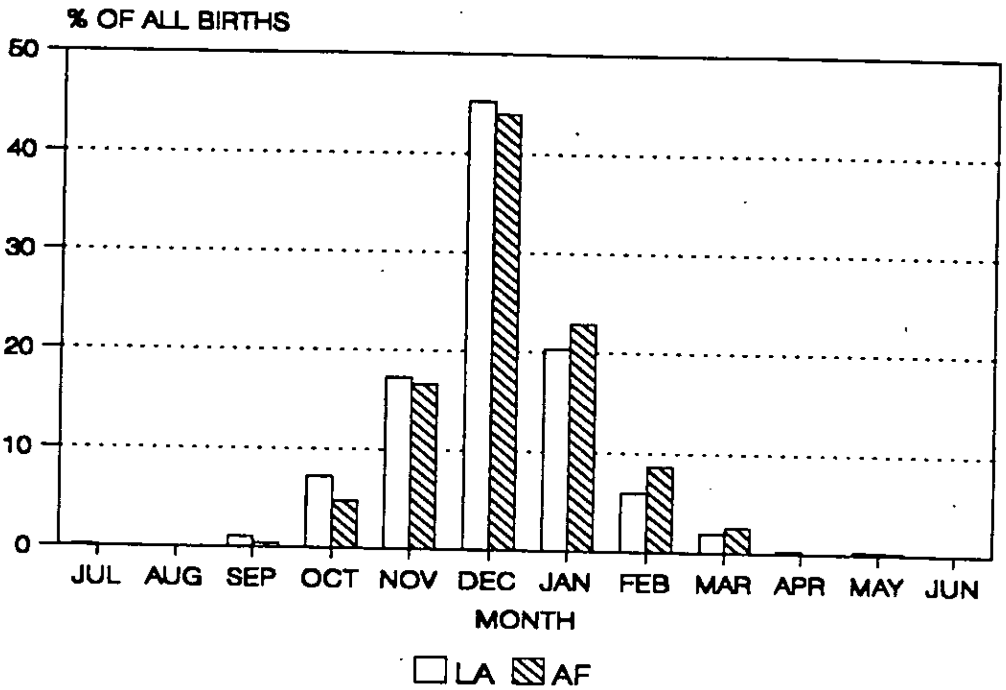


Figure 3.4. Frequency distribution of calvings by month. LA = Landim; AF = Africander.

Statistical Models.

Model 1. The statistical model for the growth traits (weights at birth, weaning, and 18 mo, and daily growth for pre- and post-weaning) was:

$$y_{ijklm} = \mu + B_i + YS_j + S_k + P_l(B_i) + (B*YS)_{ij} + b_i\{AGE_{ijklm}(B_i)\} + \epsilon_{ijklm}$$

where,

y_{ijklm} = the record of the m^{th} calf of the i^{th} breed, the k^{th} sex, and born in the j^{th} year-season to a dam in the l^{th} parity,

μ = the overall mean,

B_i = the i^{th} breed (Landim or Africander),

YS_j = the j^{th} year-season of birth,

S_k = the k^{th} sex,

P_l = the l^{th} parity nested within breed, where, to account for differences in physiological status, l=1 if a primiparous heifer; l=2 if a cow that calved in the preceding year; l=3 if a cow that did not calve in the preceding year,

$(B*YS)_{ij}$= interaction of breed i by year-season j,

b_i = the linear regression coefficient for the respective growth trait on age of dam nested within the i^{th} breed (Landim or Africander),

AGE_{ijklm} = the residual age of the dam (mo) effect for the m^{th} individual nested within breed that was unaccounted by parity, and

ϵ_{ijklm} = the vector of residuals that was assumed $N\sim(0, I\sigma^2)$.

Model 2. The statistical model for weight at first calving was:

$$y_{ijk} = \mu + B_i + YSC_j + b_i(AFC_{ijk}(B_i)) + \epsilon_{ijk}$$

where,

y_{ijk} = the record of the k^{th} animal, of the i^{th} breed, that calved in the j^{th} year-season,

μ = the overall mean,

B_i = the i^{th} breed (Landim or Africander),

YSC_j = the j^{th} year-season of calving,

b_i = the linear regression coefficient of weight at first calving on age at first calving nested within the i^{th} breed (Landim or Africander),

AFC_{ijk} = the age of the k^{th} female (mo) at first calving nested within breed, and

ϵ_{ijk} = the vector of residuals that was assumed $N\sim(0, I\sigma^2)$.

Model 3. The statistical model for age at first calving (AFC) and first calving interval (FCI) was:

$$y_{ijkl} = \mu + B_i + YS_j + G_k(B_i) + \epsilon_{ijkl}$$

where,

y_{ijkl} = the record of the l^{th} animal, of the i^{th} breed, belonging to the k^{th} calving group, and born in the j^{th} year-season,

μ = the overall mean,

B_i = the i^{th} breed (Landim or Africander),

YS_j = the j^{th} year-season of birth,

G_k = the k^{th} calving group nested within breed, where k=1 for heifers that calved following first exposure to breeding (for AFC) or cows calving in the previous year (for FCI), and k=2 for heifers calving after the second exposure (for AFC) or cows that did not calve in the previous year (for FCI), and

ϵ_{ijkl} = the vector of residuals that was assumed $N\sim(0, I\sigma^2)$.

Model 4. The statistical model for second and subsequent calving intervals was:

$$y_{ijkl} = \mu + B_i + YSC_j + G_k(B_i) + \epsilon_{ijkl}$$

where,

y_{ijkl} = the record of the l^{th} cow, of the i^{th} breed, belonging to the k^{th} calving group that calved in the j^{th} year-season,

μ = the overall mean,

B_i = the i^{th} breed (Landim or Africander),

YSC_j = the j^{th} year-season of calving,

G_k = the k^{th} calving group nested within breed, where k=1 for cows that calved in the previous year, and k=2 for cows that did not calve in the previous year, and

ϵ_{ijkl} = the vector of residuals that was assumed $N\sim(0, I\sigma^2)$.

The effect of age of cow was dropped from the model because of statistical significance was P>.8. Preliminary analysis showed high correlation (r =.8) between the effects of year-season of birth and year-season of calving. Hence, the most recent event was used. Linear contrasts of least squares means were computed to test differences within classes of main effects for all traits.

3.4.2 TOTAL PERFORMANCE INDEX

Four productivity indices were computed to compare the Landim and Africander breeds. Two indices represented annual weaner productivity (indices 1 and 2) and two indices represented annual yearling productivity (indices 3 and 4). The indices used either weight at weaning or at 18 mo, plus viability (expressed as the proportion of animals born that reached weaning or 18 mo of age), average annual calving rate, and dam's weight at first calving expressed on a liveweight (indices 1 and 3) or (indices 2 and 4) on a metabolic weight basis (Rakha et al., 1971; Buck et al., 1976; Trail et al., 1977; Trail and Gregory, 1981; Buck et al., 1982; Trail, 1986; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990).

The average calving rate for each breed was defined using the ratio between 365 days (year length) and the first calving interval (Scholtz, 1988; Dionisio and Syrstad, 1990). Survival rates to weaning and 18 mo were computed as the percentage of animals born that reached weaning and 18 mo of age. Cow metabolic weight (weight at first calving raised to the power of .75) was used to approximate productivity per unit of maintenance requirement.

The four productivity indices are written (rates are decimal fractions) as:

Weaning weight (kg) x calf viability rate x calving rate ÷ cow weight at first calving (kg) [Index 1];

Weaning weight (kg) x calf viability rate x calving rate ÷ cow metabolic weight at first calving ($kg^{.75}$) [Index 2];

18 mo weight (kg) x calf viability rate x calving rate ÷ cow weight at first calving (kg) [Index 3];

and

18 mo weight (kg) x calf viability rate x calving rate ÷ cow metabolic weight at first calving ($kg^{.75}$). [Index 4]

3.4.3 GENETIC EVALUATIONS

A mixed-model, Restricted Maximum Likelihood (REML) procedure was used to estimate sire components of variance from families of half-siblings in each breed for weights at birth, weaning and 18 mo, average daily gains in pre- and post-weaning periods, age at first calving, first calving interval, and the mean of subsequent calving intervals. These estimates of additive genetic variances and heritabilities are needed to evaluate potential breeding systems and for predicting response to selection. The number of observations in each data subset as well as the number of sires (per breed and trait) are in Table 3.2. Data subsets were constructed to avoid single progeny per sire and to avoid fewer than two sires per fixed effect subclass.

Table 3.2. Number of observations and sires per trait used to estimate sire components of variance for the Landim and Africander breeds.

	Landim		Africander	
Trait	N	Sires	N	Sires
Body weight				
Birth	399	20	362	18
Weaning	328	17	315	15
18 mo	220	13	222	11
First calving	55	8	74	12
Daily gain				
Pre-weaning	295	17	285	15
Post-weaning	216	13	216	11
Reproduction				
Age at first calving	127	17	106	14
First calving interval	88	14	42	7
≥2nd calving interval	261	21	203	20

The average and range in the effective number of progeny per sire reflects the small size of the data subsets (Table 3.3).

Table 3.3. Average and range of effective number of progeny per sire for each trait used to estimate sire components of variance for the Landim and Africander breeds.

	Landim		Africander	
Trait	N_e	Range	N_e	Range
Body weight				
Birth	13.1	1.8-21.9	10.9	3.1-22.2
Weaning	12.6	1.8-25.1	12.9	5.9-24.2
18 mo	11.0	1.8-21.8	11.8	4.5-21.7
First calving	4.2	2.7- 7.5	4.5	1.7- 8.2
Daily gain				
Pre-weaning	11.3	1.8-18.3	11.7	5.9-23.9
Post-weaning	10.7	1.8-21.8	11.5	3.6-21.1
Reproduction				
Age at first calving	4.1	1.2- 9.0	4.5	1.4- 8.3
First calving interval	3.5	1.5- 6.8	2.9	.7- 5.2
≥2nd calving interval	9.9	1.7-32.0	8.1	1.7-21.6

Two FORTRAN programs (ABSORBD and REMLD) that were written by VanRaden (1986) were used to estimate the sire variance components. The following general mixed linear model was used in the analysis:

$$y = X\beta + Zu + \epsilon$$

where,

y = the vector of observations on each trait for the Landim and Africander breeds,

β = the vector of fixed effects (yr/season of birth and sex for the growth traits, yr/season of calving for weight at first calving, yr/season of birth and calving group for age at first calving and first calving interval, and yr/season of calving and parity group for second and subsequent calving intervals),

u = the random vector of sire effects,

ϵ = the random vector of residual terms, and

X, Z = incidence matrices associating β and u with y.

The vectors of u and ϵ were assumed to be normally and independently distributed with:

$$E \begin{bmatrix} u \\ \epsilon \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \text{ and,}$$

$$Var \begin{bmatrix} u \\ \epsilon \end{bmatrix} = \begin{bmatrix} A\sigma_s^2 & 0 \\ 0 & I\sigma_e^2 \end{bmatrix}$$

where,

A = the numerator relationship matrix of additive coefficients of relationship between sires,

I = the identity matrix,

σ_s^2 = the variance due to the sire effect, which accounts for one quarter of the additive genetic variance in half-sibling families, and

σ_e^2 = the variance of random residuals.

The inclusion of **A** in the model allows, through additive genetic relationships, evaluation of all sires for the transmitted additive genetic effects to their progeny, increasing the accuracy of the estimates. The inverse of **A** was computed for each analysis using rules by Henderson (1976) as explained by Van Vleck (1983). Variance components were estimated iteratively and convergence was considered to be obtained when the estimates of $\hat{\sigma}_s^2$ and $\hat{\sigma}_e^2$ changed by less than 10^{-4} between iterations. The additive genetic variance and heritability for each trait and breed were estimated as:

additive genetic variance, $\hat{\sigma}_a^2 = 4(\hat{\sigma}_s^2)$

heritability, $\hat{h}^2 = \hat{\sigma}_a^2 / (\hat{\sigma}_s^2 + \hat{\sigma}_e^2)$

Because of the small size of the data subsets and the low effective number of progeny per sire, these estimates were expected to have large confidence intervals. Nevertheless, the resulting estimates indicate the magnitude of genetic variation in the Mozambique environment and possible implications in future breeding programs.

CHAPTER 4

WEIGHT AND GROWTH

4.1 INTRODUCTION

Although cattle production in Mozambique presently accounts for only about 2% of the GNP, it represents nearly half of the potential income (cash, services, consumption) for more than 80% of the Mozambicans (Pinto, 1989). Approximately 82% of the cattle population of 398,500 head in the census of 1988 belonged to the family sector. About 70% of these cattle are Landim, a Sanga breed indigenous to southern Mozambique that is managed with very low input. Most herds in the family sector are small, averaging about 10 head, and associated with subsistence in the sense that animals are sold or consumed only when necessary. Productivity is low with an annual offtake of only 8.6% (percent of the national herd that is sold or consumed) of which only 1 to 2% is recorded, i.e., registered by government officials (Pinto, 1989).

Landim cattle are also important to the commercial sector where most farms were established using this breed. The second most numerous breed in southern Mozambique is the Africander, also a Sanga breed, which was imported from South Africa. There are no official records that indicate when the Africander first was introduced into Mozambique. Silva (1966) indicates that this breed has existed in the south since about

1920. The relative importance of this breed is related to the commercial sector, which has shown preference for cattle of large mature size and where the role for Africander has been as a pure breed or to upgrade other breeds of cattle. Today, the number of Africander cattle (pure and upgraded) are approximately 60,000 head, representing about 12% of the national herd and about 67% of the commercial herd. Little is known about the comparative performance of these breeds in Mozambique. Results from studies in neighboring countries (Rakha et al., 1971; Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988) suggest that the Africander may not be as productive as previously assumed, especially if reproductive performance is less than for other Sanga breeds. The only study on the subject in Mozambique (Dionisio and Syrstad, 1990) gave similar conclusions because of the long calving intervals observed in Africander cows.

One of the goals in establishing the Chobela Research Station in southern Mozambique was to study the performance of the Landim and Africander when submitted to the same management in the same environment (see Chapter 3 for a detailed description). Hence, the objectives of this study were to evaluate and compare body weight and growth traits of these Sanga breeds reared at the Chobela Research Station, which represents the environmental conditions (semi-arid climate with a unimodal rainfall pattern) prevailing in southern Mozambique.

4.2 MATERIAL AND METHODS

Data for the present study were obtained from 854 calves born from 1975 to 1981 at the Chobela Research Station (latitude 32° 14′ E and longitude 25° 00′ S). A description of the environment is given in Chapter 3. The Landim and Africander breeds were managed together, grouped in smaller herds by age and sex. During the breeding season (February/April), smaller herds of around 25 breeding females each, were separated by breed and serviced by 1 bull of their respective breed. This practice allowed accurate recording of the service sires and generally facilitated management of the herd.

Calves were weaned at about 7 mo (~210 days) of age in August and September. Herd replacements were selected at about 18 mo (~540 days) of age. All animals were kept in natural pastures. Supplementation was given only in the dry seasons of the driest years and consisted of rice straw, molasses and urea. Preventive health included vaccinations against anthrax, blackleg, salmonellosis and brucellosis. All animals were annually screened for tuberculosis. External parasites (especially ticks) were controlled by weekly dipping.

Calf weight was recorded within 7 days of birth. Postpartum cows were also weighed at the same time. Thereafter, calves were weighed once per month. Weights of individual calves at weaning and 18 mo were adjusted to 210 and 540 days of age by linear interpolation between the weights preceding and subsequent to these ages.

Dates of calving (birth) were examined (Figure 3.4) and classified in two seasons. Classes were early (July to December) and late (January to June) in the rainy season.

Growth traits were body weights at birth, weaning, 18 mo and first calving, and average pre- and post-weaning daily gains (854, 701, 477, 135, 625, and 465 records respectively). Traits were analyzed using a fixed model, least squares procedures (the General Linear Model, GLM procedure; SAS, 1985) containing the effects of breed, year-season of birth, sex, parity nested within breed, year-season by breed interaction, and linear regression on dam's age nested within breed. The model for weight at first calving included the effects of breed, year-season of calving, and a linear regression on the heifer's age at first calving nested within breed. A detailed description of management, preparation and analysis of data, and the number of records per trait and breed (Table 3.1) are in Chapter 3.

4.3 RESULTS AND DISCUSSION

Unadjusted means and associated standard deviations for the growth traits of the Landim and Africander are in Table A.1 (Appendix A). Least squares means and standard errors for year-season effects on growth traits are also shown in Appendix A, Tables A.2 to A.7.

4.3.1 BIRTH WEIGHT

Birth weight least squares means and standard errors for the fixed effects of breed, sex and parity are in Table 4.1, and for the effect of year-season of birth in Table A.2. The frequency distribution of birth weights for the Landim and Africander are in Figure 4.1. Mean squares and tests of significance for the main effects are in Table 4.2.

Breed, sex, year-season of birth, parity, and year-season by breed interaction affected (P<.05) birth weight (Table 4.2). Age of dam (average of 72.6 mo for the Landim and 77.6 mo for the Africander), included in this study as a covariable nested within breed, was important in reducing the error variance (P<.05). Large differences in birth weight were also associated with year-season effects (Figure 4.2). Birth weight least squares means by year-season ranged from 28 kg (in 1980) to 37 kg (in 1977) for the Landim calves, and from 35 kg (in 1980) to 42 kg (in 1979) for the Africander calves (Table A.2).

The effect of year-season of birth on birth weight is illustrated in Figure 4.2. Seasonal influences on birth weight were also evident (Table 4.3). Calves born in the early rainy season (July through December) weighed an average of 2.0 ± .5 kg less (P<.01) than those born late in the rainy season (January through June). Cows calving early in the rainy season are in relatively poor body condition following the

Table 4.1. Least squares means ($\bar{x}$) and standard errors (SE) for breed, sex, and parity effects on birth weight (kg) of Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	459	33.4	.3
Africander	395	38.3	.4
Sex			
Female	407	35.2	.3
Male	447	36.6	.3
Parity[1]			
Landim			
Heifer	105	33.3	.6
Cow 1	265	34.1	.4
Cow 2	89	33.0	.6
Africander			
Heifer	97	37.1	.7
Cow 1	168	38.4	.5
Cow 2	130	39.4	.5

[1]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

Table 4.2. Mean squares and degrees of freedom from the analysis of variance for birth weight for Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	1023.5**
Age Dam/B[2]	2	81.8*
Year-season (YS)	10	277.1**
Sex	1	415.0**
Parity/B	4	65.3*
YS x B	10	75.8**
Residual	825	22.9

*P<.05.
**P<.01.
[1]Coefficient of determination (R^2) = .31; coefficient of variation = 15.5%; square root of the residual MS = 4.8 kg; overall mean = 35.5 kg;
[2]b_{Landim} = .02 ± .01 kg; and $b_{Africander}$ = −.01 ± .01 kg.

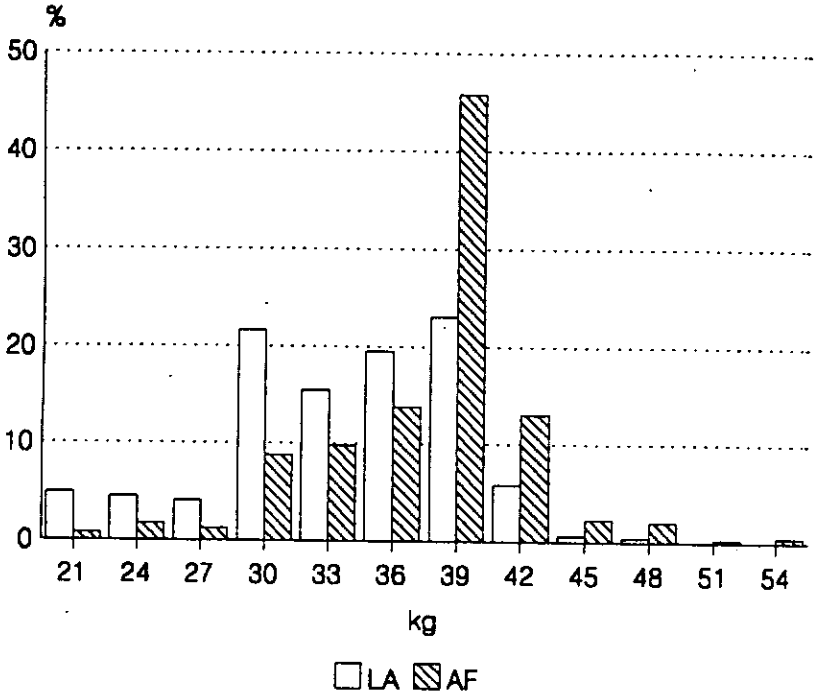


Figure 4.1. Frequency distribution of birth weight for the Landim and Africander breeds. (LA = Landim; AF = Africander).

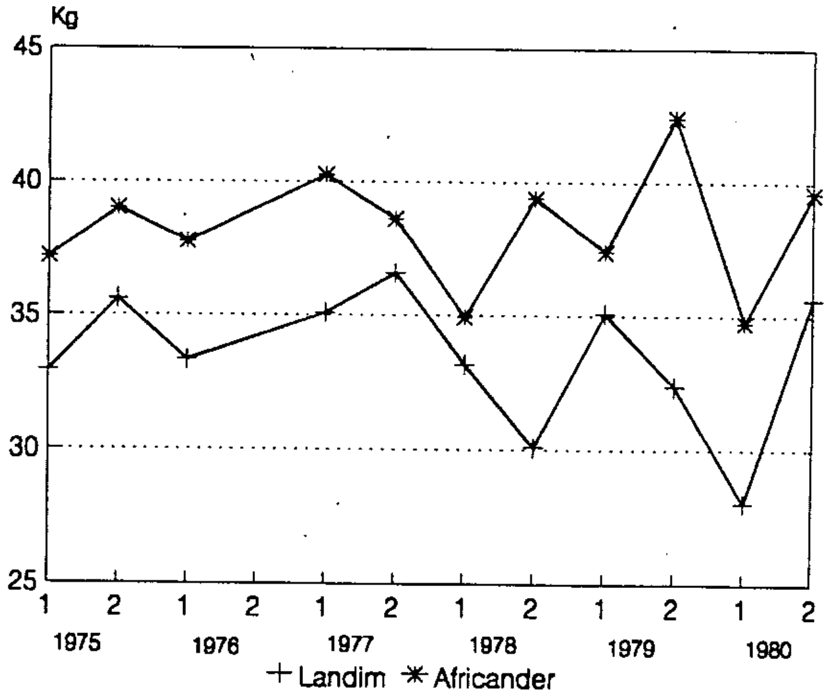


Figure 4.2. Least squares means for effect of year-season of birth on birth weights of Landim and Africander calves. (1 = early rainy season; 2 = late rainy season).

nutritionally stressful dry season. As a consequence, lighter calves are born from these cows. The nutritional environment improves dramatically with the start of the rainy season (October-November). Therefore, cows calving after December are in better body condition, which is reflected in the greater birth weights of their calves. Similar findings were obtained in Botswana (Buck et al., 1976). Sex differences were similar to those in other reports (Trail et al., 1977; Scholtz, 1988; Tawonezvi et al., 1988). Male calves averaged about 4% heavier (P<.01) than female calves, which averaged about 35 kg. Birth weights were 1.0 ± .52 kg less for calves from heifers than for pluriparous females (P<.06). Calf birth weights also differed between heifers and cows that produced a calf in the previous year (P<.05, Table 4.3). The contrasts for breed, sex of calf, and season of birth effects on birth weight are shown graphically in Figure 4.3.

Africander calves were 15% heavier at birth (4.9 ± .48 kg, P<.01) than Landim calves averaging 33.4 kg, which difference was equivalent to the within breed standard deviation (Tables 4.2 and 4.3). These results agree with reports showing the Africander as one of the indigenous breeds in the region with heaviest birth weights (Trail et al., 1977; Scholtz, 1988; Tawonezvi et al., 1988). Birth weight has little economic merit other than the fact that a heavier animal requires less gain to reach market weight. Robertson et al. (1986) indicated that larger cows usually produce larger

Table 4.3. Linear contrasts of least squares means for birth weight (kg) for Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	-4.9	.48**
Birth season (early minus late)	-1.9	.48**
Female minus Male	-1.4	.33**
Parity: Heifers minus Cows	-1.0	.52†
Heifers minus Cow 1[2]	-1.1	.54*
Heifers minus Cow 2[2]	- .9	.61
Cow 1 minus Cow 2	.1	.48

†P<.06.
*P<.05.
**P<.01.
[1]LA = Landim, AF = Africander.
[2]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

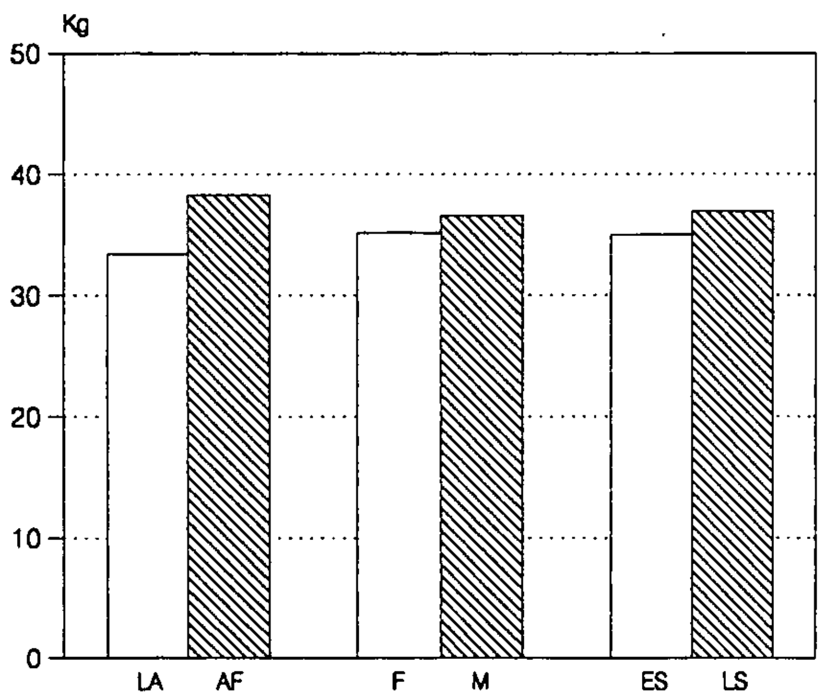


Figure 4.3. Least squares means for birth weight of Landim and Africander breeds. (LA = Landim; AF = Africander; F = female; M = male; ES = early rainy season; LS = late rainy season).

calves and that this has been attributed to a genetic maternal effect. Although calving difficulties are not common in tropical breeds (Galina and Arthur, 1989), Barlow (1981) refers to the possibility of selection for birth weight in tropical adapted breeds being detrimental if dystocia increases.

4.3.2 WEANING WEIGHT

Least squares means for weaning weight and associated standard errors for the fixed effects of breed, sex and parity are in Table 4.4. Least squares means and standard errors for the effect of year-season of birth for the Landim and Africander are in Table A.3. Figure 4.4 shows the frequency distribution of the weaning weights for each breed. Mean squares from the analysis of variance and tests of significance for the main effects in the model are in Table 4.5.

Breed, age of dam nested within breed, year-season of birth, sex, and the interaction of year-season and breed each affected weaning weight ($P<.05$). The average age of dam at weaning was 77.7 mo and 84.6 mo for the Landim and Africander, respectively. Parity class did not affect weaning weight ($P>.3$). Calves born early in the rainy season of 1977 were lighter at weaning ($P<.05$) than in other years (Figure 4.5),

Table 4.4. Least squares means ($\bar{x}$) and standard errors (SE) for breed, sex, and parity effects on weaning weight (kg) of Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	367	148.5	1.5
Africander	334	164.9	1.5
Sex			
Female	365	152.9	1.3
Male	336	161.1	1.3
Parity[1]			
Landim			
Heifer	94	149.0	2.7
Cow 1	207	148.6	1.6
Cow 2	66	149.1	3.0
Africander			
Heifer	77	162.0	3.0
Cow 1	157	164.5	2.0
Cow 2	100	168.8	2.3

[1]Cow 1 = Cow that calved in the previous year; and
Cow 2 = Cow that did not produce a calf in the previous year.

Table 4.5. Mean squares and degrees of freedom from the analysis of variance for weaning weight for Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	11930.0**
Age Dam/B[2]	2	1421.7*
Year-season (YS)	9	8438.7**
Sex	1	11040.1**
Parity/B	4	382.7
YS x B	9	948.8*
Residual	674	370.6

*$P<.05$.
**$P<.01$.
[1]Coefficient of determination (R^2) = .39;
coefficient of variation = 12.1%;
square root of the residual MS = 19.3 kg;
overall mean = 158.6 kg;
[2]b_{Landim} = .11 ± .04 kg; and
$b_{Africander}$ = -.05 ± .04 kg.

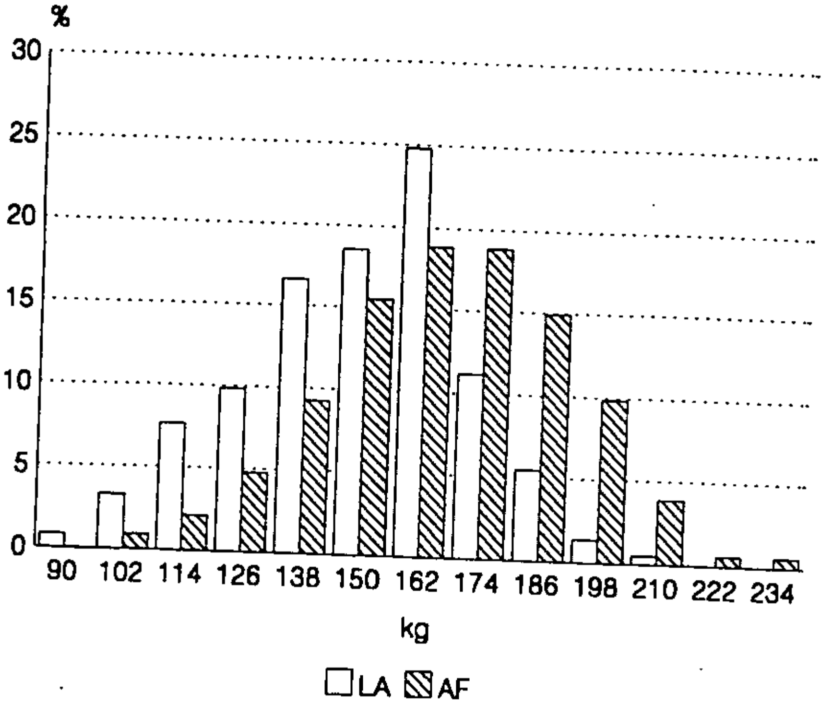


Figure 4.4. Frequency distribution of weaning weight for the Landim and Africander breeds. (LA = Landim; AF = Africander).

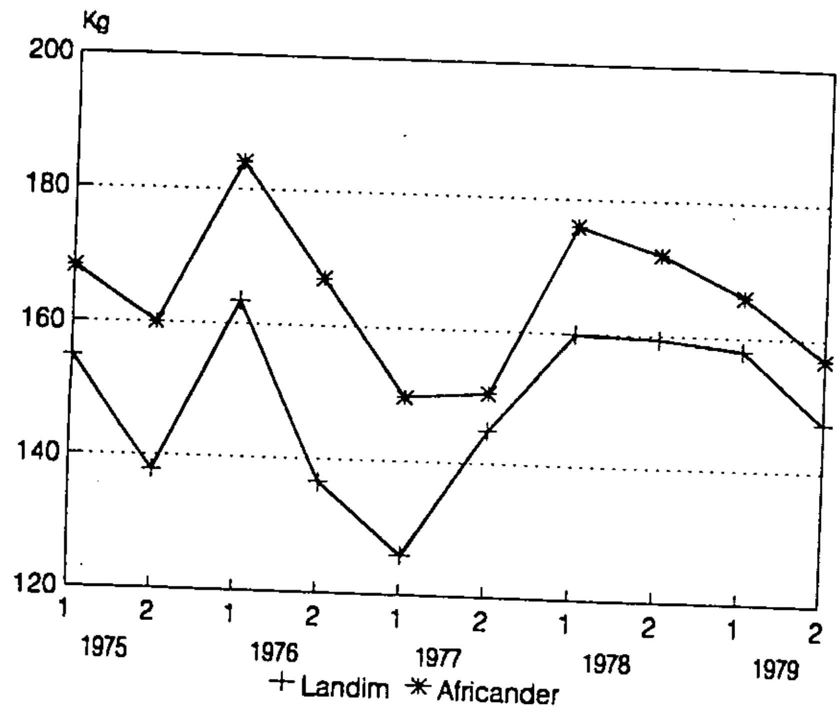


Figure 4.5. Least squares means for effect of year-season of birth on weaning weights of Landim and Africander calves. (1 = early rainy season; 2 = late rainy season).

which probably was the result of an earlier-than-expected dry season (starting before April).

Season affected weaning weight (P<.05) but in an opposite manner than for birth weight. Calves born early were 7 ± 2 kg heavier at weaning (Table 4.6) than those born late in the rainy season (i.e., after December). In support of this management system, Maule (1973) refered to studies in South Africa where weaning weight of Africander calves decreased 2.9 kg per day for each week that a calf was born after October. Cows calving late in the rainy season (January through April) encounter mature and less digestible pastures than dams of calves born before January, which most probably has detrimental influence on milk yield. Therefore, although with higher birth weights, calves born after December probably receive less nutritional support (milk) from dams grazing poorer pastures. On the other hand, the lighter calves born early in the rainy season have the advantage of better nutritional environment to support their dam's milk production, thus resulting in higher weaning weights. Therefore, weaner productivity would be increased by using a breeding season policy, restricting the mating season to ensure that the majority of calvings occur early in the rainy season before December.

Weaning weight differed between years (P<.01) but no pattern was discernible. Differences in annual rainfall, which directly influence the availability of pastures, may explain

Table 4.6. Linear contrasts of least squares means for weaning weight (kg) for Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	-16.4	2.1**
Birth season (early minus late)	7.3	2.0**
Female minus Male	-8.1	1.5**
Parity: Heifers minus Cows	-2.3	2.3
Heifers minus Cow 1[2]	-1.1	2.3
Heifers minus Cow 2[2]	-3.5	2.8
Cow 1 minus Cow 2	-2.4	2.2

*P<.05.
**P<.01.
[1]LA = Landim, AF = Africander.
[2]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

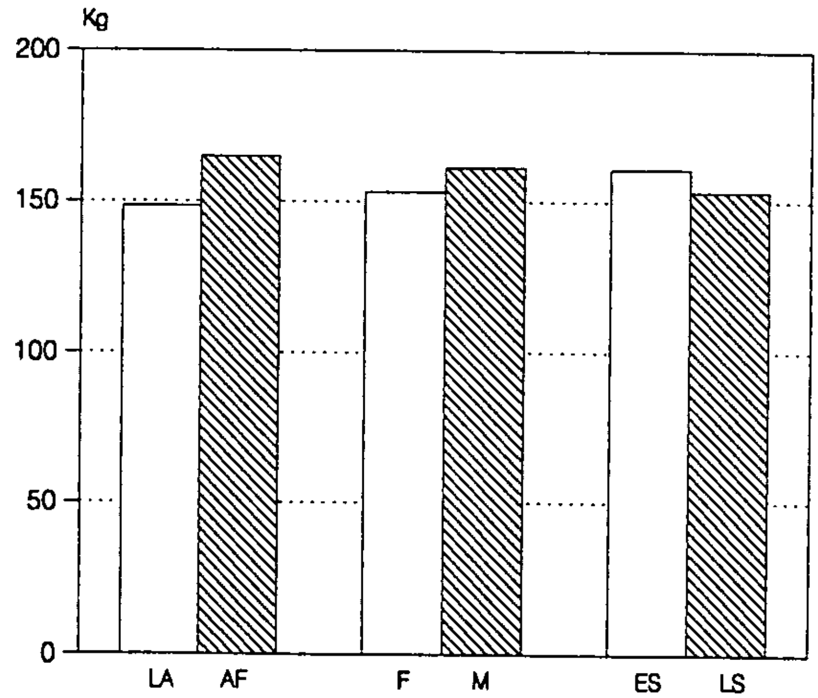


Figure 4.6. Least squares means for weaning weight of Landim and Africander breeds. (LA = Landim; AF = Africander; F = female; M = male; ES = early rainy season; LS = late rainy season).

these ups and downs in the average weaning weight through time (Figure 4.5). Weaning weights, as affected by year-season, ranged from 126 kg (in 1977) to 164 kg (in 1976) for the Landim calves, and from 150 kg (in 1977) to 176 kg (in 1978) for the Africander calves (Table A.3). Males were 8 ± 1.5 kg (5%) heavier than females (P<.01), averaging 161 kg and 153 kg, respectively. Contrasts between least squares means for breed, sex of calf, and season of birth are also shown graphically in Figure 4.6. Africander calves were on average 16 ± 2 kg heavier than Landim calves, which averaged 149 kg (P<.01). This difference corresponds to about 85% of the within breed standard deviation, which was relatively less than the breed difference (~1 SD) in birth weights (Table 4.6). Most studies in the region (Scholtz, 1988; Tawonezvi et al., 1988; and Dionisio and Syrstad, 1990) found the Africander to be heavier at weaning than other local Sanga breeds (Tswana, Nguni, Tuli, Mashona, Nkone and Landim), except for the findings by Trail et al. (1977) in Botswana. Maule (1973) refered to a study in Swaziland that found no differences in weaning weight between the Africander and Nguni. Because the Nguni is smaller, it was concluded that the larger Africander was unsuitable to humid climates like in Swaziland.

Emphasis in weaning weight varies depending upon the production system. Weaning weight is important for cow-calf producers because it measures their primary product (Robertson *et al.*, 1986). The maternal influence of the cow is a substantial source of variation in weaning weight of calves (Lasley, 1972; Koch, 1972), mostly through the milk production of the dam. In this sense, weaning weight can be considered as a measure of cow productivity. In extensive production systems as are found in southern Mozambique (e.g., 3 to 4 years for animals to reach market weight), weaning weight should receive relatively less emphasis than yearling weight (Dionisio, 1989).

4.3.3 WEIGHT AT 18 MONTHS OF AGE

Least squares means and standard errors for weight at 18 mo of age for the fixed effects of breed, sex and parity are in Table 4.7. Least squares means and standard errors for the effect of year-season of birth for the Landim and Africander are in Table A.4. Figure 4.7 shows the histogram of the distribution of weights at 18 mo for each breed. Mean squares and degrees of freedom from the analysis of variance and tests of significance for the effects in the model are in Table 4.8.

Sex, breed, and year-season affected ($P<.01$) weight at 18 mo (Table 4.8), but age of dam, parity, and year-season by breed interaction were less important sources of variation ($P>.08$). As expected, the maternal influence diminishes after weaning, whereafter growth depends especially on the animal's genotype, and on the interactions with the environment,

Table 4.7. Least squares means ($\bar{x}$) and standard errors (SE) for breed, sex, and parity effects on 18 mo weight (kg) for Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	244	237.6	2.3
Africander	233	252.2	2.1
Sex			
Female	252	230.6	1.9
Male	225	260.1	2.1
Parity[1]			
Landim			
Heifer	60	242.4	4.6
Cow 1	130	232.9	2.6
Cow 2	54	239.3	4.6
Africander			
Heifer	53	252.5	4.5
Cow 1	101	251.2	3.3
Cow 2	79	253.8	3.6

[1]Cow 1 = Cow that calved in the previous year; and
Cow 2 = Cow that did not produce a calf in the previous year.

Table 4.8. Mean squares and degrees of freedom from the analysis of variance for 18 mo weight for Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	9295.8**
Age Dam/B[2]	2	1677.4
Year-season (YS)	7	6309.5**
Sex	1	97534.2**
Parity/B	4	687.9
YS x B	7	537.4
Residual	454	681.3

**P<.01.
[1]Coefficient of determination (R^2) = .42; coefficient of variation = 10.6%; square root of the residual MS = 26.1 kg; overall mean = 246.4 kg.
[2]b_{Landim} = .13 ± .07 kg; and
$b_{Africander}$ = −.07 ± .06 kg.

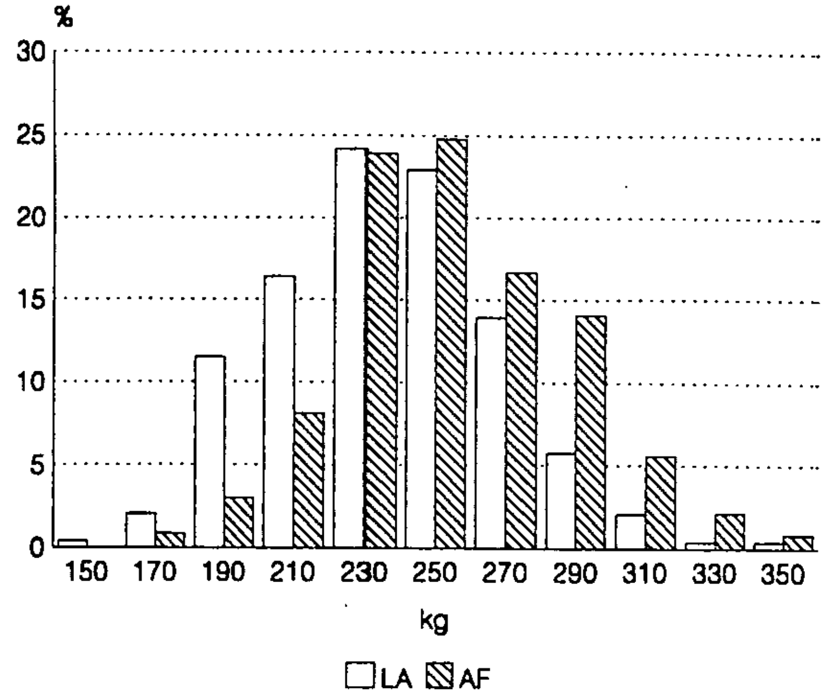


Figure 4.7. Frequency distribution of 18 mo weight for the Landim and Africander breeds. (LA = Landim; AF = Africander).

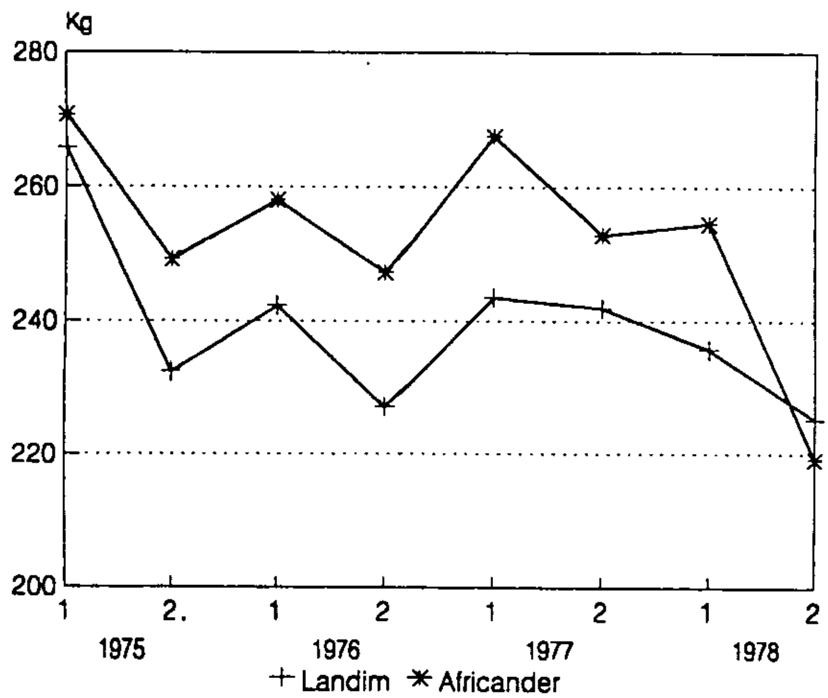


Figure 4.8. Least squares means for effect of year-season of birth on 18 mo weights of Landim and Africander calves. (1 = early rainy season; 2 = late rainy season).

especially nutrition and health. Weights at 18 mo ranged from 225 kg (in 1978) to 257 kg (in 1975) for the Landim calves, and from 219 kg (in 1978) to 271 kg (in 1975) for the Africander calves (Table A.4). The effect of year-season on 18 month weight by breed is depicted graphically in Figure 4.8. As for weaning weight, animals born early in the rainy season (Table 4.9) were 16.7 ± 2.9 kg heavier than those born late in the rainy season (P<.01). These results substantiate the management recommendation given for weaning weight to restrict the breeding season to concentrate calvings in the early rainy season before December. Males averaged 30 ± 2.5 kg (13%) heavier than females (P<.01), weighing 231 kg. Differences in least squares means are also shown graphically in Figure 4.9.

Africander calves averaged 14.6 ± 3.1 kg heavier at 18 mo than Landim calves (P<.01). Average 18 month weights were 238 kg for Landim and 252 kg for Africander calves. This difference is equivalent to about one-half (56%) of the within breed standard deviation (Tables 4.8 and 4.9).

Africander calves were heavier than the Landim ones at all ages -- birth, weaning and 18 mo -- however, the relative difference between the two breeds diminishes with age, which is illustrated by the growth curves in Figure 4.10. Figure 4.11 gives a graphic representation of the difference between the Africander and the Landim on a percentage scale [((Africander weight - Landim weight) ÷ Landim weight) x 100]. These percentage differences were 15%, 11%, and 6% for weights

Table 4.9. Linear contrasts of least squares means for 18 mo weight (kg) for Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	-14.6	3.1**
Birth season (early minus late)	16.7	2.9**
Female minus Male	-29.5	2.5**
Parity: Heifers minus Cows	3.1	3.8
Heifers minus Cow 1[2]	5.4	3.9
Heifers minus Cow 2[2]	.9	4.4
Cow 1 minus Cow 2	-4.5	3.6

**P<.01.
[1]LA = Landim, AF = Africander.
[2]Cow 1 = Cow that calved in the previous year; and
Cow 2 = Cow that did not produce a calf in the previous year.

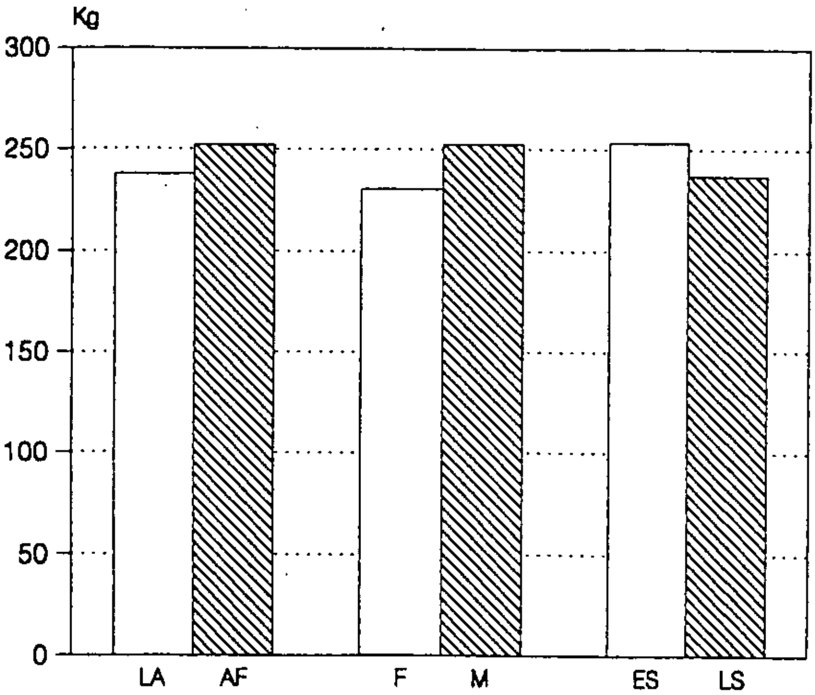


Figure 4.9. Least squares means for 18 mo weight of Landim and Africander breeds. (LA = Landim; AF = Africander; F = female; M = male; ES = early rainy season; LS = late rainy season).

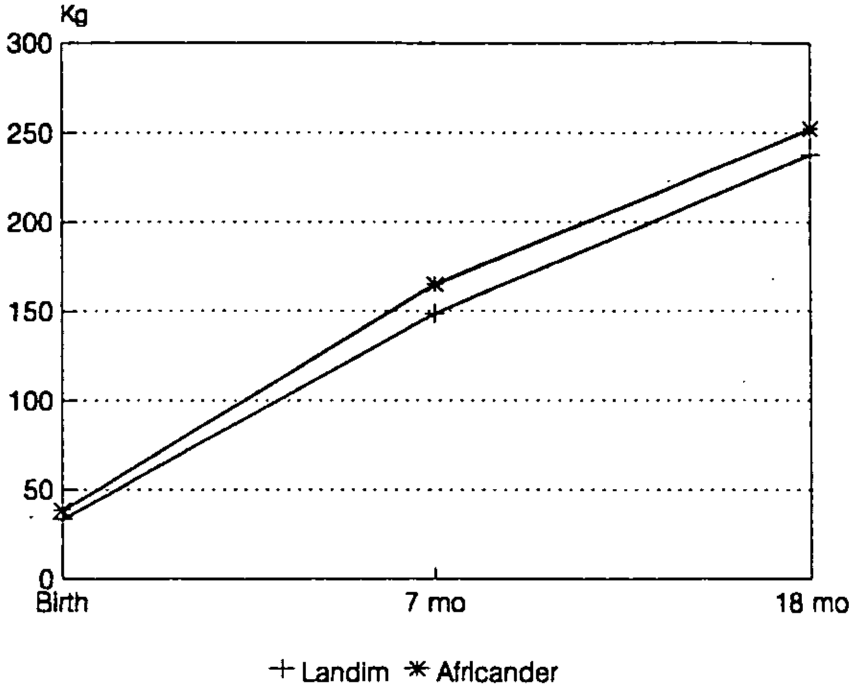


Figure 4.10. Growth curve showing adjusted body weights at birth, weaning (7 mo), and 18 mo of age for Landim and the Africander breeds (average of both sexes).

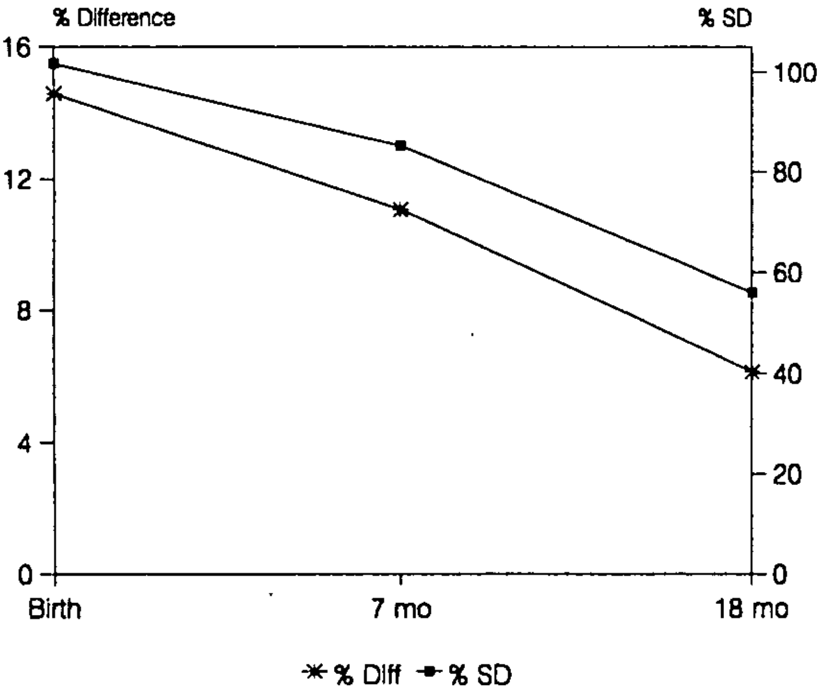


Figure 4.11. Percent differences in mean body weights (%Diff) and as a percent of the within breed standard deviation (%SD) for the Landim and Africander breeds.

at birth, weaning, and 18 mo, respectively. Figure 4.11 also shows the weight differences between the breeds as a percentage of the within breed standard deviation, which were 102%, 85%, and 56% for weights at birth, weaning, and 18 mo. A separate analysis using a data subset containing animals that were weighed at all three ages (birth, weaning and 18 mo) showed a similar trend (differences were 14%, 11% and 6% for weight, and 97%, 94% and 50% of the within breed SD, respectively). These results indicate that the Landim calves had greater adaptation to the climatic and nutritive environment to which they were subjected, and showing improved relative growth performance with age compared to the Africander.

4.3.4 PRE-WEANING GROWTH RATE

Least squares means and standard errors for pre-weaning growth rate for the effects of breed, sex and parity are in Table 4.10. Least squares means and standard errors for the effect of year-season of birth for the Landim and Africander are in Table A.5. Figure 4.12 shows the frequency distribution of the pre-weaning daily growth for each breed. Mean squares from the analysis of variance and tests of significance for the main effects are in Table 4.11.

Breed, year-season, and sex were significant sources of variation in pre-weaning average daily growth ($P<.01$). Parity

Table 4.10. Least squares means ($\bar{x}$) and standard errors (SE) for breed, sex, and parity effects on daily growth rate from birth to weaning (kg/d) for the Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
		kg/d	
Breed			
Landim	325	.555	.007
Africander	300	.602	.008
Sex			
Female	316	.561	.007
Male	309	.596	.007
Parity[1]			
Landim			
Heifer	79	.551	.014
Cow 1	183	.548	.008
Cow 2	63	.568	.014
Africander			
Heifer	67	.596	.015
Cow 1	134	.597	.011
Cow 2	99	.613	.012

[1]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

Table 4.11. Mean squares and degrees of freedom from the analysis of variance for the daily growth rate from birth to weaning for the Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	.069**
Age Dam/B[2]	2	.007
Year-season (YS)	8	.244**
Sex	1	.184**
Parity/B	4	.007
YS x B	8	.014
Residual	600	.008

**P<.01.

[1]Coefficient of determination (R^2) = .37; coefficient of variation = 15.5%; square root of the residual MS = .091 kg/d; overall mean = .589 kg/d;

[2]b_{Landim} = .0003 ± .0002 kg/d; and $b_{Africander}$ = −.00004 ± .0002 kg/d.

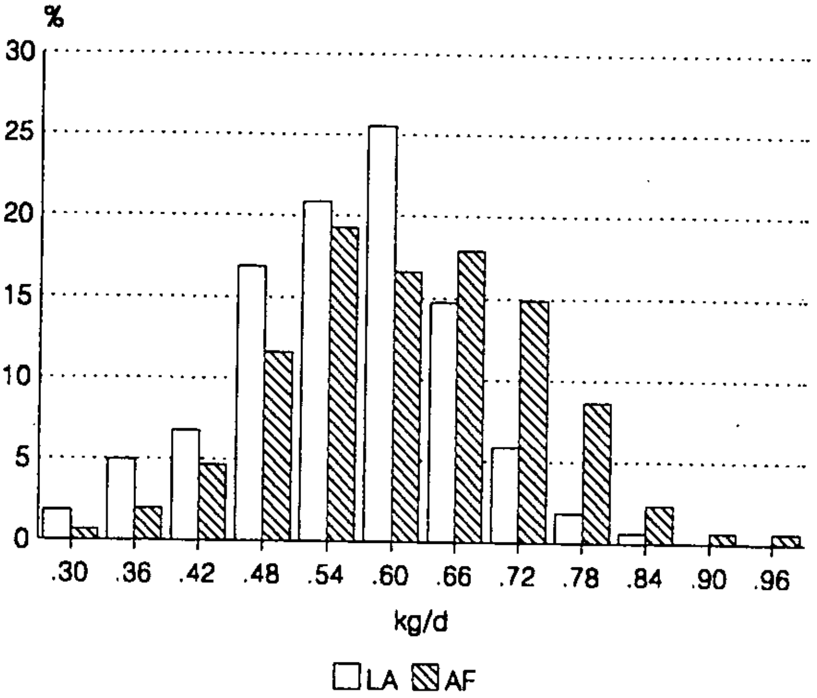


Figure 4.12. Frequency distributions of average daily growth from birth to weaning for the Landim (LA) and Africander (AF) breeds.

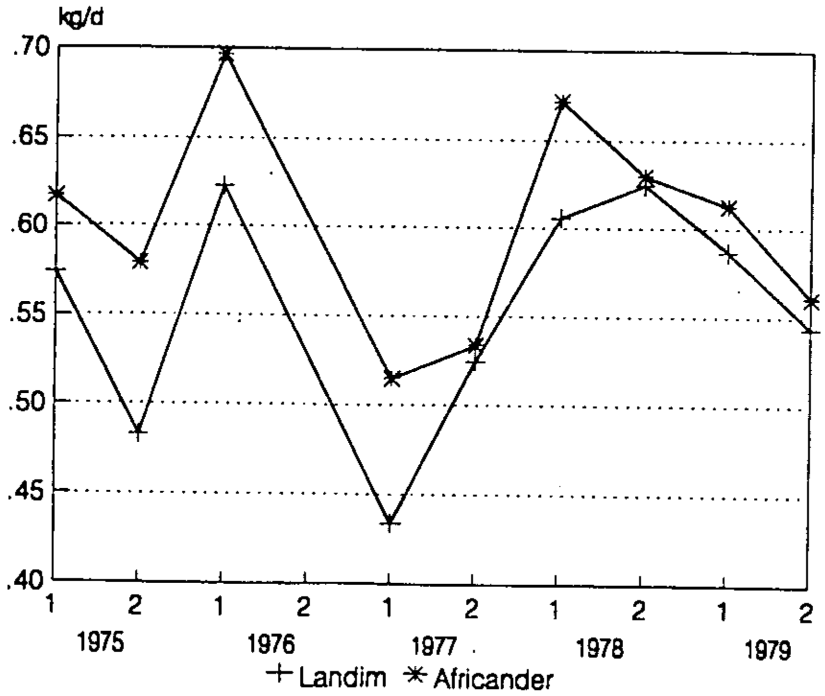


Figure 4.13. Least squares means for effect of year-season of birth on average daily growth from birth to weaning of Landim and Africander calves. (1 = early rainy season; 2 = late rainy season).

and year-season of birth by breed interaction did not detectably affect this trait. Contrary to results obtained in other studies (e.g., Koch, 1972; Robertson et al., 1986; Tawonezvi, 1989), age of dam did not importantly affect (P>.4) pre-weaning growth. Mothering ability (judged from the growth rate of their calves) is highly influenced by environmental factors, especially year-season, and may be confounded with this effect. The average age of dam was 71 mo for the Landim and 78 mo for the Africander. Calves born in the early rainy season of 1977 grew more slowly than calves born in other year-seasons, which, like in the weaning weight analysis may have been the result of an earlier-than-expected dry season (Figure 4.13). Average daily growth from birth to weaning by year-season of birth ranged from .434 kg/d (in 1977) to .625 kg/d (in 1978) for Landim calves, and from .515 kg/d (in 1977) to .697 kg/d (in 1976) for Africander calves (Table A.5). Calves born early in the rainy season grew .034 ± .007 kg/d faster (P<.01) than calves born late in the rainy season, which shows the same trend and has the same interpretation with regard to the advantage from a restricted breeding season as was given for weights at weaning and 18 mo. Also, males grew .035 ± .007 kg/d or 6% faster than females (P<.01). Differences between least squares means with respect to the main effects are in Table 4.12, and are shown graphically in Figure 4.14.

Table 4.12. Linear contrasts of least squares means for daily growth rate from birth to weaning (kg/d) for the Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	-.047	.011**
Birth season (early minus late)	.034	.011**
Female minus Male	-.035	.007**
Parity: Heifers minus Cows	-.008	.012
Heifers minus Cow 1[2]	.001	.012
Heifers minus Cow 2[2]	-.017	.014
Cow 1 minus Cow 2	-.018	.011

**P<.01.
[1]LA = Landim, AF = Africander.
[2]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

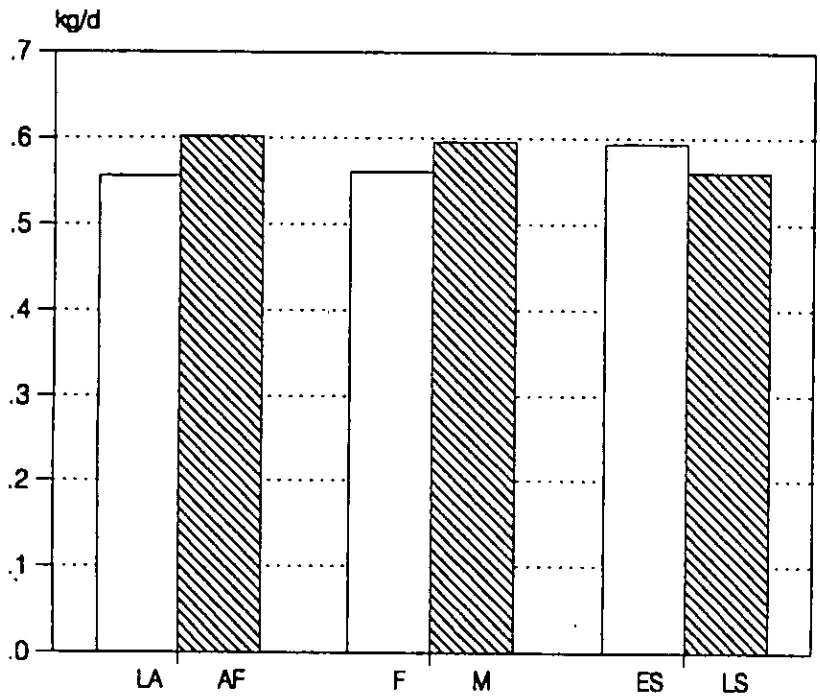


Figure 4.14. Least squares means for pre-weaning growth rate for the Landim (LA) and Africander (AF) breeds. (F = female; M = male; ES = early and LS = late rainy seasons).

The Africander calves grew 9% faster than the Landim calves with average daily growth rates of .60 ± .008 kg/d and .55 ± .007 kg/d. Growth from birth to weaning partly reflects the dam's maternal ability (e.g., milk production). Africander dams, being larger and older (they can eat more and, therefore, have more nutrients available for milk production), are more conducive to pre-weaning growth than that of other Sanga breeds. These results agree with those in the literature (Maule, 1973; Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990).

4.3.5 POST-WEANING GROWTH RATE

Least squares means and standard errors for post-weaning growth rate for the effects of breed, sex and parity are in Table 4.13. Least squares means and standard errors for the effect of year-season of birth for the Landim and Africander are in Table A.6. Figure 4.15 shows the frequency distribution of post-weaning daily growth for each breed. Mean squares from the analysis of variance and tests of significance for the fixed effects in the statistical model are in Table 4.14.

The effects of year-season and sex were significant (P<.01), but breed, age of dam, parity, and the year-season by breed interaction had no detectable effect (P>.2) on this trait. Except for dam's that were heifers or cows that calved in the previous year (Table 4.15), parity classes did not

Table 4.13. Least squares means ($\bar{x}$) and standard errors (SE) for breed, sex, and parity effects on daily growth rate from weaning to 18 mo (kg/d) of the Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed		—kg/d—	
Landim	239	.272	.006
Africander	226	.261	.006
Sex			
Female	249	.240	.005
Male	216	.294	.006
Parity[1]			
Landim			
Heifer	58	.287	.013
Cow 1	129	.258	.007
Cow 2	52	.273	.007
Africander			
Heifer	51	.270	.013
Cow 1	100	.254	.009
Cow 2	75	.258	.010

[1]Cow 1 = Cow that calved in the previous year; and
Cow 2 = Cow that did not produce a calf in the previous year.

Table 4.14. Mean squares and degrees of freedom from the analysis of variance for the daily growth rate from weaning to 18 mo for Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	<.001
Age Dam/B[2]	2	.001
Year-season (YS)	7	.154**
Sex	1	.318**
Parity/B	4	.007
YS x B	7	.005
Residual	442	.005

**P<.01.

[1]Coefficient of determination (R^2) = .42;
coefficient of variation = 26.9%;
square root of the residual MS = .072 kg/d;
overall mean = .267 kg/d;

[2]b_{Landim} = .0001 ± .0002 kg/d; and
$b_{Africander}$ = −.00004 ± .0002 kg/d.

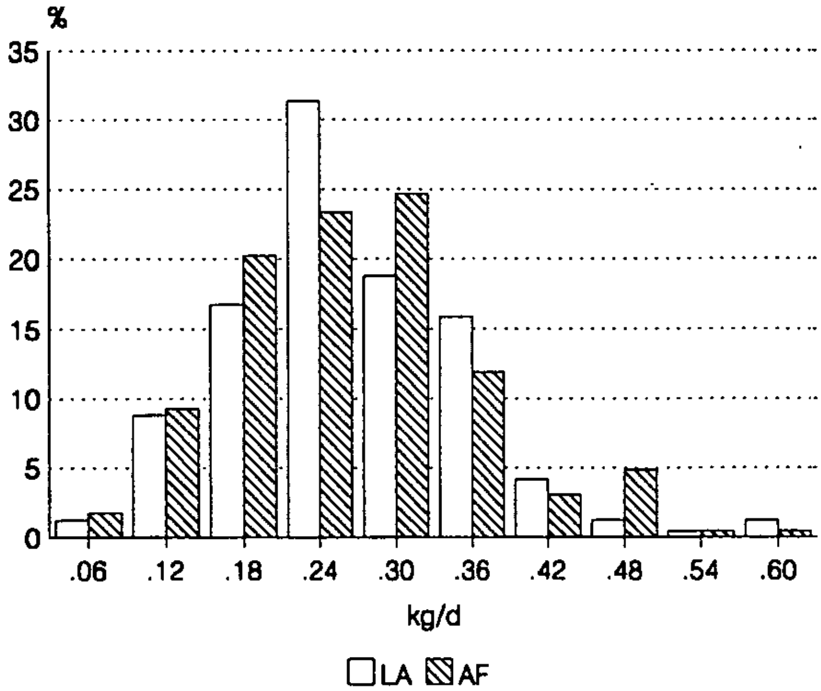


Figure 4.15. Frequency distributions for average daily growth from weaning to 18 mo for the Landim (LA) and Africander (AF) breeds.

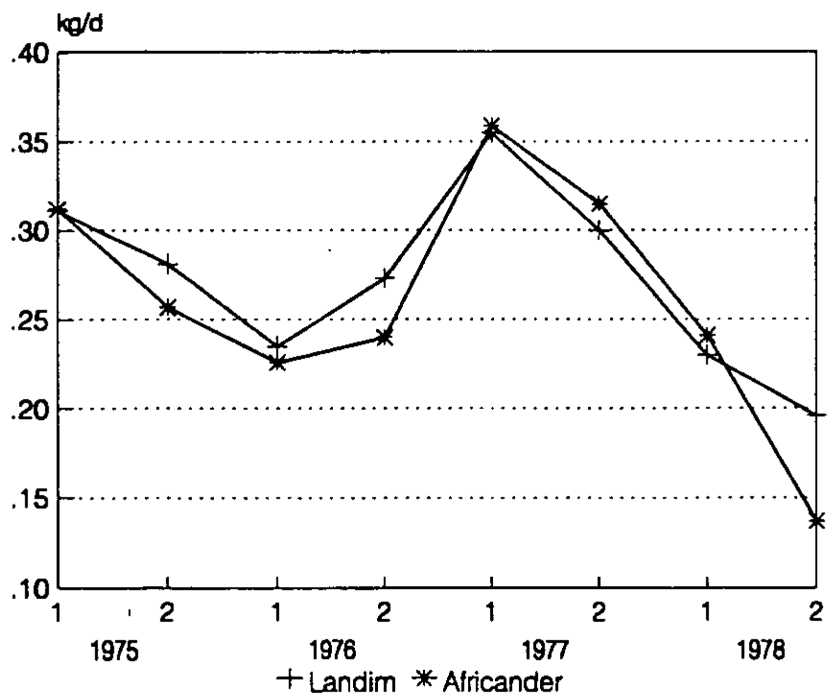


Figure 4.16. Least squares means for effect of year-season of birth on average daily growth from weaning to 18 mo of Landim and Africander calves. (1 = early rainy season; 2 = late rainy season).

affect the post-weaning growth of calves. Animals born in the late rainy season of 1978 had slower growth rates from weaning to 18 mo than those born in other years. As noted previously for other traits, this may have resulted from an earlier-than-expected dry season (Figure 4.16).

Average daily post-weaning growth by year of birth ranged from .196 kg/d (in 1978) to .355 kg/d (in 1977) for Landim calves, and from .137 kg/d (in 1978) to .359 kg/d (in 1977) for Africander calves (Table A.6). Season of birth had the same effect on post-weaning growth as for the other traits (weights at weaning, 18 mo, and pre-weaning daily growth). Animals born early in the rainy season grew faster (.034 ± .008 kg/d) than those born late in the rainy season (P<.01), thus reinforcing the need for a restricted breeding policy in environments like the one in Chobela. The differences in growth and body weight between sexes were consistent from birth. Males grew on average .294 ± .006 kg/d, a 23% advantage of .054 ± .007 kg/d (P<.01) over females averaging .240 ± .005 kg of weight gain per day. These contrasts are shown graphically in Figure 4.17.

The average daily growth for the two breeds after weaning was .272 ± .006 kg for the Landim and .261 ± .006 kg for the Africander (Table 4.14). Therefore, the Africander and the Landim cattle grew at similar rates (P>.1) in this period. Figure 4.10 illustrates this aspect with parallel post-weaning growth rates for these breeds. This result supports a

Table 4.15. Linear contrasts of least squares means for daily growth from weaning to 18 mo (kg/d) for the Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	.011	.009
Birth season (early minus late)	.034	.008**
Female minus Male	-.054	.007**
Parity: Heifers minus Cows	.018	.011
Heifers minus Cow 1[2]	.023	.011*
Heifers minus Cow 2[2]	.013	.012
Cow 1 minus Cow 2	-.009	.010

*P<.05.
**P<.01.
[1]LA = Landim, AF = Africander.
[2]Cow 1 = Cow that calved in the previous year; and Cow 2 = Cow that did not produce a calf in the previous year.

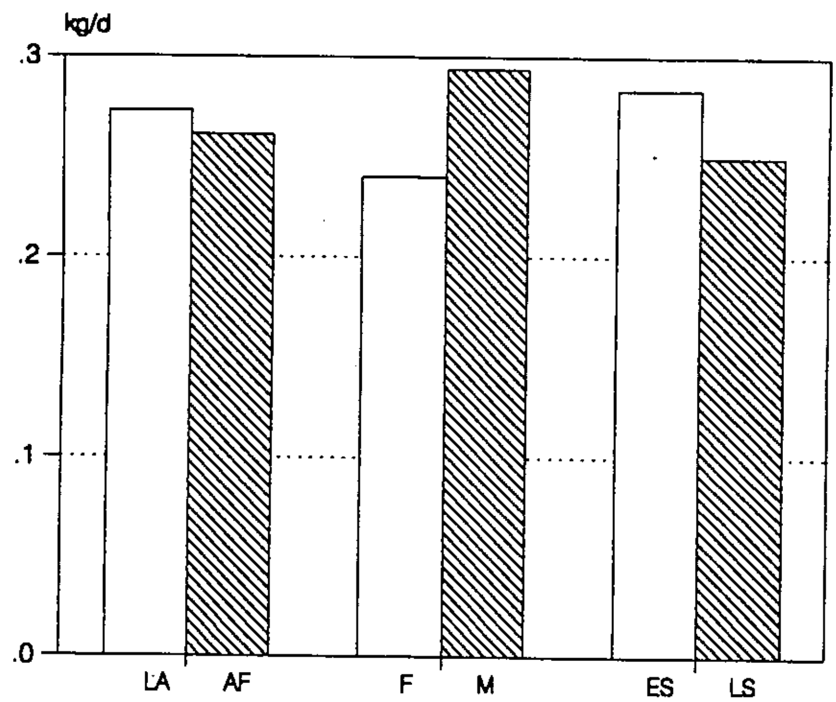


Figure 4.17. Least squares means for post-weaning growth rate for the Landim (LA) and Africander (AF) breeds. (F = female; M = male; ES = early and LS = late rainy seasons).

hypothesis for relatively greater adaptation of the Landim calves to the climatic and nutritive environment prevailing at the Chobela station, especially after weaning, when growth depends on the interaction between the animals genotype and the environmental opportunities and constraints.

4.3.6 BODY WEIGHT AT FIRST CALVING

Least squares means and standard errors for weight at first calving for the breed effect are in Table 4.16. Least squares means and standard errors for the effect of year-season of calving for the Landim and Africander are in Table A.7. Figure 4.18 is a histogram of the distribution of weights at first calving for each breed. Mean squares and degrees of freedom from the analysis of variance and tests of significance for the effects in the statistical model are in Table 4.17.

Year-season of calving importantly influenced body weights of the subset of females with recorded first calvings ($P<.01$). Large differences in weight at first calving were associated with year-season of calving. Weight at first calving least squares means by year-season of calving (Table A.7) ranged from 331 kg (early in the rainy season of 1980) to 396 kg (early in the rainy season of 1976). The average weight of these females at 18 mo of age by year-season of calving ranged from 205 kg to 239 kg, corresponding to an average

Table 4.16. Least squares means ($\bar{x}$) and standard errors (SE) for the effect of breed on body weight at first calving (kg) from heifers of Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	69	386.9	11.8
Africander	66	360.9	10.4

Table 4.17. Mean squares and degrees of freedom from the analysis of variance for body weight at first calving from heifers of Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	457.5
Age[2]/B[3]	2	15104.7**
Year-season[4]	7	8394.6**
Residual	125	1118.6

**P<.01.
[1]Coefficient of determination (R^2) = .59;
coefficient of variation = 9.0%;
square root of the residual MS = 33.4 kg; and
overall mean = 371.4 kg;
[2]Age at first calving.
[3]b_{Landim} = 3.7 ± 1.02 kg; and
$b_{Africander}$ = 5.6 ± 1.10 kg.
[4]Year-season of calving.

Table 4.18. Linear contrasts of least squares means for body weight at first calving (kg) from heifers of Landim and Africander breeds.

Contrast	Estimate	SE
LA minus AF[1]	26.1	18.5[a]
Calving season (early minus late)	-7.3	7.9

[1]LA = Landim, AF = Africander.
[a]P>.15.

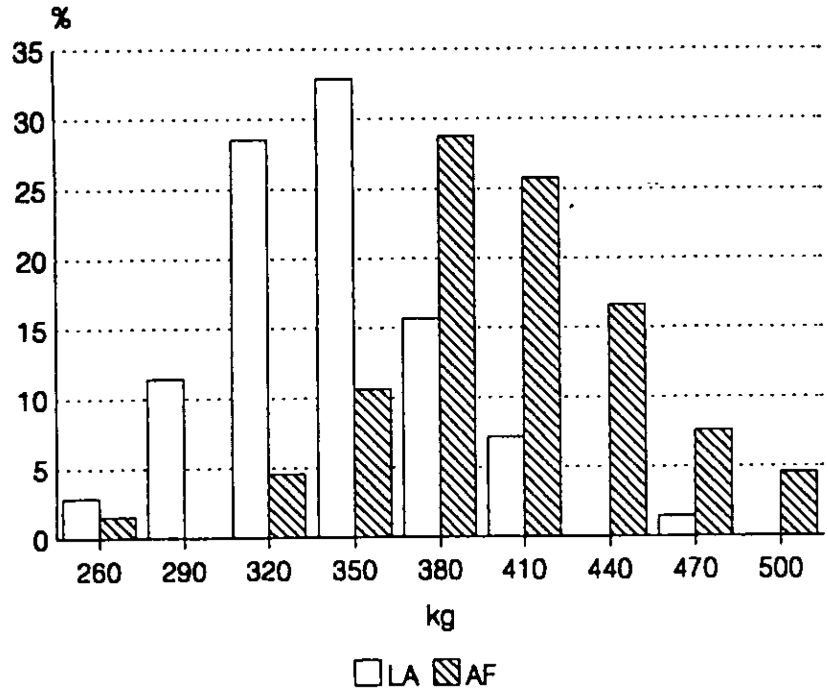


Figure 4.18. Frequency distributions of weight at first calving for the Landim (LA) and Africander (AF) breeds.

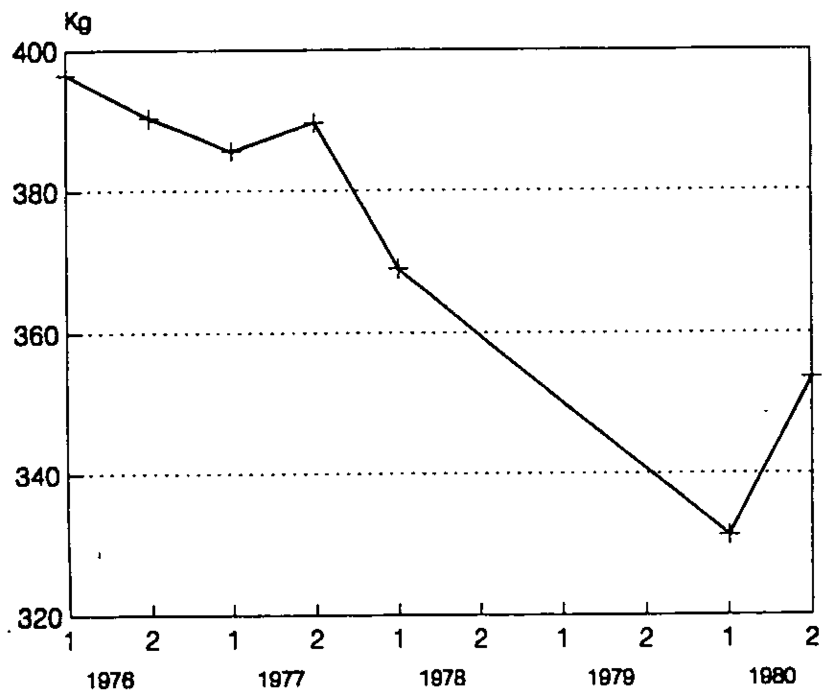


Figure 4.19. Time trend in least squares means for weight at first calving for Landim and Africander females. (1 = early rainy season; 2 = late rainy season).

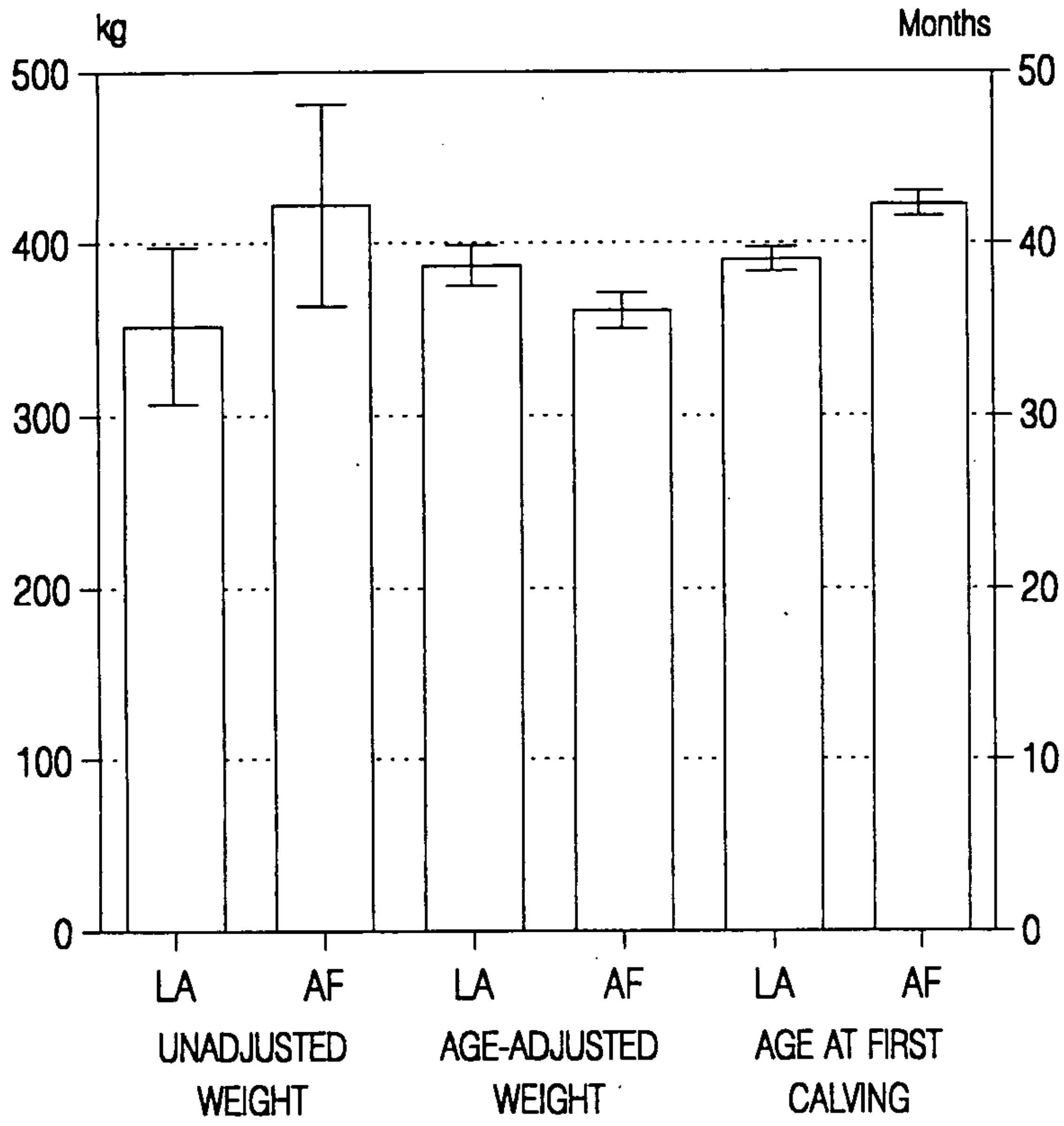


Figure 4.20. Unadjusted (and SD) and age-adjusted (and SE) mean weights at first calving and mean age (and SE) at first calving for the Landim (LA) and Africander (AF) breeds.

growth of 140 kg in about two years. There was a distinct trend to lighter weights at first calving with time (Figure 4.19). Because there was no detectable interaction between year-season of calving and breed, the average decrease (about 65 kg) in weight was similar for both breeds. This drop in weight at first calving may be a consequence of management decisions related with a decrease in age or in the weight of heifers at first breeding exposure. Other identifiable environmental effects did not change so dramatically to justify such differences in weight at first calving. This management policy, if true, may be related with findings by Ward (1968, after Maule, 1973) where a critical mating weight range of 270 kg to 290 kg was found for the Mashona breed (a Sanga breed indigenous to Zimbabwe), below or above which the cows did not conceive. Season of calving (early vs late rainy season) did not affect weight at first calving ($P>.3$). Age of female at first calving (average of 39 mo and 42 mo, respectively, for the Landim and Africander), was important in reducing the error variance ($P<.001$).

Weight at first calving least squares means were 387 ± 11.8 kg and 361 ± 10.4 kg for the Landim and Africander heifers, respectively, showing a difference of 26 ± 18.5 kg between breeds. No breed effect ($P>.5$) was detected after adjusting for age of female at first calving (Table 4.17). The large difference in average age at first calving (almost 3 mo) between Landim and Africander heifers accounted for 45% of the variation in weight at first calving, about three-fourths of the coefficient of determination from the full model (R^2 = .59), which resulted in no detectable residual differences in weight at first calving.

Differences between age-adjusted body weights since birth for the Landim and Africander calves showed a remarkable reduction when compared in a percentage basis. Percentage differences in body weight, which favored the Africander calves (Figure 4.11) were 15% at birth, 11% at weaning, 6% at 18 mo of age, but had no detectable difference at first calving (7%). This trend was confirmed in the subset of 52 animals with records at all ages. As suggested previously, these results may indicate relatively better adaptation of the Landim to the environmental conditions prevailing in southern Mozambique especially through earlier ages at puberty and at first calving.

4.4 CONCLUSIONS

Most of tropical Africa is characterized by marked seasonal and annual differences in rainfall, which results in seasonality of parasite burdens and large fluctuations in both the quantity and quality of feed available to the grazing animal. Large differences in body weights and average daily growth were associated with year-season of birth effects in this study. When natural pasture is the sole source of nutrients, differences in annual rainfall may explain much of the variation observed. Vegetative growth is mostly limited by water availability rather than by temperature. In this sense, environmental conditions mediated by season and climate are clearly important in the context of this analysis. Severity of the dry season in some years (determining the availability of forages) had substantial consequences for most of the traits.

Another aspect that merits consideration is that the total herd size varied little during the period of study. Grazing pressure was greater (the stocking rate increased) in dry years. Consequently, there were larger losses in body weight and slower growth (Figures 4.2, 4.5, 4.8, 4.13, and 4.16). There was a distinct trend to lighter weights at first calving with time (Figures 4.19). As pointed out, this may have resulted from management to reduce age at first calving.

Animals born in the early rainy season had smaller birth weights but grew subsequently more rapidly than calves born after December. The early calving season coincided with the beginning of the rains. Cows calving at this time were in relatively poor body condition right after the nutritional stress of the dry season. Consequently, their calves were lighter at birth. On the other hand, cows calving late in the rainy season (January through April) had available vegetatively young grass to nutritionally support growth of their fetuses. As a consequence, their calves were heavier at birth. However, afterwards cows calving late in the rainy season encountered mature and less digestible pastures, which probably had a negative effect on their milk yields. Therefore, although they were heavier at birth, calves born after December had diminished nutritional support of growth because of less milk yielded by dams grazing less nutritive pastures. Conversely, the lighter calves born early in the rainy season grew more rapidly and were heavier at weaning and at 18 mo of age. For environments like southern Mozambique, a restricted breeding policy is justified to concentrate calvings in the early season.

Except for birth weight, parity was an unimportant source of variation for the growth traits. As expected, sex was a major source of variation. Bulls were 4%, 5% and 13% heavier than heifers at birth, weaning and 18 mo of age, and grew 6% and 23% more rapidly during pre-weaning and post-weaning periods.

The effect of age of dam was important only for birth and weaning weights. This finding is consistent with other reports (e.g., Trail and Gregory, 1981; Tawonezvi, 1989), where the ability of a cow to nourish her fetus probably increases with age to maturity reflecting improvement in milk production and uterine environment with age.

Average daily gains were less in the post-weaning than in the pre-weaning period. Africander calves grew 9% faster than Landim calves from birth to weaning. The maternal influence of the probably older Africander cow is typically more conducive to pre-weaning growth than for other Sanga breeds (Maule, 1973; Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990). Furthermore, there were no detectable differences between Landim and Africander breeds in post-weaning daily growth rate and age-adjusted weight at first calving.

Birth weight has little economic merit other than the fact that heavier calves at birth require less gain to reach a specific market or breeding weight. But, as Koch (1980) and Barlow (1984) emphasized, even though weight at birth is associated with subsequent growth potential and is moderately heritable, selection for heavier birth weights may be unwise because of possible increases in calving difficulty.

Weaning weight, on the other hand, is a measure of cow productivity and its economic importance depends largely on the production system (weaner vs yearling production). In extensive production systems, like in southern Mozambique where the final product is an animal 3 to 4 years old weighing approximately 400 kg, yearling weight is a relevant criterion for management decisions including breed choice. There was considerable convergence in weight differences between the Landim and Africander breeds on a percentage basis through time. The Africander calves were 15%, 11% and 6% heavier than the Landim for birth, weaning and 18 mo adjusted weights, but no difference were detected in age-adjusted weight at first calving. The same trend was observed when comparing the adjusted weight differences between the Landim and Africander breeds with the corresponding within breed standard deviation (Figure 4.11). These percentages were reduced from 102% at birth, to 85% at weaning, and to 56% at 18 mo of age. This percentage reduction in weight difference may indicate a greater adaptation of the Landim to the climatic and nutritive environment prevailing in southern Mozambique, especially after weaning, when performance depends on the animal's genotypic response in the given environment. This relatively greater adaptation of earlier maturing Landim cattle, if associated with higher reproductive performance, may compensate for the lighter body weights (and beef per animal unit), leading to greater beef offtake per reproducing female or per unit of land in these environmental conditions.

CHAPTER 5

REPRODUCTION PERFORMANCE

5.1 INTRODUCTION

Efficient meat animal production depends on costs and returns resulting from herd reproduction and the growth of progeny. High reproduction rate is important because it lowers the overhead costs of maintaining breeding females per animal marketed (Koch, 1974). Reproduction has been estimated at least 10 times as important as other components in cattle production systems in terms of net returns to commercial producers in the US (Willham, 1974). For each calf produced, the direct role of the dam ends when the calf is weaned. Economic returns are less for cows not producing calves each year because dam's maintenance cost is charged against the calves produced (Lasley, 1974). Thus, fertility is an important factor in the productivity of beef cattle.

Some measures of female reproductive performance include the intervals from birth to (age at) puberty, and first and subsequent calvings. The shorter these intervals, within physiological limits, the higher the rates of female (re)production (or the breed if the measurement represents the average in that breed). Reproduction traits in beef cattle have heritabilities of about 10% or less, meaning that about 90% or more of the variation observed in this function is due to environmental factors. Progress from selection based on single records will be slow when heritability is small.

The slower reproductive rate of cattle in the tropics compared to those in temperate regions is probably related to environmental limitations of inadequate nutrition, diseases and parasites, various management factors, and genetic interactions with these environmental factors (Kebede, 1992). Under extensive conditions, particularly in tropical and subtropical regions with a prolonged dry season (or winter), nutritional deficiencies are likely to depress reproductive performance. Conception may be expected to be delayed when nutrition is inadequate, especially when cows are lactating. In these conditions, cows lose substantial amounts of body weight, which delays postpartum ovarian cyclicity, and calves will tend to born in alternate rather than in successive years or seasons. For example, Buck et al. (1976) reported that low reproductive performance and maternal ability are the main factors depressing the productivity of cattle in Botswana. Similarly, Frisch and Vercoe (1982) indicated that improved fertility in northern Australia, where calving rate is typically below 70%, should increase overall herd productivity.

Like in other tropical countries, the herd management systems corresponding to the traditional and commercial sectors in Mozambique largely determine the corresponding reproductive rates. The traditional (family) sector usually practices a sedentary agropastoral production system with low external inputs that is associated with subsistence. In contrast, farms in the commercial sector provide greater inputs in health control (e.g., pharmaceuticals), and other management practices to enhance productivity. For example, Morgado (1954) reported an average calving rate of 86% for Landim cows at the Chobela Research Station for the period 1945-49. Conversely, reports about Mozambique's traditional sector and elsewhere in the tropics (Pinto, 1989; Galina and Arthur, 1989b) indicate that the overall calving rate infrequently exceeds 50%. The principal objective of the present study was to compare the reproductive and fitness performance of Landim and Africander cattle at the Chobela Research Station. Performance measures were age at first calving and lengths of first and the mean of subsequent calving intervals.

5.2 MATERIAL AND METHODS

The rainy season at the Chobela Research Station starts around mid-October and continues until the beginning of April. The calving season is managed to start with the first rains and to end in mid-February. A 3-mo controlled mating season from February to April ensures that improved nutrition comes from the new pastures provided by initiation of the rainy season. The climatic conditions, type of vegetation, and general management are described in Chapter 3. Prior to the mating season, breeding females were grouped by breed in small herds of 25 animals, and confined to small paddocks of about 50 ha with the selected service sire for that group (1 bull per 25 females). All females had two breeding exposure opportunities to become pregnant before they were culled.

Data on age at first calving (174 and 124 records), first calving interval (113 and 50 records), and second and subsequent calving intervals (285 and 225 records) for the Landim and Africander (respectively) were used to evaluate and to compare the reproductive performance of these breeds in the Chobela environment. The General Linear Model (GLM) procedure was used to analyze the data (SAS, 1985). The models for age at first calving and first calving interval included main effects for breed, year-season of birth, and conception group nested within breed. Conception groups were pregnancies resulting from first breeding exposure or from second exposure in the subsequent year. The model for the mean of second and subsequent calving intervals included breed, year-season of calving, and parity nested within breed. These mathematical models were described in Chapter 3. Linear contrasts of least squares means were computed to evaluate differences within class of main effect for each reproductive trait.

5.3 RESULTS AND DISCUSSION

Unadjusted means and associated standard deviations for each reproductive trait of the Landim and Africander are in Table B.1 (Appendix B). Least squares means and standard errors for the year-season effect on reproductive traits of Landim and Africander, are also shown in Appendix B, Tables B.2 to B.4.

5.3.1 PROBABILITY OF CONCEPTION AND AGE AT FIRST CALVING

Least squares means and standard errors for age at first calving by breed and conception group are in Table 5.1, and for the effect of year-season of birth in Table B.2. The frequency distributions for age at first calving are in Figure 5.1. Mean squares, degrees of freedom, and tests of significance for the main effects are in Table 5.2.

Year-season of birth and the effect of conception group in which the heifers got pregnant importantly affected (P<.01) this trait (Figure 5.2). Environmental factors like year and season of birth, rainfall, and nutrition during the dry season are known to be important causes of variation in age at first calving (Galina and Arthur, 1989a).

The range in age at first calving by year-season of birth was 39 mo (late in the rainy season of 1975) to 43 mo (early in the rainy season of 1973) for Landim heifers, and 39 mo

Table 5.1. Least squares means ($\bar{x}$) and standard errors (SE) for breed, and conception group[1] effects on age at first calving (mo) for the Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	174	40.4	.12
Africander	124	42.1	.14
Conception group[1]			
Landim			
1st year	100	35.3	.15
2nd year	74	47.3	.18
Africander			
1st year	56	35.6	.20
2nd year	68	47.5	.19

[1]Breeding season (year) in which heifer got pregnant.

Table 5.2. Mean squares and degrees of freedom from the analysis of variance for age at first calving (mo) for the Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	3.6†
Year-season	13	24.2**
Conception group[2]/B	2	3697.9**
Residual	281	1.6

**$P<.01$.
†$P<.2$.
[1]Coefficient of determination (R^2) = .96;
coefficient of variation = 3.1%;
square root of the residual MS = 1.3 mo; and
overall mean = 41.3 mo.
[2]Breeding season (year) in which heifer got pregnant.

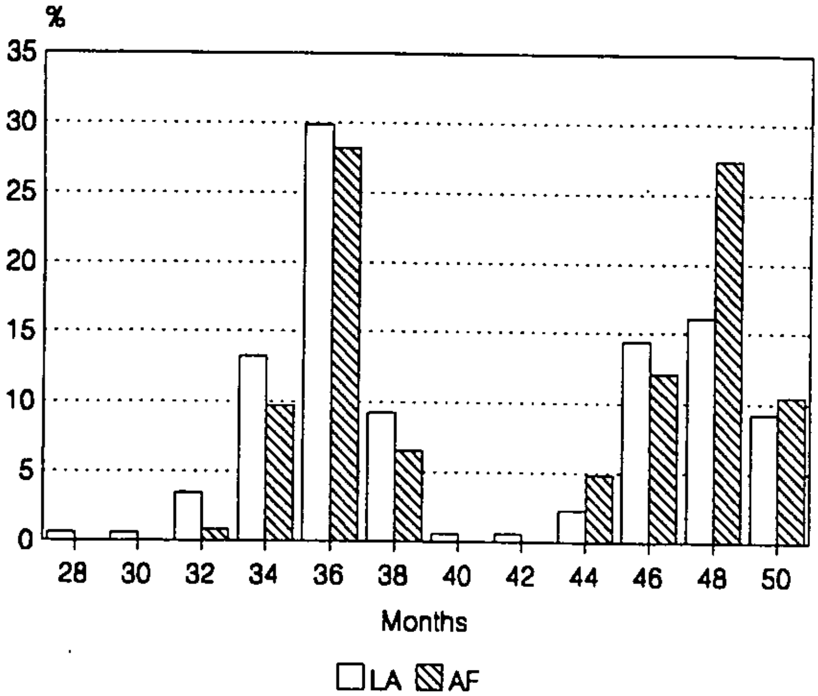


Figure 5.1. Frequency distribution of age at first calving for the Landim (LA) and Africander (AF) breeds.

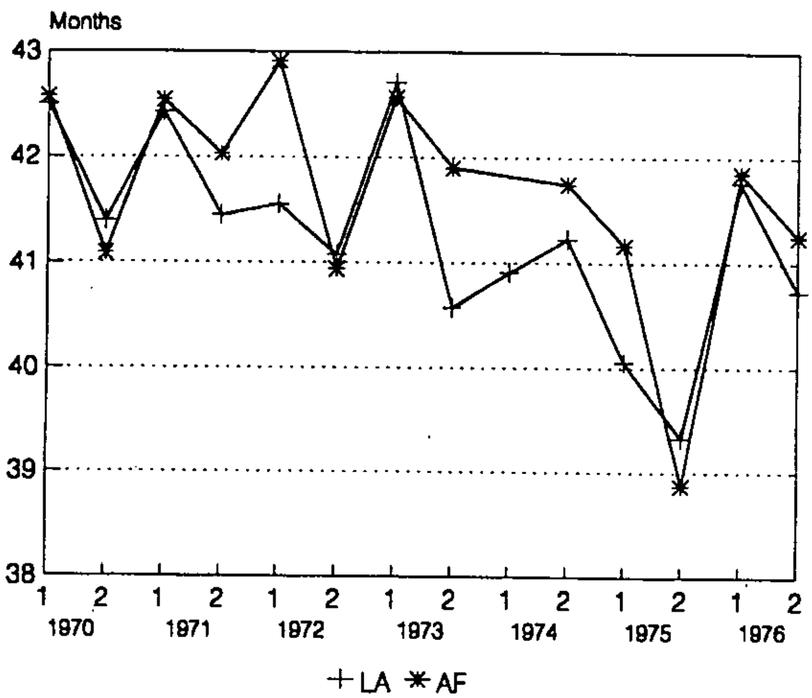


Figure 5.2. Least squares means for effect of year-season of birth on age at first calving of Landim (LA) and Africander (AF) breeds. (1 = early; and 2 = late rainy seasons).

(late in the rainy season of 1975) to 43 mo (early in the rainy season of 1972) for Africander heifers (Table B.2). Because there was no detectable interaction between breed and year-season of birth ($P>.5$), the observed variation in age at first calving by year-season of birth was similar for the two breeds. There was a significant decrease ($P<.05$) in age at first calving for heifers of both breeds born late in the rainy season of 1975. There is no straightforward explanation for this drop, but it was clearly of management origin because the age at first calving returned to the usual range of 41 mo to 42 mo in heifers that were born in subsequent year-seasons (Figure 5.2).

Season of birth also affected age at first calving. Heifers born early in the rainy season were $.9 \pm .21$ mo older at first calving than those born in the late rainy season (Table 5.3). This result is in apparent contradiction with results found earlier in the analysis of weight and growth traits (Chapter 4), where calves born early in the rainy season were heavier at weaning and 18 mo of age, and grew more rapidly than their late-born counterparts. This outcome resulted from a uniform management decision so that heifers born early in the rainy season had to wait a average of two months after reaching breeding age before starting the next breeding season (they were born before December and the breeding season starts in February). Actually, these heifers are in better body condition (see Chapter 4) and, so,

Table 5.3. Linear contrasts of least squares means for age at first calving (mo) for the Landim and Africander breeds.

Contrast	Estimate	SE
Early minus late season	.93	.21**
LA minus AF[1]	-1.71	.16**

**P<.01.
[1]LA=Landim; AF=Africander.

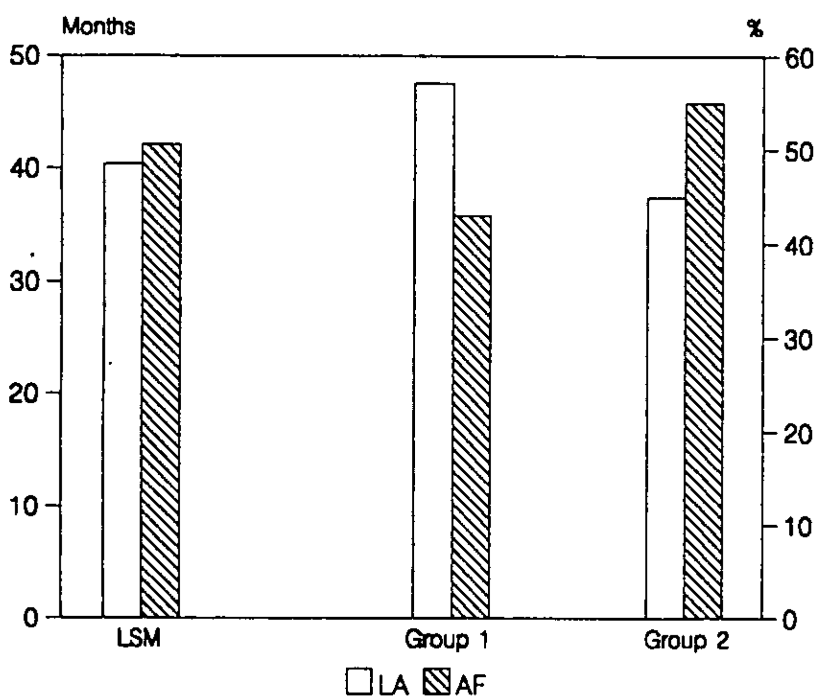


Figure 5.3. Least squares means for age at first calving (LSM), and proportions of heifers calving 1 (Group 1) or 2 years (Group 2) after first exposure. (LA=Landim, AF=Africander).

physiologically more prepared for pregnancy and other related stresses.

The frequency distributions of age at first calving are clearly bimodal (Figure 5.1). Mean ages were 35.3 mo for Landim and 35.6 mo for Africander heifers that calved after first exposure and 47.3 mo for Landim and 47.5 mo for Africander heifers calving after the second exposure. This bimodal distribution, partly results from a management policy giving all females at least two opportunities to get pregnant before being culled. The effect of heifer conception group (probability of conception) within breed and the breeding season in which heifers got pregnant were highly significant ($P<.001$), explaining as much as 66% of the total variation on the trait, which represented about 70% of the coefficient of determination ($R^2 = .96$). The conception group effect adjusted the age at first calving for the important source of variation represented by the different proportions of females of each breed that got pregnant at first and second exposure. From the group of heifers that calved after the first exposure, 64% were Landim and only 36% were Africander. Because of the restricted breeding system, the remaining heifers calved one year later (the difference between the means of the two conception groups is precisely 12 mo). The impact of the adjustment for this conception group was so important that breed (as an effect in the model) became much less significant ($P<.2$).

Adjusting for these important effects (taking into account the proportion of heifers that got pregnant at first and second exposures for each breed) revealed a large breed contrast (Table 5.3), wherein Landim heifers were more than 1.5 mo younger ($P<.01$) at first calving than Africander heifers in the Chobela environment (Figure 5.3). Least squares means were 40 ± .13 mo for the Landim and 42 ± .14 mo for the Africander. Age at first calving is related with age at puberty (Galina and Arthur, 1989a). Heifers that start cycling earlier also tend to be younger at first calving. The fact that the Landim heifers were younger than Africander heifers at first calving also may be related with younger ages at puberty.

Reports from Chobela indicate that the average age at puberty of Landim heifers was 20 mo, ranging from 16 mo to 25 mo (IPA, 1987). Delayed puberty in Africander heifers has been indicated as one important factor in reducing fertility in this breed (Buck et al., 1976). The difference in age at first calving in this study suggested that Landim heifers were more fertile than Africander heifers. Young age at first calving is economically important because it reduces the lag time to produce replacements and offspring for slaughter, and because it reduces the generation interval, thereby increasing the opportunity to accelerate genetic gains by selection. These results are in agreement with ages at first calving reported by Scholtz (1988) of 36 mo for Landim/Nguni and 41 mo for Africander for the period 1976 to 1985 in South Africa.

Evidence that Landim heifers outperformed Africander heifers is that 57% of Landim heifers calving for the first time got pregnant at their first breeding exposure compared with only 45% of the Africander heifers (Figure 5.3). The remaining 43% and 55% of Landim and Africander heifers got pregnant at the second exposure, one year later. These differences were tested by χ^2 procedures (with equal expected frequencies in each subclass), and a significant difference ($P<.025$) was detected between the breeds. Landim heifers showed a greater tendency to get pregnant at first exposure. These frequencies can be considered as measures of the probabilities of conception within fertile heifers, and with the Landim showing greater reproductive propensity.

5.3.2 FIRST CALVING INTERVAL

Least squares means and associated standard errors for first calving interval are in Table 5.4 for the effects of breed and conception group, and in Appendix Table B.3 for the effect of year-season of birth. Figure 5.4 shows the frequency distributions for first calving interval for each breed. Mean squares from the analysis of variance, degrees of freedom, and tests of significance for the effects in the model are in Table 5.5.

Table 5.4. Least squares means ($\bar{x}$) and standard errors (SE) for breed, and conception group[1] effects on first calving interval (days) for the Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	113	433.0	6.0
Africander	50	480.3	7.9
Conception group[1]			
Landim			
1st year	94	371.3	6.1
2nd year	19	738.1	11.3
Africander			
1st year	35	384.4	8.8
2nd year	15	704.1	11.8

[1]Breeding season (year) in which cow got pregnant.

Table 5.5. Mean squares and degrees of freedom from the analysis of variance for first calving interval (days) for the Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	2409.4[†]
Year-season	12	3945.5[**]
Breeding S^2/B	2	1300314.9[**]
Residual	147	1547.9

[**]P<.01.
[†]P<.3.
[1]Coefficient of determination (R^2) = .94;
coefficient of variation = 8.8%;
square root of the residual MS = 39.3 d; and
overall mean = 448.8 d.
[2]Breeding season (year) in which cow got pregnant.

The calving period starts in the beginning of November each year. With the breeding season beginning in February, females average 2 mo after calving before the next mating season begins. This short period represents a challenge especially to primiparous females who need to complete uterine involution and to resume ovarian cyclicity with fertile estrus. Thus, the interval between the first and second calving is a useful measure of reproductive performance in response to the restricted breeding season.

Year-season of birth and the conception group effect accounting for the breeding exposure (within breed) that resulted in pregnancy (Table 5.5) were important factors influencing variation in length of first calving interval ($P<.01$). As for age at first calving, the inclusion of the conception group effect (probability of conception) reduced the contribution by the breed effect ($P<.3$) for the total variation in the first calving interval. In an extensive review on cattle reproduction in the tropics, Galina and Arthur (1989b) reported that year-season and body condition of heifers at calving affected subsequent calving interval and milk yield. In this analysis, differences in first calving interval due to year-season of birth on the Landim and Africander were important and ranged from 539 d (late in the rainy season of 1971) to 576 d (late in the rainy season of 1975) for Landim heifers, and 507 d (late in the rainy season

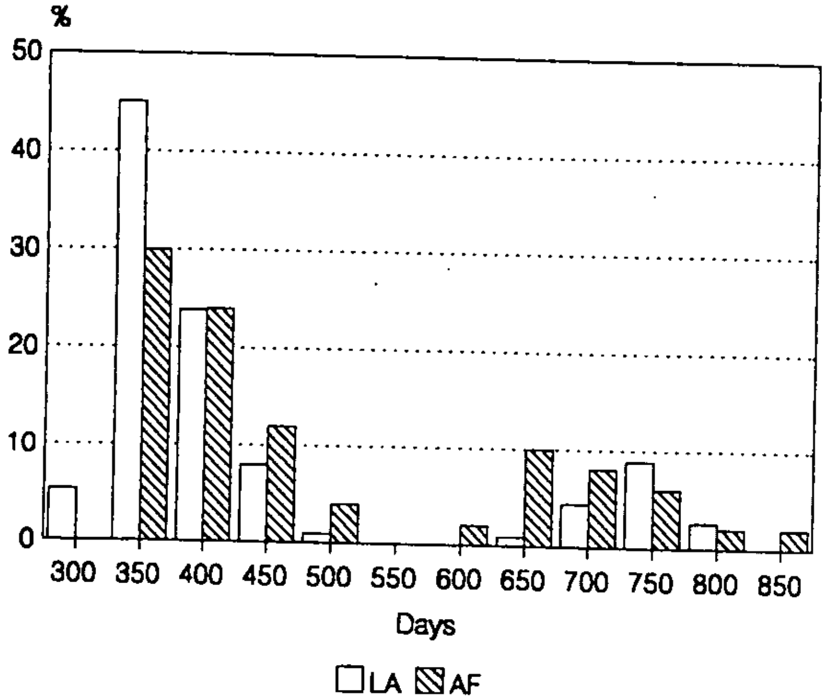


Figure 5.4. Frequency distributions for first calving interval for the Landim (LA) and Africander (AF) breeds.

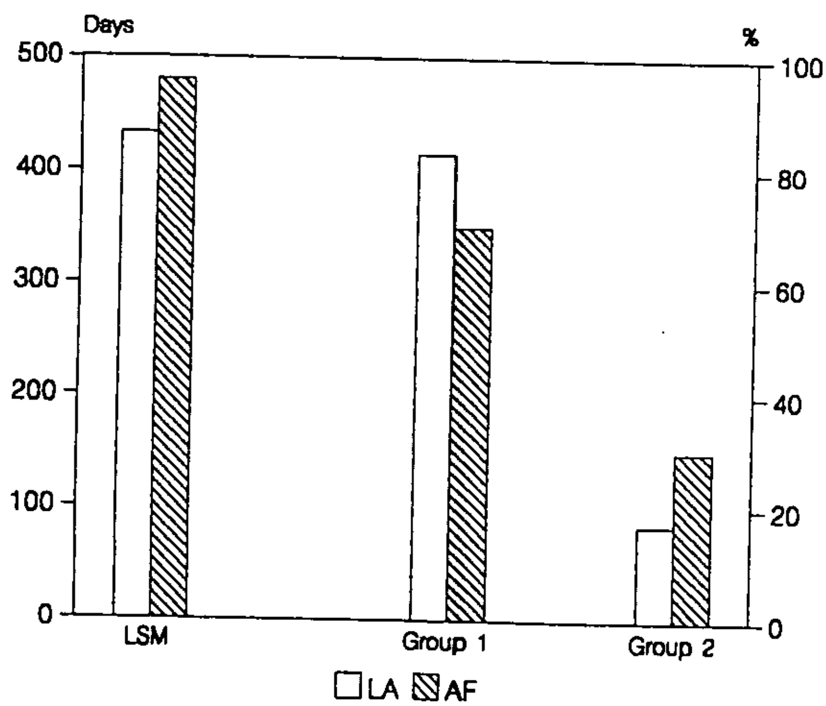


Figure 5.5. Least squares means for first calving interval (LSM), and proportions of heifers calving 1 (Group 1) or 2 years (Group 2) after the first parturition. (LA=Landim, AF=Africander).

of 1971) to 601 d (late in the rainy season of 1975) for Africander heifers (Table B.3).

As for age at first calving, there was no breed by year-season of birth interaction resulting in similar year-season variations of first calving intervals for the Landim and Africander. Heifers born in 1975 had mean first calving interval above the overall average (Table B.3). This group of females is largely the same as the one with youngest ages at first calving. These results may be related as heifers that calve early in life may have more difficulties in nursing their calves and in growing and repleting tissue reserves to prepare for the next pregnancy. Prolonged calving intervals resulting from early pregnancy is well documented (e.g., Galina and Arthur, 1989b). Differences in first calving interval due to season of birth were not detected (Table 5.6).

As for age at first calving, the frequency distributions are bimodal showing a tendency for most females in both breeds to calve early in the rainy season (Figure 5.4). Mean calving intervals were 371 d for Landim and 384 d for Africander heifers that calved after first exposure and 738 d for Landim and 704 d for Africander heifers calving after the second exposure. The within breed conception group effect (probability of conception) accounted for 74% of the total variation in this trait.

Adjustment of first calving intervals for the effect of conception group had similar effect as for age at first calving. From the group of heifers that got pregnant at the first exposure after their first calving, 73% were Landim and only 27% were Africander. The first calving interval (after accounting for the differential proportions of females in each breed that got pregnant at first and second exposures) was 47 ± 7 d longer (P<.01) for the Africander (480 ± 8 d) than for the Landim, which averaged 433 ± 6 days between first and second calvings (Table 5.6). Again, these differences are interpreted as an indication that Landim females were more fertile than the Africander ones. These results (shorter calving intervals and younger ages at first calving) indicate that the Landim breed is well adapted to this environment. Scholtz (1988) also reported a first calving interval of 442 days for Landim/Nguni and 512 days for the Africander in South Africa, which may further attest to the greater reproductive efficiency of the Landim compared to Africander cows under these conditions.

Table 5.6. Linear contrasts of least squares means for first calving interval (days) for the Landim and Africander breeds.

Contrast	Estimate	SE
Early minus late season	-2.3	11.6
LA minus AF[1]	-47.4	7.1**

**P<.01.
[1]LA=Landim; AF=Africander.

However, the proportion of Landim heifers that got pregnant while nursing their first calf (i.e., first exposure) was greater than for Africander heifers, 83% vs 70% (Figure 5.5). These proportions were tested by χ^2 procedures, and a significant difference (P<.04) was detected with Landim cows showing a greater tendency to get pregnant at first exposure. Limitations on the data structure allowed comparisons only between fertile females, i.e., females that did not conceive and for that reason were culled, did not contribute for these comparisons. This limitation narrows the discussion about reproductive performance to only fertile females from both breeds which may underestimate the real differences between them.

5.3.3 SECOND AND SUBSEQUENT CALVING INTERVALS

Least squares means for length of second and subsequent calving intervals and standard errors are in Table 5.7 for the effects of breed and parity, and in Table B.4 for the effect of year-season of calving. Figure 5.6 shows the frequency distributions for the second and subsequent calving intervals for each breed. Mean squares from the analysis of variance, degrees of freedom, and tests of significance for the effects in the model are in Table 5.8.

The effects of year-season of calving (Figure 5.7) and parity were important (P<.01). Parity was responsible for 56%

Table 5.7. Least squares means ($\bar{x}$) and standard errors (SE) for breed, and parity group effects[1] on second and subsequent calving intervals (days) for the Landim and Africander breeds.

Effect	N	$\bar{x}$	SE
Breed			
Landim	285	444.3	2.9
Africander	225	467.8	2.9
Parity[1]			
Landim			
Group 1	232	379.7	3.1
Group 2	53	726.6	4.8
Africander			
Group 1	170	383.5	3.2
Group 2	55	728.0	4.6

[1]With (Group 1) or without (Group 2) a calf in previous year.

Table 5.8. Mean squares and degrees of freedom from the analysis of variance for second and subsequent calving intervals (days) for the Landim and Africander breeds[1].

Source	df	MS
Breed (B)	1	500.0[†]
Year-season	22	12762.2[**]
Parity[2]/B	2	3166849.4[**]
Residual	484	792.6

[**]P<.01.
[†]P<.5.
[1]Coefficient of determination (R^2) = .97; coefficient of variation = 6.4%; square root of the residual MS = 28.2 d; and overall mean = 442.7 d.
[2]With or without a calf in previous year.

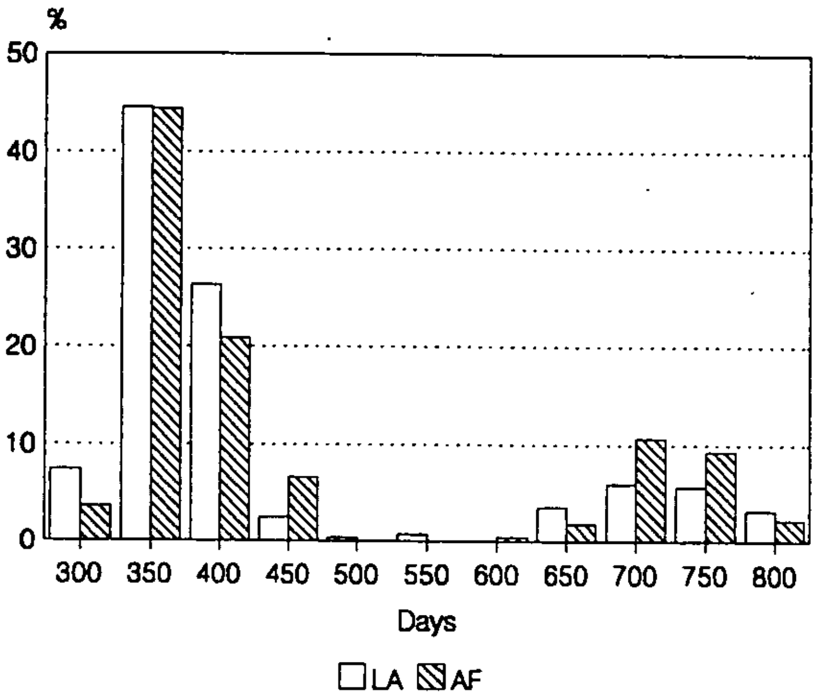


Figure 5.6. Frequency distributions for second and subsequent calving intervals for the Landim (LA) and Africander (AF) breeds.

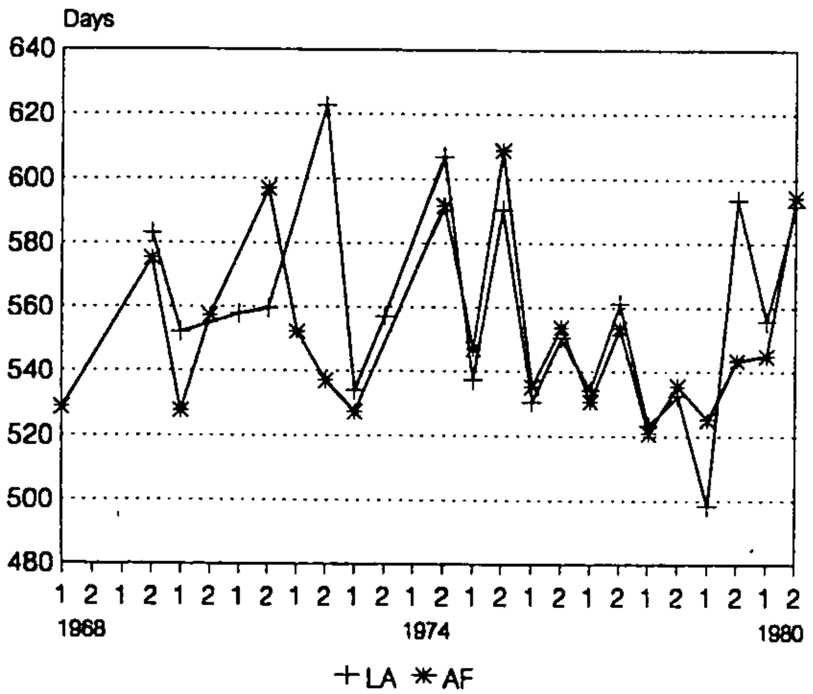


Figure 5.7. Least squares means for effect of year-season of calving on second and subsequent calving intervals of Landim (LA) and Africander (AF) breeds. (1 = early; and 2 = late rainy seasons).

of the total variation in this trait. Because primiparous females were not relevant, the parity effect for second and subsequent calving intervals had only two classes -- cows that either calved or did not calve in the preceding year. The resulting residual breed effect ($P<.5$) after adjusting for parity in these fertile females, lost much of its importance compared to the other reproductive traits.

As in the other reproductive traits, annual variation in the availability of adequate forage and in rainfall affected calving interval, and young cows appear to have longer intervals than older ones. Plasse et al. (1972) working with Brahman cattle in Venezuela, also found that the first calving interval tends to be the longest. It seems that there is enough evidence in the literature (e.g., Galina and Arthur, 1989b) to show that the year and season in which the cow calves are the principal sources of variation in calving interval on farm conditions.

Similar to age at first calving and first calving interval, there was no breed by year-season interaction showing no differences in annual variation of calving intervals between breeds (Figure 5.7). Second and subsequent calving intervals least squares means by year-season of calving ranged from 498 d (early in the rainy season of 1979) to 623 d (late in the rainy season of 1972) for Landim heifers, and 521 d (early in the rainy season of 1978) to 609 d (late in the rainy season of 1975) for Africander heifers

Table 5.9. Linear contrasts of least squares means for second and subsequent calving intervals (days) for the Landim and Africander breeds.

Contrast	Estimate	SE
Early minus late season	-33.5	5.1**
LA minus AF[1]	-23.5	2.6**

**P<.01.
[1]LA=Landim; AF=Africander.

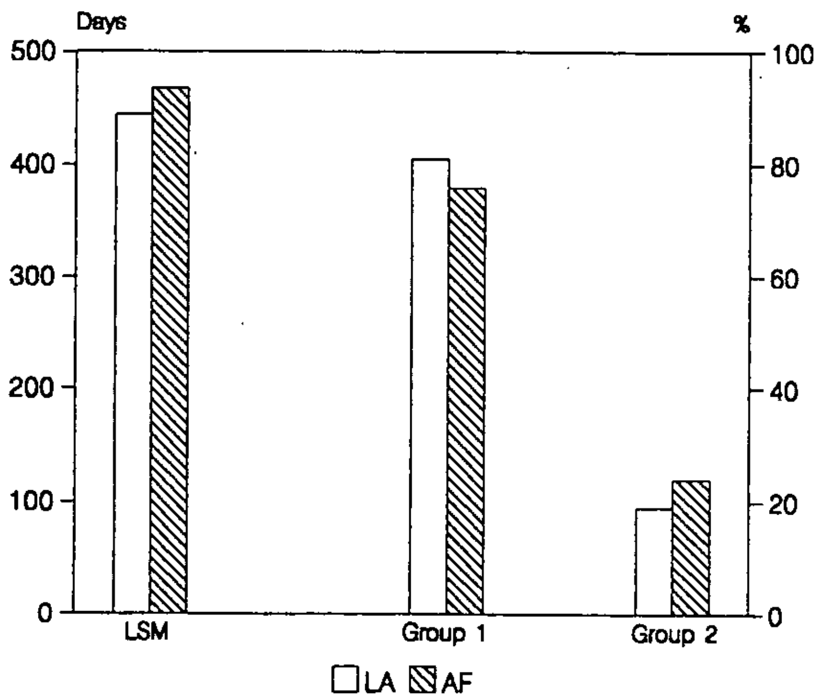


Figure 5.8. Least squares means for second and subsequent CI (LSM), and proportions of cows calving 1 (Group 1) or 2 years (Group 2) after the previous parturition. (LA=Landim, AF=Africander).

(Table B.4). Season of calving affected second and subsequent calving intervals with cows calving in the early season averaging 33 ± 5 d shorter (P<.01) calving intervals than cows calving after December (Table 5.9). These results are consistent with those from the analysis of growth where, calves born early in the rainy season grew faster and were heavier at weaning and 18 mo than those born late in the rainy season.

The management decision of allowing each cow two chances to become pregnant before culling for reproductive reasons, resulted in a bimodal distribution (Figure 5.6). Mean calving intervals were 379 ± 3.1 d for Landim and 383 ± 3.2 d for Africander cows that calved in the previous year and 726 ± 4.8 d for Landim and 728 ± 4.6 d for Africander cows that did not calve in the previous year. After adjusting for the proportion of cows that calved in the previous year (conceived while nursing their calves -- 58% and 42% of Landim and Africander cows, respectively), and cows that did not calve in the preceding year, the Landim had an advantage of almost 24 days shorter calving intervals (P<.01) over the Africander (Table 5.9). Therefore, this evidence further supports the earlier assessment that Landim was more fertile than the Africander in the Chobela environment. The least squares mean calving intervals were 444 ± 3.1 d and 468 ± 3.1 d, respectively, for Landim and Africander cows (Figure 5.8). Convergence in cow reproductive performance with age (41 d difference between breeds in first calving interval and 24 d difference in subsequent calving intervals) was expected because only fertile females could be considered, i.e., data on females with reproductive disfunction were not available.

Although a majority of females in both breeds conceived while nursing their calves, Landim cows showed a greater rate of pregnancy at their first exposure (81%) than the Africander cows (76%). As for first calving interval, these frequencies were statistically significant (P<.07), resulting in important differences between the breeds.

5.4 CONCLUSIONS

The effects of year-season and the conception (exposure) group resulting in pregnancy accounted for most of the variation observed on the traits studied. Except for first calving interval, season of birth or calving was also an important effect on the traits studied. In age at first calving, where heifers that born early in the rainy season were almost one month older than those born late in the rainy season, the significance of this effect is probably the result of management as they have to wait for about two months for the beginning of the breeding season. On calving interval of older cows, season of calving was important in reducing the interval for cows calving early in the rainy season. These findings are consistent with those from the analysis of growth and weight traits (Chapter 4), where, for conditions similar to those in southern Mozambique, a policy of restricted breeding is recommended to be adopted in order to concentrate calvings early in the rainy season.

Inclusion of the conception group effect in the statistical models to evaluate age at first calving and first calving interval, and the effect of parity to evaluate second and subsequent calvings intervals, substantially decreased the residual effect of breed because the unequal proportions of pregnancies resulting from first breeding exposure were ignored.

The larger proportions of Landim females that got pregnant in their first exposure (heifers and cows) compared to the Africander females, resulted in important differences favoring the Landim in all three reproductive traits studied. Because both breeds were managed in the same environment it is reasonable to consider that the Landim is better adapted to this environment through greater reproductive performance which portends more calves per cow per lifetime. The mechanism for this superior reproductive performance was the greater probabilities of conception for Landim females at first breeding exposure as heifers and as cows ($P<.04$). Although information from the data set was restricted to performance in fertile cows (which may contribute to an overestimation of the performance, especially in the least fertile breed), results showed the Landim cattle to be 4% younger at first calving, to require 10% fewer days between first and second calving, and to average 5% shorter intervals between subsequent calvings (second and more) than Africander cows.

Similar results were reported by Scholtz (1988) using data from the National Beef Cattle Performance and Progeny Testing Scheme of South Africa. This worker indicated that selection can be effective to increase fitness traits. He added that natural selection represented by the challenges of a difficult environment as in southeastern Africa, in the case of the Landim/Nguni produced an adapted and highly fertile breed. This is in agreement with the present study. The higher reproductive rates detected in this study provide evidence that the Landim is better adapted than the Africander breed to the (Chobela) environment of southern Mozambique.

The study on growth performance (Chapter 4) showed an advantage of the Africander breed over the Landim breed, the former being heavier at birth, weaning and 18 mo of age. On the other hand, Landim females had better performance in terms of reproductive efficiency, being younger at first calving, and having shorter calving intervals than Africander females. These differences in performance between the two breeds in the Chobela station environment (diminishing differences in growth with age and in fitness traits) makes important a total performance comparison to evaluate the beef offtake rates from these breeds. Buck <u>et al.</u> (1982) indicated that profitability in range beef production depends primarily on efficient calf production, which is a function of growth, viability and reproductive performance. The results obtained in the present study (growth and reproduction) permit combining these parameters in a productivity index to compare these breeds.

CHAPTER 6

TOTAL PERFORMANCE INDEX

6.1 INTRODUCTION

Beef production in Mozambique is primarily from natural grazing. There are two coexisting production systems -- a fenced ranch system (the commercial sector), where 18% of the cattle population is maintained, and a communal grazing system (the traditional or family sector) with 82% of the cattle. Most of the cattle population (71%) is located in the south, which is relatively free of tsetse fly because of a drier climate and it has been largely deforested.

The profitability of range beef production depends primarily on efficient calf production (Buck et al., 1976). Thus, characterizing breeds for the major traits contributing to weaner or yearling production is essential for decisions about genetically managing purebreeding and crossbreeding systems. Crossbreeding in Mozambican commercial beef herds is now a widely accepted means to increase productivity especially through upgrading local indigenous breeds. Usually the objectives of these crossbreeding programs are to upgrade the local breed to the introduced breed. No herds of intermediate genotypes are maintained and no information on their performance is available.

The two main beef breeds in southern Mozambique are the Landim, a local indigenous breed, and the Africander which was imported from South Africa and, for this reason, may be referred as an exotic indigenous breed. Both are Sanga breeds (Mason and Maule, 1960) but the Africander has greater mature weight because of selection also for draught power. In Mozambique, commercial beef farmers favored the Africander over the Landim mainly because of its larger mature size, which resulted in upgrading the commercial Landim population to a largely Africander one. The potential benefits of producing crossbreds have not been investigated. Studies in neighboring countries have indicated that local indigenous cattle are potentially more productive in terms of weaner or yearling production per cow per year than exotic types (including the Africander) primarily due to their higher reproductive and survival rates (Rakha et al., 1971; Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988a; Tawonezvi et al., 1988b).

Objectives in previous chapters (Chapters 4 and 5), were to characterize the growth and reproductive performances of the Landim and Africander breeds in southern Mozambican conditions. Those results provide information for a keener comparison of these breeds. Hence, the objective of the present study was to assess the productivity of the Landim and Africander cows through an index combining growth and reproduction information to evaluate the rate of annual calf production per cow.

6.2 MATERIAL AND METHODS

The study was conducted at the Chobela Research Station where the Landim and Africander breeds were managed together but without crossbreeding, using the same type of management as in the commercial sector. A detailed description of the environment is in Chapter 3. The Station is situated in southern Mozambique at an average altitude of 40 m. The environment is semi-arid, with an average rainfall of 686 mm, most of which falls between the end of October and the beginning of April. From April to October, rainfall is rare and natural vegetation is not more than standing mature hay with low nutritive value. Temperature varies from a mean maximum of 32.5°C to a mean minimum of 18.7°C. The breeding season was confined to a 3 mo period from February to April. Calves were born from the end of October to mid-February and weaned in August/September at an average age of 7 mo. Weights at weaning and 18 mo were adjusted to 210 and 540 days of age, respectively. Weight, growth and reproductive performances were analyzed for both breeds (see Chapters 4 and 5), using least squares, fixed model procedures (GLM, SAS, 1985).

Four productivity indices were used to compare the Landim and Africander breeds (see Chapter 3). The four indices representing annual weaner productivity (indices 1 and 2) and annual yearling productivity (indices 3 and 4) were computed using alternatively the calf weights at weaning and at 18 mo with their respective survival rates, average calving rate, and dam's weight at first calving (Buck et al., 1976; Trail et al., 1977; Trail and Gregory, 1981; Buck et al., 1982; Trail, 1986; Scholtz, 1988; Tawonezvi et al., 1988; Dionisio and Syrstad, 1990).

The four productivity indices are written (rates are in decimal fractions) as:

Weaning weight (kg) x calf viability rate x calving rate ÷ cow weight at first calving (kg) [Index 1];

Weaning weight (kg) x calf viability rate x calving rate ÷ cow metabolic weight at first calving ($kg^{.75}$) [Index 2];

18 mo weight (kg) x calf viability rate x calving rate ÷ cow weight at first calving (kg) [Index 3];

and

18 mo weight (kg) x calf viability rate x calving rate ÷ cow metabolic weight at first calving ($kg^{.75}$). [Index 4]

Least squares means and standard errors for the traits included in the productivity indices are from Chapter 4, Tables 4.4, 4.7, and A.1, and Chapter 5, Table 5.4, and summarized in Table 6.1.

Table 6.1. Least squares means and SE for weights at weaning, 18 mo, first calving and length of first calving interval for Landim and Africander breeds[1].

	Breed				
	Landim		Africander		Percentage difference
Trait	$\bar{x}$	SE	$\bar{x}$	SE	(%)[2]
Weights (kg)					
Weaning	149	1.5	165	1.5	-11
18 mo	238	2.3	252	2.1	- 6
First calving[3]	352	5.0	422	6.3	-20
Interval (days)					
First calving	433	6.0	480	7.9	-11

[1]Source: Chapter 4, Tables 4.4, 4.7, and A.1, and Chapter 5, Table 5.4.
[2]Percentage difference between breed means.
[3]Unadjusted means.

The average calving rate for each breed was estimated using the ratio between 365 days (year length) and length of the first calving interval (Scholtz, 1988; Dionisio and Syrstad, 1990). Weight at first calving was affected by age of heifers at first calving. For this reason, unadjusted weights at first calving were used instead of the age-adjusted least squares means to not penalize Landim females for being much younger than Africander females at first calving. Information on calf weaning and 18 mo survival rates were not available and they were approximated from the present data. These apparent survival rates were computed as the percentage of animals born in each breed that reached weaning and 18 mo of age in the time period of this study (1970-81). Cow metabolic weight (weight at first calving raised to the power of .75) was used to approximate productivity per unit of maintenance requirement. Indices using metabolic weight as the divisor represented the liveweight returns to feed for maintaining the cow herd. The productivity indices were computed for each individual, and the statistical significance of the mean differences between breeds were tested by computing Student's *t*-statistic,

$$t = (\bar{x}_1 - \bar{x}_2) \div \sqrt{(s_1^2 + s_2^2)}$$

where, $\bar{x}_1$ and $\bar{x}_2$ are the means of the productivity indices for each breed and s_1^2 and s_2^2 are their variances.

6.3 RESULTS AND DISCUSSION

The percentage difference between the breeds (Table 6.1) show an advantage for the Africander of 11%, 6% and 20% for weights at weaning, 18 mo and at first calving. On the other hand, Landim females had on average 47 days shorter first calving intervals, an advantage of 11% over the Africander females. Since feed requirements for cow maintenance vary with differences in body weight and are the largest overhead cost in beef production, such differences must be considered when estimating cow productivity. In this sense, large cows with high body weights may actually be at disadvantage when compared with smaller cows with lower feed requirements for maintenance. Table 6.2 presents the estimated calving rate and the apparent survival rates at weaning and 18 mo of age for the Landim and Africander breeds. The four indices representing annual weaner and yearling productivities are also presented in Table 6.2.

Africander cows were less productive than the Landim although their progeny were heavier at weaning and 18 mo. The Landim was about 21% superior (P<.001) in terms of annual yield (kg) of weaned calf per kg of cow and 15% superior (P<.001) in terms of annual yield of weaned calf per unit of dam's metabolic weight.

The apparent calf viability rate at weaning differed little between breeds. A separate analysis assuming identical survival between the Landim and the Africander showed the same conclusion (20% and 15% of advantage for the Landim, respectively). Sensitivity analysis (changing each parameter of the productivity indices while maintaining others constant) showed that fertility (expressed as calving rate) was the most important factor affecting weaner productivity. This is

Table 6.2. Calf weight at weaning and 18 mo, calf viability rate[1], calving rate, cow weight at first calving, metabolic weight of cow at first calving, and indices for weaner and yearling productivity.

	Landim		Africander	
Trait	$\bar{x}$	SE	$\bar{x}$	SE
Weaning weight (kg)[2]	149	1.5	164	1.5
18 mo weight (kg)[2]	238	2.3	252	2.1
Calf Viability (%)[1]	97		95	
Calving rate (%)	84		76	
Cow weight				
At first calving (kg)	352	5.0	422	6.3
Metabolic weight ($kg^{.75}$)	81		93	
Productivity[3]				
Index 1 (kg)[a]	.35	.002	.29	.001
Index 2 (kg)[a]	1.5	.007	1.3	.005
Index 3 (kg)[a]	.55	.003	.44	.002
Index 4 (kg)[a]	2.4	.013	2.0	.010

[1]Apparent viability rate.
[2]Least squares means.
[3]Index 1 = kg of weaned calf per kg of cow per year;
Index 2 = kg of weaned calf per kg of metabolic weight ($kg^{.75}$) of cow per year;
Index 3 = kg of 18 mo calf per kg of cow per year;
Index 4 = kg of 18 mo calf per kg of metabolic weight ($kg^{.75}$) of cow per year.
[a]Breed differences significant at P<.001.

important because higher calving rates have been reported for the Landim (e.g., Morgado, 1954; Scholtz, 1988; Dionisio, 1989), which might increase their potential productivity. Therefore, higher calving rate and lower feed requirements for cow maintenance were the main factors in defining the superiority of the Landim in the weaner productivity.

These results agree with the report by Tawonezvi et al. (1988a) who found the Africander (89.1 kg) to be less productive than other Sanga breeds in Zimbabwe (Nkone, Tuli and Mashona) in terms of weight of weaned calf per cow per year (Africander calves were 12 kg heavier than Mashona calves at weaning). When productivity differences were expressed as proportions of the productivity of Africander cows, Nkone, Tuli, and Mashona were 20%, 32%, and 36% more productive, respectively. Lower reproductive performance and viability of progeny were concluded to be the principal factors resulting in less weaner productivity for Africander cows in Zimbabwe.

Landim cows yielded 25% (Index 3) and 20% (Index 4) more 18 mo calf weight than the Africander. As may be seen from Table 6.2 the Landim showed a superiority in terms of kg of 18 mo old calf per kg of cow per year of .11 kg (P<.001) and .4 kg (P<.001) per kg of metabolic weight of cow per year, respectively. The divergence in productivity between the two breeds increased from weaning to 18 mo in 4% and 5% per kg of cow per year and per kg of metabolic weight of cow per year. Studies from Botswana also showed lower productivity per cow per year at 18 mo of age for Africander cows than for Tswana and Tuli cows. Trail et al. (1977) found Tswana and Tuli breeds to be 18% and 44% more productive than Africander cows, which yielded 155 kg of 18 mo calf weight per cow per year. Buck et al. (1982) also found Tswana, Bonsmara, and Tuli breeds to be 31%, 38%, and 39% more productive than Africander cows, which produced 163 kg of 18 mo calf weight per cow per year.

As for the productivity of weaned calves, the apparent calf viability rate to 18 mo of age was similar among the survivors of both breeds in these data. This rate, computed as the percentage of animals born that reached 18 mo of age, may not accurately reflect the correct breed averages under field conditions. Sensitivity analysis of the yearling productivity index showed that fertility (calving rate) was the dominant component, followed by weight of calf and dam's weight. Therefore, advantage for the Landim in the index was because of higher reproductive performance and (less feed for maintenance of) lower body weights of dams, which compensated for lower weights at 18 mo compared to Africander calves. The indices in this study did not account for the younger ages at first calving of the Landim females which would be expected to increase the differences between breeds. These results indicate that the Landim breed is more productive than Africander in conditions of southern Mozambique.

6.4 CONCLUSIONS

In southern Mozambique, where most of the beef cattle production is concentrated, the environment is semi-arid and cattle are reared based on natural pastures. Therefore, the use of well adapted breeds, capable of economically producing in these harsh conditions is necessary for sustainable production systems. Consequently, the productivity of indigenous and exotic breeds of cattle needs to be evaluated to determine appropriate genetic and non-genetic management systems.

The characters of reproductive performance, survival rates of calf at weaning and 18 mo of age, growth and cow weight of the Landim and Africander breeds were incorporated into four indices of productivity where weight of calf at weaning and 18 mo were expressed as fractions of cow weight at first calving (actual weight and in units of metabolic weight) per year. These productivity indices allowed comparisons between the two breeds on a total performance basis.

The ability to survive is an important determinant of beef cattle productivity (Frisch and Vercoe, 1982). The apparent viability rates for the Landim and Africander calves as computed in this study were similar and did not contribute to breed differences in the productivity indices. Morgado (1954) reported a mortality rate in Chobela station of 4% and 8% for Landim and Africander calves up to one year of age (average for the period 1940 to 1949). These mortality rates corresponds to 96% and 92% of viability rates respectively, which are not much different from the values computed in this work (96% and 93% for Landim and Africander calves up to 18 mo of age).

With the management and environmental conditions existing in the Chobela Station where cows are simultaneously under the stresses of lactation and pregnancy during part of the dry season, a lower maintenance feed requirement may represent a big advantage in terms of coping with these adverse conditions. Maule (1973) discussed the importance of size of cow when considering maintenance requirements in low input systems. He showed that a 550 kg cow required 35% more energy for maintenance alone than a 370 kg cow. In other words, grazing sufficient for 65 large cows would maintain 100 small cows. The lower maintenance feed requirements and probable a higher feed selectivity behavior of reproducing Landim females compared to the Africander ones were reflected in the higher annual productivity per kg of cow and per kg of metabolic weight of cow obtained in this study.

The greater proportion of Landim cows that calved annually (Chapter 5) compared to Africander cows may be a reflection of their greater adaptation to this environment. In the case of Landim, the greater calf crop weaned more than compensated for weaners being 16 kg lighter than Africander weaners or weanlings. Fertility (expressed by calving rate) was the major factor affecting breed differences in the productivity indices.

The Landim breed performed better than the Africander mainly because of higher calving rates (most important) and lighter body weights of dams. The results of this evaluation should encourage the use of Landim instead of Africander in the commercial sector in southern Mozambique. In the current upgrading scenario, the Landim is being downgraded to the

Africander. Research evidence is now leading to a consensus about the superiority of the Landim, and other Sanga breeds, over the Africander. The traditional sector in southern Mozambique owns exclusively Landim cattle. This preference is most probably based on the knowledge (though empirical) of the greater adaptability of the Landim cattle in this stressful environment. Several other studies (Trail et al., 1977; Buck et al., 1982; Scholtz, 1988; Tawonezvi et al., 1988a; Tawonezvi et al., 1988b) have indicated other Sanga breeds (e.g., Tswana, Tuli, Mashona) in the southern African region to be more productive than Africander, which cows have lower reproductive performance. The lower productivity of Africander germplasm was also detected in crossbred offspring in Zimbabwe (Tawonezvi et al., 1988b).

The performance of the Landim as documented in this study suggests that this breed may have considerable beef production potential, given reasonable management, in southern Mozambique conditions. This study has also shown that, in terms of weaner and 18 mo production, the Landim exceeds the Africander primarily due to superior reproductive performance (younger age at first calving and higher calving rates) and less feed maintenance for smaller cows. These are the probable mechanisms for adaptability of a population of livestock to nutrient-limiting environments like the one found in southern Mozambique.

CHAPTER 7

ESTIMATES OF GENETIC PARAMETERS

7.1 INTRODUCTION

Selection of beef cattle for growth, particularly 18 mo old calf weight, is common in commercial herds in Mozambique. However, little is known about the genetic potential for improvement of virtually all breeds currently in use. The two most numerous beef cattle in southern Mozambique are the Landim and the Africander. The Landim is a local indigenous breed while the Africander was imported from South Africa about 1920 (Silva, 1966). Both breeds are Sanga types (Mason and Maule, 1960) and a detailed description is in Chapter 2. The Africander is larger than the Landim (in terms of mature size) and, especially for this reason, it is predominant in the commercial sector.

Studies about the productivity of these breeds in Mozambique are limited. With the exception of the study of Dionisio and Syrstad (1990) and the present one (Chapter 6), there are no reports about the productivity of the Landim and Africander in Mozambique and how they compare in this environment. In the present study (Chapter 6), the Landim breed was found more productive than the Africander in terms of weaner and yearling production (as functions of growth -- calf weights at weaning and 18 mo of age --, viability and reproductive performance -- calving rates) per kg of cow per year, due to high reproductive performance and lower feed requirements to maintain smaller cows.

The environment in southern Mozambique (climate, disease incidence, nutrition, management) may be considered difficult for cattle production. The improvement of existing genotypes in this environment depends on the knowledge of the attributes of those genotypes and of the factors that affect production. Where environmental conditions prohibit full expression of genotypes, situations may exist where genetic variances are so small as to preclude genetic improvement. For example, studies analyzing milk response of daughters of US Holstein sires in Latin America, found that less genetic variance is expressed in these tropical and subtropical environments (59% of the corresponding sire variances estimates in the US) than in temperate ones (Stanton _et al._, 1991a). Short _et al._ (1990a) also supports the hypothesis that expression of genetic variation depends on the opportunity provided by the environment. The less restrictive is the environment, the greater will be the expression of the genetic potential and, hence, the larger the genetic variances. Heterogeneous variances for a specific trait between environments are implicated as a manifestation of interaction between genotype and environment (Stanton _et al._, 1991a). This form of genotype by environment interaction may be especially important in stressful environments. Trail (1986) indicated that where breeds with differing degrees of adaptation to stress are managed together in harsh environments, significant genotype by environment interactions usually occur.

The potential for genetic improvement in growth and reproduction and the choice of selection criteria for the Landim and Africander breeds in southern Mozambique will depend on the magnitude of genetic parameters (additive genetic variances and heritabilities). Information on heritability is essential for planning breeding systems and for predicting response to selection. Reports are few about heritability estimates for weights and growth and reproduction traits of Bos indicus breeds in tropical Africa (Arnason and Kassa-Mersha, 1987). Only one study (Fonseca, 1970) reported an estimate of the heritability of birth weight of the Landim (.27) using data from the Chobela Research station by regressing offspring weight on dam weight. No indication of the variance of this estimate was reported.

This study was undertaken to estimate additive genetic variances and heritabilities of growth and fitness traits required for the development of improved programs in the Landim and Africander cattle in southern Mozambique. Genetic variance components due to sires of half-sibling families, and heritabilities computed from paternal half-siblings were estimated for weights at birth, weaning, 18 mo of age, first calving, and pre- and post-weaning average daily growth, and for age at first calving, first calving interval, and second and subsequent calving intervals.

7.2 MATERIAL AND METHODS

Data for the present study were from Landim and Africander breeds maintained from 1968 to 1981 at the Chobela Research station in southern Mozambique. Animals were maintained under the same management throughout the period of study (see chapter 3). Each animal unit (AU=450 kg liveweight) grazed approximately 4 ha of natural pastures. No supplementation was given, except for rice straw, molasses and urea in very dry years. During the breeding season (February to April) groups of 25 females were placed with a single sire of the same breed in 50 ha paddocks. Females not calving for two consecutive years were culled. Calvings began in October and continued through mid-February. Most cows (~65%) calved before December. Calving dates (Figure 3.4) were classified in two seasons, an early rainy season from July through December and a late rainy season from January to June. A routine health control program (vaccinations against anthrax, blackleg, salmonellosis and brucellosis) was conducted annually. External parasites (especially ticks) were controlled through weekly dipping. A detailed description of management and preparation and analysis of data is in Chapter 3.

The number of observations in each data sub-set as well as the number of sires (per breed and trait) are in Table 7.1. The data subsets were constructed to avoid single progeny per sire and to avoid fewer than two sires per fixed effect subclass.

Table 7.1. Number of observations and sires per trait used to estimate sire components of variance for the Landim and Africander breeds.

	Landim		Africander	
Trait	N	Sires	N	Sires
Body weight				
Birth	399	20	362	18
Weaning	328	17	315	15
18 mo	220	13	222	11
First calving	55	8	74	12
Daily gain				
Pre-weaning	295	17	285	15
Post-weaning	216	13	216	11
Reproduction				
Age at first calving	127	17	106	14
First calving interval	88	14	42	7
≥2nd calving interval	261	21	203	20

The average and range in the effective number of progeny per sire are in Table 7.2 reflecting the small size of the data subsets.

The Restricted Maximum Likelihood (REML) procedure was applied using a mixed model to estimate sire and residual variance components for each breed for weights at birth, weaning, 18 mo and first calving, daily growth for pre-weaning and post-weaning periods, age at first calving, and length of first calving interval and 2nd and subsequent calving intervals.

Table 7.2. Average and range of effective number of progeny per sire for each trait used to estimate sire components of variance for the Landim and Africander breeds.

Trait	Landim		Africander	
	N_e	Range	N_e	Range
Body weight				
Birth	13.1	1.8-21.9	10.9	3.1-22.2
Weaning	12.6	1.8-25.1	12.9	5.9-24.2
18 mo	11.0	1.8-21.8	11.8	4.5-21.7
First calving	4.2	2.7- 7.5	4.5	1.7- 8.2
Daily gain				
Pre-weaning	11.3	1.8-18.3	11.7	5.9-23.9
Post-weaning	10.7	1.8-21.8	11.5	3.6-21.1
Reproduction				
Age at first calving	4.1	1.2- 9.0	4.5	1.4- 8.3
First calving interval	3.5	1.5- 6.8	2.9	.7- 5.2
≥2nd calving interval	9.9	1.7-32.0	8.1	1.7-21.6

The following general mixed linear model was applied in the analysis using two FORTRAN programs (ABSORBD and REMLD) by VanRaden (1986) to estimate the sire variance components:

$$y = X\beta + Zu + \epsilon$$

where,

y = the vector of observations on each trait for the Landim and Africander breeds,

β = the vector of fixed effects (yr/season of birth and sex for the growth traits, yr/season of calving for weight at first calving, yr/season of birth and calving group for age at first calving and first calving interval, and yr/season of calving and parity group for second and subsequent calving intervals),

u = the random vector of sire effects,

ϵ = the random vector of residual terms, and

X, Z = incidence matrices associating β and u with y.

The vectors of u and ϵ were assumed to be normally and independently distributed with:

$$E\begin{bmatrix} u \\ \epsilon \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \text{ and,}$$

$$Var\begin{bmatrix} u \\ \epsilon \end{bmatrix} = \begin{bmatrix} A\sigma_s^2 & 0 \\ 0 & I\sigma_e^2 \end{bmatrix}$$

where,

A = the numerator relationship matrix of additive coefficients of relationship between sires,

I = the identity matrix,

σ_s^2 = the variance due to the sire effect, which accounts for one quarter of the additive genetic variance in unrelated half-siblings families, and

σ_e^2 = the variance of random residuals.

The inverse of **A** was computed for each analysis using rules by Henderson (1976) as explained by Van Vleck (1983). Variance components were estimated iteratively and convergence was considered to be obtained when the two estimates of $\hat{\sigma}_s^2$ and $\hat{\sigma}_e^2$ changed less than 10^{-4} between iterations. The additive genetic variance and heritability for each trait and breed were estimated as:

additive genetic variance $\hat{\sigma}_a^2 = 4(\hat{\sigma}_s^2)$

heritability $\hat{h}^2 = \hat{\sigma}_a^2 \ / \ (\hat{\sigma}_s^2 + \hat{\sigma}_e^2)$

7.3 RESULTS AND DISCUSSION

Variance component estimates (genetic and residual expressed as .5 power) are in Table 7.3 and heritability estimates are in Table 7.4. Sire variances were generally greater for the Landim than for the Africander. As expected, the small number of progeny per sire and few sire families resulted in large standard errors (and confidence intervals) for the estimates of sire variance. The environment (nutrition, management, disease and parasites incidence) in southeast Africa is considered to be one of the most difficult for cattle production in Africa (Scholtz, 1988). Stressful environments are known (Stanton et al., 1991a) to reduce the expression of genetic potentials in cattle populations. Arnason and Kassa-Mersha (1987) reported genetic variances of .63, 10.55 and .04 $(kg^2)^{.5}$ for weights at birth, weaning and pre-weaning average daily gain, respectively, for Boran cattle in Ethiopia. These results are higher than the ones obtained in the present study, with the exception of the estimated genetic variance for birth weight of the Landim cattle [$\hat{\sigma}^2_a$ = 2.55 $(kg^2)^{.5}$].

In the Landim breed, the estimated heritabilities for weight at birth (.26 ± .19) and 18 mo of age (.31 ± .28), and average daily growth from weaning to 18 mo (.29 ± .28) were lower than the median values of .38 and .44 for weights at birth and 18 mo summarized by Preston and Willis (1974). Koch (1972) reported a range from .14 to .18 for the heritability of birth weights for cattle from the temperate regions, lower than the value estimated for the Landim breed (Table 7.4). All other heritability estimates (Table 7.4) for both breeds on growth and reproductive traits were less (or very close to the limits of the scale) than corresponding estimates in the literature for the tropics (Preston and Willis, 1974; Thorpe et al., 1981; Turner, 1982; Arnason and Kassa-Mersha, 1987; Tawonezvi, 1989), and for temperate regions (Davenport et al., 1965; Koch, 1972; Johnson and Notter, 1987).

Table 7.3. Sire and residual variance components (expressed as .5 power) and associated standard errors for weights at birth, weaning, 18 mo of age, and first calving, and pre- and post-weaning average daily gain, age at first calving, first calving interval, and 2nd and subsequent calving intervals, for the Landim and the Africander breeds in southern Mozambique.

	Landim				Africander			
Trait	$\hat{\sigma}^2_s$	SE	$\hat{\sigma}^2_e$	SE	$\hat{\sigma}^2_s$	SE	$\hat{\sigma}^2_e$	SE
Weight at	$(kg^2)^{.5}$							
Birth	1.3	1.1	4.8	1.4	.21	.8	4.7	1.3
Weaning	2.6	3.4	17.2	5.1	1.6	3.8	21.2	6.3
18 mo	6.8	6.7	23.4	7.7	.3	4.9	26.2	8.5
First calving	14.8	14.9	25.6	12.2	25.3	22.6	43.9	20.4
Daily gain								
Pre-weaning	.00	.01	.08	.02	.00	.02	.1	.03
Post-weaning	.02	.02	.06	.02	.01	.02	.07	.02
Reproduction	$(mo^2)^{.5}$							
Age at first calving	.13	.3	.9	.4	.00	.3	.9	.4
	$(d^2)^{.5}$							
First CI	12.8	14.6	32.3	13.9	.3	21.5	48.4	27.5
2nd & subsequent CI	.25	4.1	22.6	7.8	.04	5.6	27.4	10.7

Table 7.4. Heritability estimates and associated standard errors for weights at birth, weaning, 18 mo of age, and first calving, and pre- and post-weaning average daily gain, age at first calving, first calving interval, and 2nd and subsequent calving intervals, for the Landim and the Africander breeds in southern Mozambique.

	Landim		Africander	
Trait	$\hat{h}^2$	SE	$\hat{h}^2$	SE
Weight at:				
Birth	.26	.19	.00	.12
Weaning	.09	.15	.02	.12
18 mo	.31	.28	.00	.14
First calving	1.0	.79	1.0	.62
Daily gain:				
Pre-weaning	.00	.12	.00	.12
Post-weaning	.29	.28	.10	.21
Reproduction:				
Age at first calving	.07	.39	.00	.36
First CI	.54	.61	.00	.79
2nd & subsequent CI	.00	.13	.00	.17

Arnason and Kassa-Mersha (1987) reported heritability estimates of .11 ± .06, .22 ± .09, and .22 ± .09 for weights at birth and weaning, and for average daily gain from birth to weaning for the Ethiopian Boran cattle. They suggested that these low estimates could be associated with the environmental conditions which in that area is expected to inhibit the true expression of the animals genetic potential. Tawonezvi (1989) found for the Mashona breed (a Sanga breed) in Zimbabwe, heritabilities of .44 ± .11 for birth weight, .38 ± .1 for 205-day weaning weight, .39 ± .1 for 18 mo weight, .37 ± .1 for pre-weaning daily liveweight gain, and .41 ± .11 for daily gain from weaning to 18 mo of age. These estimates however, were higher than those reported for other Bos indicus in the tropics (Preston and Willis, 1974; Thorpe et al., 1981; Turner, 1982; Arnason and Kassa-Mersha, 1987). Thorpe et al. (1981) also found heritability estimates for calf weight of Africander, Angoni, Barotse and Boran breeds in Zambia, higher than average values given by Preston and Willis (1974). These workers also reported a moderate heritability for fertility in Angoni and Barotse breeds, although noting that estimates were subject to considerable sampling variation.

Improvement in the genotype for reproductive performance by selection has been indicated to be limited by low heritabilities of calving interval and services per conception in beef cattle (Davenport et al., 1965). In Australia and working with four crosses of Bos taurus x Bos indicus, Turner (1982) found estimates of heritability for fertility (measured as success or failure in producing a calf at term) and birth weight of .44 ± .13 and .14 ± .24, respectively. Using data from US Holsteins, Short et al., (1990b) found heritabilities of .05 or less ($\hat{\sigma}^2_s$ ranging from 21 to 41 d^2) for first and second calving intervals which they found consistent with the literature.

When multiple trait analysis are possible, estimates of genetic and phenotypic correlations between traits are important to determine indirect responses on traits due to direct selection on the correlated trait. Working with data from Mashona cattle in Zimbabwe, Tawonezvi (1989) reported low but positive genetic correlations for birth weight with weaning (.42 ± .18) and 18 mo (.56 ± .16) weight, suggesting that selection for one trait would result in a correlated response in the other traits. Because increases in birth weight are often undesirable due to associations with increased incidences in calving difficulties, selection for growth in that breed will have to be restricted in order to reduce the incidence of dystocia (Tawonezvi, 1989).

Estimates of genetic components of variance as well as heritability estimates for the Landim and Africander in the present study were small, while the associated standard errors were high. There are few reports in the African context that discusses the magnitude of genetic variances on growth and reproductive traits and their relationships with the environment. Without reference points, it is difficult to speculate about possible practical applications of these results in future breeding programs for the Landim and Africander breeds in southern Mozambique. Possible causes for this low estimates are related to the small size of the data set and low effective number of progeny per sire. One possible explanation for the low heritability estimates and high associated standard errors, is that environmental conditions (climate, nutrition, disease incidence, management) may have limited the expression of the genetic potential of the animals. Sampling error or perhaps the application of an incomplete model to the data are other reasons that may explain the results observed in this study.

Stanton et al. (1991b) indicated that a scaling down of genetic expression in harsh environments (such as in southern Mozambique) make it more difficult to distinguish between bulls, necessitating therefore, more progeny per sire. Efficiency of breeding programs are dependent on the magnitude of genetic parameters (genetic variances and heritabilities). Reduced genetic variances will diminish the opportunity to maximize production through selection. If genotype by environment interactions are associated with the scaling effect of reduced sire and residual variances as suggested by Stanton et al. (1991b), and if increases in genetic variances results from scalar increases on the environmental opportunity, the problem will be to determine the value(s) of the scalar(s) which will depend on the knowledge about the effect on the variances due to different environments (Short et al., 1990a). Statistical models that reduce the heterogeneous variation between environments are needed for these estimations.

Considering the restrictive effects that the environment of the Chobela Station may have on the expression of genetic variances (reduced) of both, the Landim and Africander cattle, the higher estimates obtained for the Landim in practically all traits, may be another manifestation of the greater adaptability, through additive genetic controls, of the Landim to this environment, agreeing with previous results on growth and reproductive performances.

7.4 CONCLUSIONS

Studies on genetic parameters of economically important traits on Bos indicus breeds in the tropical Africa seem to be sparse in the literature (Arnason and Kassa-Mersha, 1987).

The main objective of this study was to estimate additive genetic variances and heritabilities of growth and fitness traits required for planning breeding systems and for predicting response to selection in the Landim and Africander cattle in southern Mozambique. The results obtained in this additive genetic study were statistically nonsignificant partly because of the small number of sire families and of progeny per sire and other possible reasons. Nonetheless, these estimates represent the best ones available to genetically characterize Landim and Africander potentials in southern Mozambique. Although small, additive genetic variation probably contributes to differences in breed expression in the environment studied.

Presumably draught and periodically severe grazing conditions at the Chobela station caused severe disturbances in the normal activity of the animals and inhibit the expression of their true genetical potential for growth and reproduction. Reduced expression of genetic variances in the

Chobela environment were expected. Hammond (1947), as cited by Short et al. (1990a), stated that genetic variance for a trait may only be expressed when environmental variation (opportunity) is sufficient to permit differential genetic expression. In areas where the environmental effects comprise a large proportion of the total variance, as in the case of the present study, the genetic component becomes small. This leads to difficulties in estimating the merit of the breed and is a bottleneck to appropriate sire evaluations (McDowell, 1985).

The estimated genetic variances of the Landim were higher for most traits than for the Africander breed. In a restrictive environment as the one in Chobela Research Station where the expression of genetic variances are expected to be reduced, the higher estimates obtained for the Landim might signal one mechanism of greater adaptation of this breed to conditions of the local environment. This is in agreement with the previous results on growth and reproductive performances which resulted in the Landim being a more productive breed in terms of weaner and yearling production per cow per year than the Africander breed.

CHAPTER 8

SUMMARY AND CONCLUSIONS

Cattle account for the most important forms of livestock production in Mozambique. Although a great part of the agriculture land is only suitable for use by ruminant livestock (about 155,000 km^2), Mozambique has the lowest ratio of cattle to human inhabitants in southern Africa (.07 head per capita) and one of the lowest densities of cattle per total area (.62 head per km^2) in Africa. These figures imply room for substantial improvement in cattle production if constraints are alleviated. The most important constraint for cattle production in Mozambique is that two-thirds of the country is infested with tsetse fly, the vector for trypanosomiasis, which causes high rates of morbidity and mortality in domestic ruminants. This explains much of the cattle distribution pattern in the country, where 71% of the national herd is found in the southern provinces, which are relatively free of tsetse fly or the incidence is low enough to permit cattle production.

The most numerous indigenous cattle breeds in southern Africa are of the Sanga type (Mason and Maule, 1960), which are smaller than the European breeds. Maule (1973) noted that there were inadequate data on the performance of the indigenous breeds of southern Africa. Frequently such breeds have been rejected as unproductive, an assessment based on observations made under the resource-poor conditions of traditional husbandry (Buck <u>et</u> <u>al.</u>, 1982). Studies comparing these breeds have been carried out in the region (Buck <u>et</u> <u>al.</u>, 1976; Trail <u>et</u> <u>al.</u>, 1977; Buck <u>et</u> <u>al.</u>, 1982; Scholtz, 1988; Tawonezvi <u>et</u> <u>al.</u>, 1988; Dionisio, 1989; Dionisio and Syrstad, 1990).

The Chobela Research Station in Mozambique initiated a program with the objective of comparing the performance of the two most common indigenous beef breeds in the south of the country: the Landim and the Africander. Both are Sanga breeds, the Landim is a local breed and the Africander is an imported one from South Africa. The Africander is a breed that has been selected for beef and with a greater mature weight than the Landim. Especially for this reason, commercial beef farmers favor the Africander, not paying attention to other factors that may influence overall productivity. In this context, analyses were performed to characterize and compare the Landim and the Africander breeds in the growth and fitness traits influencing beef production, and to estimate genetic variances and heritabilities for the development of improved programs in the conditions of southern Mozambique.

Data for the present study were obtained at Chobela Research Station from 1968 to 1981. Growth and reproduction records from 854 calves were evaluated using fixed models to obtain analysis of variance, least squares means, and linear contrasts. Genetic variance estimates were obtained from the sire variance components for each breed by use of the Restricted Maximum Likelihood (REML) procedure applied to mixed models where the sire effect was included as a random effect.

The effect of season of birth was important for most of traits. Animals born in the early rainy season had smaller birth weights but subsequently grew more rapidly than calves born after December. Calves born in the early rainy season were heavier at weaning and at 18 mo of age, and grew more rapidly than calves born late in the rainy season. Cows calving early in the rainy season also had shortest calving intervals. These findings are consistent with those from the analysis of growth and weight traits. It seems that, for similar environmental condition as in southern Mozambique, a policy of restricted breeding is recommended to be adopted in order to concentrate calvings early in the rainy season.

Results showed that Africander calves grew more rapidly than Landim calves before weaning (P<.01) but no difference was detected after weaning. There was a reduction in the weight differences on a percentage basis between the Landim and Africander breeds through time. The Africander were 15%, 11% and 6% heavier than the Landim for birth, weaning and 18 mo adjusted weights (P<.01), but no difference was detected for age-adjusted weight at first calving (P>.5).

The same trend was observed when comparing the adjusted weight differences between the Landim and Africander breeds as proportions of the pooled within breed standard deviation. These percentages were 102% at birth, 85% at weaning, and 56% at 18 mo of age. The reduction observed in weight differences indicate a greater adaptation of the Landim to the climatic and nutritive environment prevailing in southern Mozambique, especially after weaning, when performance depends on the animal's own genotype. The effect of age of dam was important only for birth and weaning weights. Landim dams were on average 5 mo younger than Africander dams for the analyses of birth and weaning weights. This differential on age of dam favored the Africander calves because larger, older cows generally provide a better environment to their calves, especially through greater milk yields.

The Landim and Africander differed in reproductive performance (age at first calving, first calving interval and second and subsequent calving intervals). Because these breeds were co-managed in the same environment, it is reasonable to suspect that the differences observed were attributable to different genotypic expressions. Results showed the Landim cattle were 4% younger at first calving, required 10% fewer days in first calving interval, and had 5% shorter calving intervals subsequently (second and later) than Africander cows. The higher reproductive rates of the Landim is a strong indication that this breed is well adapted and more fertile than the Africander in the environment of southern Mozambique. The mechanism for this superior reproductive performance was the greater probabilities of conception for Landim females at first breeding exposure as heifers and as cows (P<.04).

This study has also showed that, in terms of weaner and 18 mo production, the Landim was more productive than the Africander. The Landim was 21% superior in terms of kg of weaned calf per kg of cow per year and 15% superior in terms of kg of weaned calf per kg of metabolic weight of cow per year. Landim cows also yielded more 18 mo calf weight than the Africander. They showed a superiority of 25% and 20%, respectively, in terms of kg of 18 mo old calf per kg of cow per year and per kg of metabolic weight of cow per year. Comparing the differences in productivity between the two breeds, Landim cows increased its productivity from weaning to 18 mo in 4% and 5% per kg of cow per year and per kg of metabolic weight of cow per year when compared with Africander cows. The advantage of the Landim was due primarily to superior reproductive performance and smaller dam body weight, which means less feed for cow maintenance. The results of this evaluation should encourage the use of Landim instead of Africander in the commercial sector in southern Mozambique. In the current upgrading scenario (i.e., replacing), the Landim is being downgraded to the Africander. Research evidence is now leading to a consensus about the superiority of the Landim, and other Sanga breeds, over the Africander.

Estimates of additive genetic variances and heritabilities for the traits analyzed (growth and reproduction) were statistically nonsignificant partly because of the small number of records, sires and progeny per bull, among other possible reasons. Nevertheless, these estimates represent the best ones available to genetically characterize Landim and Africander potentials in southern Mozambique. Although small, additive genetic variation probably contributes to differences in breed expression in the environment studied. Reduced expression of genetic variances in harsh environments like in southern Mozambique should be expected.

Presumably draught and periodically severe grazing conditions at the Chobela station caused severe disturbances in the normal activity of the animals and inhibit the expression of their true genetical potential for growth and reproduction. The estimated genetic variances of the Landim were higher for most traits than for the Africander breed. In a restrictive environment like the Chobela Research Station, where the expression of genetic variances are expected to be reduced, the larger estimates obtained for the Landim might signal one mechanism of greater adaptation of this breed to conditions of the local environment. This is in agreement with the results on growth and reproductive performances which overall, resulted in the Landim being a more productive breed in terms of weaner and yearling production per cow per year than the Africander breed in the conditions of southern Mozambique.

The performance of the Landim (compared with the Africander) as described above show that this breed is well adapted (diminishing weights with age, younger and lighter dams, and greater reproductive efficiency which resulted in a more productive breed) and may have considerable beef production potential in southern Mozambique conditions, given reasonable management. Growth and reproductive efficiency are directly related with the availability of good quality forage and disease and parasites incidence. Research on managing pasturelands (stocking rates, brush control) and on resistance (tolerance) to the main diseases and parasites existing in the region, are priorities that should be implemented to improve production and productivity.

Although results of the present study indicate that Landim is a productive breed by its own merit, more information is needed about the possibilities to raise production and productivity, either by selection or by crossing with specialized breeds. Crossbreeding with European or specialized tropical breeds that combine adaptability (reproductive capacity, disease resistance) with the high beef or milk potential of the specialized breed, is now recognized as preferable to achieve that objective (Ansell, 1985). Therefore, studies that will evaluate heterosis and complementarity (in the sense of combining breeds which excel in different characteristics) between the Landim and other breeds (Holstein-Friesian, Simmental, Brahman, Sahiwal) known to improve production and productivity in similar conditions, deserves consideration in future research programs. Trypanosomiasis is an endemic disease in almost two-thirds of the country and, for this reason, a low density of cattle is found in this area. Formation of synthetic breeds by crossing the Landim with known trypanotolerant breeds (e.g., Ndama), should be of particularly importance for these areas and merits thorough investigation. In the long term, increases in cattle productivity will be dependent on the use of genotypes that are well adapted to existing environment but that can respond to environmental improvement (Frisch and Vercoe, 1982).

APPENDIX A. DESCRIPTIVE STATISTICS FOR THE WEIGHT AND GROWTH TRAITS

APPENDIX A

DESCRIPTIVE STATISTICS FOR THE WEIGHT AND GROWTH TRAITS

Table A.1. Unadjusted means ($\bar{x}$) and standard deviations (SD) by breed and sex of Landim and Africander for weights (kg) at birth, weaning, 18 mo of age, first calving, and average daily growth (kg/d) for pre- and post-weaning period.

	Landim		Africander	
Trait	Males	Females	Males	Females
Birth				
$\bar{x}$	34.4	32.8	38.4	36.9
SD	5.4	5.6	4.7	5.1
N	256	215	198	201
Weaning				
$\bar{x}$	156.2	145.2	170.9	164.3
SD	20.8	21.5	25.3	21.4
N	175	192	161	174
18 mo				
$\bar{x}$	256.7	219.3	270.8	243.0
SD	28.6	24.7	32.4	25.7
N	120	124	105	128
First calving				
$\bar{x}$	...	352.3	...	422.3
SD	...	45.2	...	58.8
N	...	82	...	87
Pre-weaning growth				
$\bar{x}$	.58	.54	.63	.61
SD	.10	.10	.13	.10
N	162	163	147	153
Post-weaning growth				
$\bar{x}$	.30	.23	.30	.24
SD	.10	.07	.10	.08
N	115	124	101	125

Table A.2. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on birth weight (kg) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1975	54	33.0	.7	51	37.2	.7	37	35.6	.8	26	39.0	1.0
1976	51	33.3	.7	51	37.8	.7		...			...	
1977	55	35.1	.7	33	40.3	.9	19	36.6	1.1	24	38.6	1.0
1978	48	33.2	.7	52	34.9	.7	14	30.1	1.3	15	39.4	1.2
1979	89	35.1	.5	69	37.4	.6	9	32.4	1.6	3	42.4	2.8
1980	63	28.0	.6	34	34.8	.8	20	35.6	1.1	35	39.6	.8

[1]Birth season (Early, from July to December; Late, from January to June).

Table A.3. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on weaning weight (kg) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1975	49	154.9	2.8	42	168.3	3.1	30	137.8	3.6	23	160.1	4.1
1976	51	163.5	3.0	51	184.2	2.7	34	136.6	3.5	29	167.2	3.7
1977	39	125.9	3.4	34	149.8	3.5	9	145.0	6.6	22	150.7	4.2
1978	48	160.0	2.9	51	176.0	2.7	17	159.5	4.8	13	172.1	5.4
1979	82	158.0	2.3	65	166.1	2.5	8	147.4	6.8	4	156.9	9.7

[1]Birth season (Early, from July to December; Late, From January to June).

Table A.4. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on 18 mo weight (kg) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1975	45	256.8	4.1	40	270.7	4.4	30	232.4	4.9	24	249.4	5.6
1976	39	242.4	4.5	43	258.1	4.0	24	227.2	5.6	24	247.4	5.6
1977	34	243.6	5.1	32	267.6	5.0	8	242.0	9.7	17	253.0	6.4
1978	48	235.8	4.0	46	254.7	3.9	16	225.2	6.8	7	219.2	10.0

[1]Birth season (Early, from July to December; Late, from January to June).

Table A.5. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on daily growth rate from birth to weaning (kg) for the Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1975	46	.574	.014	41	.617	.015	29	.483	.017	21	.579	.020
1976	51	.623	.014	51	.697	.013		...			...	
1977	38	.434	.016	33	.515	.017	9	.525	.032	22	.534	.020
1978	48	.606	.014	51	.672	.013	14	.625	.025	13	.630	.026
1979	82	.587	.011	65	.613	.012	8	.544	.032	3	.561	.053

[1]Birth season (Early, from July to December; Late, from January to June).

Table A.6. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on daily growth rate from weaning to 18 mo (kg) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1975	44	.311	.011	39	.312	.012	27	.281	.014	21	.257	.016
1976	39	.235	.012	43	.226	.011	24	.274	.015	24	.240	.015
1977	34	.355	.014	32	.359	.014	7	.300	.028	15	.315	.019
1978	48	.230	.011	46	.241	.011	16	.196	.019	6	.137	.030

[1]Birth season (Early, from July to December; Late, from January to June).

Table A.7. Least squares means ($\bar{x}$) and standard errors (SE) for year-season effect on weight at first calving (kg) for Landim and Africander breeds.

	Early[1]			Late[1]		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1976	25	396.5	7.5	23	390.4	7.6
1977	10	385.7	10.8	6	389.8	14.4
1978	27	369.0	8.7	...	...	...
1980	27	331.3	8.7	17	353.6	11.1

[1]Birth season (Early, from July to December; Late, from January to June).

APPENDIX B. DESCRIPTIVE STATISTICS FOR THE REPRODUCTIVE TRAITS

APPENDIX B

DESCRIPTIVE STATISTICS FOR THE REPRODUCTIVE TRAITS

Table B.1. Unadjusted means ($\bar{x}$) and standard deviations (SD) by breed of Landim and Africander for age at first calving, first calving interval, and second and subsequent calving intervals.

	Landim	Africander
Age at first calving (mo)		
$\bar{x}$	40.6	42.3
SD	6.1	6.0
N	174	124
First calving interval (d)		
$\bar{x}$	433.6	482.9
SD	142.4	153.2
N	113	50
≥2nd calving interval (d)		
$\bar{x}$	432.0	456.3
SD	142.8	154.7
N	285	225

Table B.2. Least squares means ($\bar{x}$) and standard errors (SE) for year-season of birth effect on age at first calving (mo) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1970	17	42.5	.4	15	42.6	.3	4	41.4	.7	3	41.1	.6
1971	29	42.4	.3	4	42.5	.5	9	41.5	.5	5	42.0	.4
1972	5	41.6	.6	3	43.0	.6	5	41.1	.6	9	41.0	.3
1973	27	42.7	.3	25	42.6	.2	5	40.6	.7	3	42.0	.6
1974	8	40.9	.5		...		1	41.2	1.4	1	41.7	1.0
1975	17	40.1	.4	15	41.2	.3	16	39.3	.4	9	38.9	.3
1976	17	41.8	.3	20	41.9	.2	14	40.7	.4	12	41.3	.3

[1]Birth season (Early, from July to December; Late, from January to June).

Table B.3. Least squares means ($\bar{x}$) and standard errors (SE) for year-season of birth effect on first calving interval (d) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1970	12	556	11	3	540	27	3	561	22		...	
1971	20	543	9	3	534	28	9	539	13	3	507	28
1972	5	570	16	3	538	28	3	568	21	9	538	16
1973	25	543	8	12	529	13	3	545	22	2	515	34
1974	1	546	37		...			...			...	
1975	15	571	11	9	576	16	14	576	11	6	600	20
1976	2	547	26		...		1	560	37		...	

[1]Birth season (Early, from July to December; Late, from January to June).

Table B.4. Least squares means ($\bar{x}$) and standard errors (SE) for year-season of calving effect on second and subsequent calving intervals (d) for Landim and Africander breeds.

	Early[1]						Late[1]					
	Landim			Africander			Landim			Africander		
Year	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
1968		...		1	529	28		...			...	
1969		...			...		2	583	19	1	575	28
1970	2	552	19	1	528	28		...		2	558	20
1971	7	558	10		...		2	560	19	2	597	20
1972		...		3	552	16	1	623	27	4	537	14
1973	8	534	10	13	528	8	4	557	14		...	
1974		...			...		4	607	14	4	592	14
1975	15	537	7	18	547	7	10	591	9	5	609	13
1976	24	531	6	18	535	7	15	551	7	13	554	8
1977	47	534	5	29	531	6	17	561	7	15	554	8
1978	28	523	6	24	521	6	13	563	8	10	536	9
1979	38	498	5	32	525	5	1	594	27	1	544	28
1980	39	556	5	9	545	9	8	592	10	20	595	7

[1]Calving season (Early, from July to December; Late, from January to June).

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