



MEAT FROM GOATS IN TANZANIA

by

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DECLARATION

I, Martin Luther Kyomo, do hereby declare to the Senate of the University of Dar es Salaam that this dissertation has not been submitted for a higher degree award in any other University.

Signature

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11th May 1978.



ABSTRACT

The shortage of protein of high biological value in the tropics could be decreased by raising larger numbers of indigenous ruminant livestock, and of increasing off-take and weight per animal destined for slaughter. In Tanzania, where there are about five million goats and their meat is already very popular, improvement of goats through better breeding, feeding and disease control methods could lead to a several-fold increase in the present annual production of 1.3 million goat carcasses. The paucity of data on which to base goat improvement methods was the major reason for undertaking this study.

A comparison was made in reproductive performance, growth rate and carcass yield between the Tanzania indigenous goats and the Tanzania x Boer and the Tanzania x Kamorai goats. The total numbers of animals involved in the study, which was conducted between 1972 and 1976, inclusive, were 7 sires, 177 dams and 559 progeny.

The study confirmed earlier untested theories that the Tanzania goat, which belongs to the East African breed type of goat, produces kids throughout the year. There were, however, peak periods in which more dams kidded than in other periods. The total amount of rain falling during a given period was the only environmental factor affecting the time of conception of the dams ($P < 0.001$). This relationship seemed to be an indirect one, in that more rain meant more forage growth.

and availability and therefore better body condition of the dams. Better fed dams ovulate, conceive when mated, and maintain pregnancy to term more readily than underfed dams. The twinning rates and mortality of kids have been reported in the thesis.

The effects of year, sex, seasons and birth type, whether singles or twins, on weight at various ages have been reported. The slight superiority of castrates over the entire male kids in growth rate observed in this thesis calls for more studies to see if the hormonal patterns related to growth were different from those of animals of similar sexes in other domestic livestock. The heritability estimates for weight at birth, weaning, one year and 72 weeks of age were 0.7 ± 0.10 , 0.14 ± 0.14 , 0.07 ± 0.11 and 0.017 ± 0.16 , respectively. The weight of kids could, for practical purposes on the farms, be predicted by the formula :

$$\begin{aligned} \text{Weight (in kg)} &= - 4.22 \pm 0.15 + (0.00806 \pm 0.00007 \\ &\quad \times \text{Girth (in cm)} \times \text{Length (in cm)}. \\ &\quad (R^2 = 88.2\%) \end{aligned}$$

The cold dressed carcass percentages of the Boer and Kamorai crossbred and Tanzania purebred kids were 45.57, 45.34 and 45.34 per cent, respectively. The areas of the eye muscle (Longissimus dorsi) measured on the 10th and 11th ribs of the male and castrated kids ranged between 11.77 and 14.27 square centimetres. The castrated kids had more total lean, fat and bone than the entire

male kids. The heritability estimates for cold dressing percentage, total lean, total fat and total bone within the carcass were 0.7, 0.3, 0.04 and 0.4, respectively.

It is concluded that this study has contributed to the knowledge on meat goat production characteristics in the tropics and will form a basis on which to plan the breeding and management of commercial meat goats in Tanzania.

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GLOSSARY OF TERMS, ABBREVIATIONS
AND SYMBOLS NOT DEFINED IN THE TEXT

Buck refers to a fully grown male goat

Carcass weight refers to the weight of a slaughtered goat after the skin, the head, and the extremities of the limbs have been removed, in accordance with the commercial dressing requirements

Doe refers to a fully grown female goat

Dressing percentage is the ratio of the weight of a warm or cold carcass to live weight of the same animal before slaughter x 100

Kid refers to a young goat

Kidding means giving birth by a doe

kg	kilogramme
g	gramme
mm	millimetre
m	metre
M	male
F	female
CP	crude protein
df	degrees of freedom
Dm	dry matter
EE	ether extract
ME	metabolisable energy
n	number
R ²	multiple correlation coefficient
SE	standard error
TDN	total digestible nutrients

CHAPTER IINTRODUCTION

Recent statistics by the Food and Agriculture Organisation of the United Nations (FAO) indicate that there are about 409 million goats (Capra hircus L.) in the world. Amongst the world's ruminant livestock, this figure is exceeded only by the numbers of cattle and sheep. It is estimated that two-thirds of the world's goats are found in the tropics where they are mainly used for meat. FAO has undertaken several studies which have drawn attention to the shortage of protein, particularly animal protein, in the diets of people inhabiting a majority of the tropical and sub-tropical countries. It has proposed that this shortage could be met by increasing livestock numbers, weight per animal destined for slaughter, and by improving the productivity of forage based ruminant livestock systems.

In Tanzania, where numerically amongst ruminant livestock goats rank second after cattle, 5 and 12 million heads, respectively, and where their meat is very popular, there is a lot of interest in utilising them further for meat production for domestic and export markets. However, there is generally lack of data on which to base meat production systems from goats throughout the tropics (Devendra and Burns, 1970; French, 1970). Applying improved methods of breeding, feeding, management and disease control, producers in temperate countries have been

able to design sheep production systems in which an off-take of up to 80 per cent per annum has been achieved. Even if a moderate off-take of about 52 per cent or double the present figure was achieved in goats in Tanzania, this would mean a rise in the number of carcasses per year from the present 1,250,000 to 2,500,000. This would result in an increase in meat supply of at least 15,000,000 kg per year. The paucity of data in various aspects of goat breeding, physiology, nutrition and reaction to various environmental factors, and the importance of the goat in Tanzanian agriculture were the major reasons for undertaking the study.

The experiment reported in this thesis was designed to study various traits of economic importance, namely, reproductive performance, growth pattern, and carcass yield and composition in a sample representing the Tanzania meat goat.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

FAO has estimated the demand for livestock products in developing countries between 1967 and 1985 to grow between 4 and 5 per cent per annum and the supply of these products to increase between 1.5 and 2 per cent per annum only (FAO, 1970). For a constant price an increasing gap between demand and supply was predicted. The increased demand was expected to come from increased human population and from a higher consumption per capita as income levels rise. In order to bridge the gap between supply and demand for livestock products it was recommended that production be increased by 2.9 per cent per annum between 1962-75 and by 3.8 per cent per annum between 1975-85. The biological cycle in cattle, sheep, goats and buffaloes is long, so that meat production from non-ruminant animals such as pigs and poultry, which have a shorter reproductive cycle, was encouraged. However, the above predictions were made at the time when there were surplus stocks of grain for sale at relatively low prices. The unexpected bad weather which occurred between 1975 and 1976 in several developing countries led to mass importation of grain for human consumption, and therefore the livestock enterprises, especially those of pig and poultry which depended on grain, were seen to be competing with humans

for this food source. The rising cost of energy from non-renewable fossil fuel, which is used in grain production, and the resultant high price of the latter in both grain exporting and importing countries, will most likely also make the cost of raising livestock on grain prohibitive and meat production from forage will most likely dominate other systems of ruminant animal production.

The aim in animal production in the developing countries should, because of the above factors, be to study ways and means of increasing the efficiency of agricultural production systems which are based on ruminant livestock which eat and convert forages and crop by-products, which are not consumed directly by humans, into products of high biological value such as milk and meat (Spedding, 1974; Dristchilo, 1977; Preston, 1977; Vandemaele, 1977). In countries where goats are found in large numbers (Table 2.1) and where goat meat is an acceptable food product, as is the case in most countries in the tropics (Tables 2.2 and 2.3), there is a need to study breeding, nutritional, physiological and management aspects of the goat and to use this knowledge in increasing its productivity. To meet the demand for meat in most countries, it has been suggested that the aims should be to increase the liveweights of individual animals at slaughter and to increase off-take (FAO, 1970). This review will therefore look at what is already known about reproduction, mature size, growth and carcass characteristics in the East African goat.

Table 2.1. Livestock Numbers in millions by Region during 1975 (Based on FAO 1975)

Region	Ruminant Livestock				
	Cattle	Sheep	Goats	Buffa- loes	Camel
Europe	135.4	125.8	11.7	0.4	0.0
North & Central America	193.4	21.6	12.2	0.0	0.0
South America	212.4	117.4	29.6	0.2	0.0
Africa	151.4	150.0	120.3	2.3	9.6
Asia	356.4	275.6	224.0	128.5	4.2
USSR	109.1	145.3	5.9	0.4	0.3
Oceania	43.1	207.2	0.2	0.0	0.0
World Totals	1,201.2	1,042.9	403.9	131.8	14.1
Species of Livestock as a % of its Class	43.0	37.3	14.5	4.7	0.5

Table 2.2. Meat Production from Livestock in millions of MT^a by Region during 1975
(Based on FAO 1975)

Region	Beef & Veal	Mutton & Lamb	Goat	Buffaloes	Pigs	Poultry	Horse	Total Meat	Prodn. per Region as % of World Total	
Europe	10.3	1.1	0.1	0.1	15.7	5.3	0.2	32.7	26.8	
North & Central America	13.4	0.2	0.0	0.0	6.4	7.2	0.1	27.3	22.3	
South America	6.3	0.3	0.1	0.0	1.4	1.1	0.1	9.2	7.5	
Africa	2.3	0.6	0.4	0.8	0.3	0.4	0.0	5.1	4.2	
Asia	3.3	1.3	1.0	6.1	12.6	5.2	0.1	29.6	24.2	
USSR	6.5	1.0	0.0	0.0	5.9	1.5	0.0	14.9	12.2	
Oceania	2.0	1.0	0.0	0.0	0.2	0.2	0.0	3.5	2.9	
World Totals	44.1	5.5	1.5	7.0	42.5	21.3	0.4	122.3		
Type of Meat as a % of Total Meat	36.1	4.5	1.3	5.7	34.7	17.4	0.3		100.0	
World Prodn. by Ruminants only	58.1									
Prodn. by Individual Ruminant as % of all Ruminant Species	75.9	9.5	2.6	12.0						

a = Metric tons

Table 2.3. Livestock Numbers in Tanzania and their relative contribution towards meat production during 1975 (based on FAO, 1975)

Item	Cattle	Goats	Sheep	Pigs	Poultry
Livestock Nos. x 1000	12,000	4,600	2,900	24	22,300
Ratio human population:no. of animals	1:0.8	1:0.3	1:0.2	1:0.0	1:1.4
No. slaughtered x 1000	1,100	1,200	750	5	Not given
% Offtake	9.2	26.1	25.9	20.8	Not given
Meat production x 1000 MT	116	18	11	0.2	23
Meat production per species as % of total meat	69.1	10.7	6.6	<1	13.6

2.2 Adaptation to the Tropical Environment

The East African goat is widely distributed throughout Kenya, Tanzania and Uganda (Mason and Maule, 1960; FAO, 1967). The population sizes are shown in Table 2.4.

Table 2.4. Recent Goat Population Figures in East African Countries (FAO, 1975)

Country	Y e a r			
	1961-65	1973 (Numbers x 1000)	1974	1975
Kenya	5,070	3,900	3,800	3,900
Tanzania	4,365	4,400	4,500	4,600
Uganda	<u>2,294</u>	<u>1,950</u>	<u>2,000</u>	<u>2,050</u>
Total	11,729	10,250	10,300	10,550

Langdale-Brown et al. (1964) and the East African Range Classification Committee (quoted by FAO, 1967) define areas where, in the absence of irrigation, extensive livestock production is likely to be the most efficient form of land use. The 762 mm isohyet is generally taken as the lowest limit for reliable crop production in East Africa. The areas having less than 762 mm of rainfall per annum form about 75 per cent of the land area in Kenya, about 67 per cent in Tanzania and just under 20 per cent in Uganda. Although goats are found in both the good farming areas and the areas which receive less than 762 mm of rain per annum, the majority of them are found in the latter category of land area, namely the semi-arid and

arid areas. In the good arable farming areas they are normally herded during the day on their own or together with cattle and sheep on communally owned grazing areas. Some farmers who have few goats choose occasionally to restrict their grazing and their movements by tethering them to pieces of bush or tree during the day. During the night all domestic livestock are normally confined to kraals in order to protect them from predators and thieves. In some few cases, goats are stall fed in order to fatten them or in order to restrict them from foraging in arable fields. In the semi-arid and arid areas, herding goats on their own or together with cattle and sheep is also practiced but here, due to low density of human population and due to the sparseness of forages, animals range over larger areas. Nomadism is a way of life for some tribes in these areas. In both the good arable areas and the dry areas feed conservation for livestock is not normally practiced. The East African goat is therefore expected to withstand the conditions in the semi-arid and arid areas where the problem of shortage of forage and water is further aggravated by the frequent occurrence of droughts. This animal seems to be the only domesticated ruminant which is able to survive and reproduce in areas which are infested with tsetse flies - the carrier of a disease known as trypanosomiasis (Lowe, 1943). Throughout the centuries of survival in this region, natural selection seems to have conferred this goat with certain adaptive characteristics. Some of these characteristics will now be discussed.

2.2.1 Adaptation and Feeding Habits

Mackenzie (1957) has attributed the goat's ability to forage extensively to its possession of the mobile upper lip and the very prehensile tongue. In the study on the grazing habits of the East African goat, Wilson (1957) observed that the goat was not selective as regards the state of growth of plant material. It was, however, observed to be reluctant to graze or browse on vegetation which was below neck height from the ground. It was often seen standing on its hind legs with the fore legs up on the stems and branches of small trees and bushes in an attempt to reach leaves, inflorescence and pods which were high up above the ground. Similar observations on the grazing habits of the goat led the workers at Mpwapwa in Tanzania (Hornby, 1936; Staples et al., 1942; Hornby and van Rensburg, 1948) to conclude that, contrary to views held by administrators and some agriculturists, the goat does not compete with but is complementary to cattle and sheep for grazing.

The browsing habit of the goat, coupled with its wide ecological distribution, has led some workers to conclude that the goat is responsible for the destruction of trees and bushes and therefore bringing about deserts (Maher, 1945). However, from the studies conducted at Mpwapwa, Staples et al. (1942) and Hornby and van Rensburg (1948) concluded also that goats could be kept advantageously without fear of causing pasture degeneration or soil erosion, that they should not be regarded as bush-clearing agents,

and that the number of goats required per unit area to check the process of reversion to bushland would be unreasonably high. It is likely also that their effectiveness in controlling bush would depend on the climate of the area and the vegetation type. In high and medium rainfall areas in the tropics, bush regeneration is a problem in arable farming and range management and there would probably be a need to fence the goats in to give them a chance to attack bush either as coppice or as seedlings. In the dry areas, however, poor management of goats and lack of application of sound range management techniques could lead to overgrazing and destruction of the vegetation cover.

2.2.2 Efficiency of Feed Utilisation

Devendra and Burns (1970) have reviewed the factors relating to the digestive efficiency of feed by goats compared with cattle, sheep and buffaloes. They point out that there is a general agreement that these ruminant animals do not differ in their digestive efficiency of feeds. However, the goat is superior to others in the utilisation of crude fibre (cellulose). It is suggested that this difference may be due to inherent physiological differences between the species involved. El Hag (1976) has shown that the goat and sheep do not differ in digesting the nutrients present in high quality feeds. They, however, differ slightly in digesting crude fibre and crude protein contained in medium and poor quality feeds. It is

suggested that this difference in the digestion of low quality roughages is due to the greater activity of rumen micro-organisms in goats than in sheep. The production of the volatile fatty acids (VFA), the ultimate metabolic products of the food degradation in the rumen, is a good indicator of the activity of the rumen micro-organisms. There was in the above study a higher production of VFA in the goat than in sheep when fed low quality roughages, thus indicating the better ability of the former species in utilising low quality feeds. However, as degradation of crude fibre in the rumen results mainly in acetic acid, the analysis of the VFA obtained in this study would have confirmed the efficiency of the goat in utilising crude fibre. Unfortunately, such an analysis was not undertaken. Gihad (1976) demonstrated in Zambia that crude fibre digestibility was higher for indigenous goats than for the Dorper sheep (a cross between the Dorset Horn, a wool sheep, and the Blackhead Persian, a tropical hair sheep). The digestibility figures for goats and sheep were 60.25 and 56.50 per cent, respectively. This difference in digestibility figures between the two species was significant at $P < 0.05$. If it is generally demonstrated that the goat is more efficient than other ruminant livestock in digesting poor quality roughages, then this could be an explanation for its ability to subsist on fibrous feeds found in semi-arid and arid areas where few other domestic livestock exist. Such information would also be useful to goat producers in East Africa where the majority of the livestock production systems are based on relatively

poor quality forage in the marginal areas. It would be useful also to measure the quality and quantity of the browse and grass readily eaten by the East African goat under normal grazing conditions in the range areas in order to know what nutrients the goats were ingesting.

2.2.3 Water Requirement and Utilisation

In the drier areas of East Africa, domestic ruminant livestock may get watered once in three or four days (FAO, 1967). Whereas cattle would lose weight under these conditions, the goat does not seem to suffer very much. Schoen (1968) studied the water utilisation of the East African goat under normal and high ambient temperatures. Water economy was achieved by drastic reduction in all avenues of water loss, such as in the urine, faeces and evaporation. This worker also observed temperature and respiration rate to rise with the rise of ambient temperature but feed intake was not affected. Quartermain and Broadbent (1974), working with the Zambia goat which they describe as a type of the East African goat, found similar responses to heat stress as those observed by Schoen, except that feed intake was reduced during heat stress. Shkolnik et al. (1972) obtained similar results to those of Schoen when they compared the water economy under heat stress of the Sinai goat which is said to inhabit the "harshest of the deserts in Israel" and the Mountain goat which lives in a better environment. The Sinai goat lost weight more slowly than the Mountain

goat when they were subjected to 40°C. The former continued to feed even with the loss of 30 per cent of body weight and with water depletion. The Mountain goat, however, stopped eating after losing 25 per cent of its initial weight due to water deprivation. At the termination of the experiment water was offered ad libitum. The Sinai goat drank continuously for 90 to 150 seconds until its original weight was regained and it refused to take water again when it was offered on the same day. The Mountain goat on the other hand drank for longer times and needed water more frequently. Shkolnik et al. (1972) also observed reduced metabolic rates during water deprivation. The Mountain goats lost weight when fed high crude fibre diets during the acclimatisation period. The same feeds were adequate for maintenance requirements for the Sinai goats. The faeces of the Sinai goat were drier and their water content was less than 40 per cent of their fresh weight compared with 50 per cent for the Mountain goats. These workers concluded that low metabolic rate at high temperatures may be of adaptational significance in a hot environment because low metabolism generates less heat and thereby saves water otherwise needed for its dissipation. The low metabolic rate also reduces the ventilation of the lungs and the amount of food needed, which is important in an area where food is scarce. This knowledge is useful in understanding what might happen when breeds of goats from temperate countries or from the cool areas in the tropics are introduced into the marginal areas of East Africa.

2.3 Reproduction

A higher reproductive rate produces more animals for replacement and for sale. To raise the reproductive performance of goats, one must understand the factors which affect it at different stages of the life cycle.

2.3.1 Age at Puberty

2.3.1.1 In the female goat

Dýrmundsson (1973) has reviewed puberty and early reproductive performance in ewe lambs. He agrees with the workers who have defined puberty as the time at which reproduction first becomes possible, characterised by the release of germ cells, and sexual maturity as the time when the animal expresses its full reproductive power. He also agrees with those who wish to distinguish between puberty and sexual maturity in sheep since ewe lambs do not attain their full reproductive capacity until the adult stage is reached. He argues that physiological puberty in the female, i.e. the production and liberation of viable ova, cannot, however, be taken to imply the ability to carry a foetus to term. Devendra and Burns (1970) reporting on goats, have stated that early physiological maturity is closely related to growth rate and within breed differences are generally due to variations in feeding, management and disease. They cite studies undertaken on Syrian Mountain and Negev goats in Israel, where under good feeding females kidded at one year of age, whereas under poor management conditions they kidded at

two years of age. They also state that body weight was more important than age in determining puberty. This statement is similar to one made by Hafez (1968) who claimed that puberty depends on a certain threshold of body weight. Wilson (1958) found that sexual maturity in the East African goat may be reached before four months of age when goat kids weigh 14-16 kg. Skinner (1972) found that the Boer female kids reached puberty at six months of age. It seems therefore that there are breed differences in the age at puberty. Although it could be concluded from these studies that kids reach puberty at about six months of age, management practices are normally designed to delay mating until the kids are approaching mature body weight. Thus pregnancy does not coincide with the period when the goat is in active growth (Devendra and Burns, 1970). Hutchison (1963) recommended that East African female kids could be mated when fully grown at 68 weeks of age. Devendra and Burns (1970) have cited examples from West Africa where female kids are mated at first oestrus, i.e. at the time of onset of puberty, and first kidding occurs at 11 to 12 months of age. They, therefore, recommend that the management practices which delay first kidding should be re-assessed by means of critical experiments on the effects of early breeding on lifetime production in the tropics. Dyrmondsson (1973) cited about 39 studies on early breeding of ewe lambs. The general conclusion reached by him is that early breeding has no detrimental effects on subsequent

reproductive performance, and in fact early breeding could result in enhanced subsequent fertility and ultimately lead to a worthwhile increase in the overall productivity of the ewe. In some of the studies he cited, there was an indication that ewes which had been bred as ewe lambs tended to be more reliable breeders, made better mothers and had fewer lambing troubles at the yearling stage. Genetic factors, nutrition, daylength, temperature and the presence of rams seemed to affect sexual development in ewe lambs.

2.3.1.2 In the male goat

Puberty in the male is commonly defined as the time at which reproduction first becomes possible, i.e. when spermatozoa are released, or more precisely, as the stage when the endocrine function of the testes becomes clearly evident (Dýrmundsson, 1973). This worker cites studies in male sheep which show that age at puberty is affected mainly by breed differences and nutrition. Concerning the use of ram lambs for breeding, he states that young rams tend to have a lower breeding capacity than mature rams. But there was no effect on subsequent growth and development if the ram lambs which had fully grown testes were used for early breeding. He concludes that early use of ram lambs would be particularly useful in performance and progeny testing. The generation interval would be reduced and information on their breeding value would be obtained at an earlier age. Skinner (1972) has reported that the Boer male kids start displaying masculine behaviour

at 28 days of age and spermatogenesis commences at 84 days of age. At 140 days of age spermatozoa were present in the epididymis and at 157 days they were observed in the ejaculate. It was observed, therefore, that the male Boer goat could successfully mate at 168 days of age. It would be very useful to know the age at puberty in the male kids of the East African goat and their lifetime performance. This could be done by studying the onset of spermatogenesis by studying the development of the testes after either removing them or just opening them up by surgical means. Some recent studies on reproduction in the male goat in the tropics have been shown in Table 2.5.

2.3.2 Reproductive Performance in Mature Does

2.3.2.1 Oestrus cycle

Hafmeyr et al. (1965) found in South Africa that the female Boer goat shows oestrus throughout the year with peak sexual activity from April to June (the autumn months for the southern hemisphere). This is a cool and dry time of the year in this area. Devendra and Burns (1970) have reviewed the literature on the subject and have reported the tropical breeds of goats which are seasonal breeders and those which breed throughout the year. The East African goat is in the group which breed throughout the year. They have also cited studies which show that there is an association between incidence of oestrus and

Table 2.5. Recent reports on reproduction in male goats in the tropics

Breed	Locality	No. of Animals	Traits studied	Findings	Reference	
Barbari	India	2	Dilution and preservation of semen at 5-7°C	Conception Rate	Low	Tewari <u>et al.</u> (1968)
				Sperm motility		
		Dilution 1:1	16.09±0.82			
			1:3	27.60±2.25		
			1:5	36.40±2.12		
		Dilution 1:10	50.40±2.27			
			(6 hr. storage)			
			Dilution 1:1	6.96±1.20		
		1:3	16.80±1.80			
		1:5	22.40±2.10			
1:10	35.00±2.30					
(30 hr. storage)				Differences between dilution rates *		
				Differences between storage intervals *		
Barbari Jamnapari	India	4	Influence of season on semen quality	<u>Barbari</u>	<u>Jamnapari</u>	Sahni and Roy (1969)
				0.52±0.03-	0.72±0.06-	
		3	Sperm volume	0.76±0.03	1.18±0.01	
				Initial motility	3.20±0.04	
			3.98±0.04	4.03±0.01		

Table 2.5 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	Reference
Barbari Jamnapari (cont'd)			Sperm concentration (x 10 ⁸ /ml)	<u>Barbari</u> 18.10±0.10-	<u>Jamnapari</u> 18.05±1.41-
			Sperm no./ejaculate (x 10 ⁸)	24.10±0.04	33.09±2.64
			% live spermatozoa	11.60±0.09-	13.52±2.23-
				14.40±0.08	25.13±3.16
				65.29±2.23-	55.75±3.87
				71.62±1.41	71.17±2.82
			Season on sperm motility ^a	*	
			Season on sperm concentration ^a	*	
			Season on sperm volume ^b	*	
			Season on sperm number ^b	*	
			Season on % live ^b	*	
Damascus	Egypt	14	Birth to separation of penis from prepuce	243 days	El Wishy and El Sawa: (1971)
			Wt. at this stage	21 kg	
			Vol. of testes at this stage	60.0 ml	
			Birth to 1st ejaculate	509 days	
			Body wt. at this stage	36.6 kg	
			Vol. of testes at this stage	139.4 ml	

Table 2.5 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	Reference
Barbari Jamnapari	India	2	Semen quality	Differences between bucks ***	Mittal and Pandey (1972)
Jamnapari, Barbari and Jamnapari x Saanen	India		Incidence of abnormal spermatozoa	0.5-4.0%	Sahni and Roy (1972)
vs sheep : Corriedale (exotic) & Romney Marsh (exotic)	India		Effect of season on trait	None	
Local Sheep Local x Corriedale			Incidence of abnormal sperm	0-48.8%	
			"	1.6-63.7%	
			"	1.0-2.0%	
			"	1.0-2.0%	
Jamnapari Barbari	India		Effect of deep freezing of semen to -79°C	In exotic sheep highest summer	Sahni and Roy (1972)
			Survival rate after thawing	Better Jamnapari	
				30-40%	

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Table 2.5 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	Reference
Boer Zambian (Z)	Zambia	12 11	Age 1½-4 years Ejaculate volume (B) Ejaculate volume (Z) Sperm motility (B) Sperm motility (Z) Sperm concentrate (B) Sperm concentrate (Z) % live spermatozoa (B) % live spermatozoa (Z)	1.34±0.05 ml 0.67±0.03 ml 53.2±1.2% 52.2±1.3% 2.70±0.03 ml* 1.65±0.02 ml* 87.7±1.0 87.2±1.0	Igboeli (1974)
Boer	South Africa		Freezing of Boer semen to - 0C Motility after thawing at room temperature	38%	Rossouw (1974)
Boer	South Africa	33	Puperty in South African goat breeds <u>Testicular weight</u> At birth At 84 days At 140 days Start of spermatogenesis Spermatozoa in epididymis Spermatozoa in vasa efferentia	1.3 g 9.9 g 35.0 g 84 days 120 days 140 days	Skinner (1975)

Table 2.5 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	Reference
Anglo-Nubian	Brazil	3	Age 3 years Semen vol. greatest Semen vol. smallest Sperm conc. highest Sperm conc. lowest	Autumn 1.68 ml Summer 1.30 ml Summer 1.8x10 ⁶ /mm ³ Autumn 1.3x10 ⁶ /mm ³	Vinha (1975)
			Motility highest Motility lowest Abnormal sperm highest Abnormal sperm lowest	Differences NS Spring 86.87% Summer 67.76% Spring 13.72% Autumn & 9.92% Winter 9.61%	
				Differences *	

a = Seasonal effect significant (P<0.05) in both breeds
 b = Seasonal effect significant (P<0.05) in Jamnapari breed only
 * Effect significant at P<0.05
 *** Difference significant at P<0.001

climatic factors. In Northern India the highest incidence of oestrus in local goats occurred towards the end of the rainy season. In the Dwarf West African goats in Ghana births occurred throughout the year but were most frequent during the dry and cool season, and therefore high incidences of conception must occur after the rains. They suggested, however, that more studies were needed to partition the effects of various environmental influences (climatic and otherwise) on the incidence of oestrus in goats in various parts of the tropics. Breeding seasonality in sheep has been linked with photoperiodism (Hafez, 1968), the animals in the temperate countries came into oestrus in response to declining daylength. It is not known what makes some of the tropical breeds of goats breed seasonally in an environment where daylength varies only by ± 30 minutes, as opposed to the temperate environments where differences between short and long days can be up to 12 hours or more. The observation by Ducker et al. (1973) that, in the absence of adequate changes in daylength, the seasonal nature of oestrous activity eventually returns due to an inherent rhythm in the ewe, can partly explain the reason for the retention of the seasonal breeding rhythm in some breeds of tropical goats. Dutt and Bush (1955), Lees (1964, 1966) and Hunter (1968) have reported on the studies made on sheep in the U.S.A., the United Kingdom, Australia and South Africa, in which it was shown that environmental temperatures can influence the onset of the breeding seasons. Other studies

on Merino ewes in South Africa and Australia cited by Lees (1966) showed that experimental levels of nutrition, particularly during the previous winter and spring, can influence the time of the onset of oestrus activity. It would seem that there will be a need in the tropics to understand all factors affecting reproductive patterns of the indigenous and introduced breeds of goats. This knowledge will enable the producers to plan matings and derive maximum output of kids per given number of dams. Some recent studies on the subject in goats have been shown in Table 2.6.

2.3.2.2 Prolificacy

Since the number of kids produced and reared per dam per year determines the number of animals available for market, it is important to pay attention to the factors affecting prolificacy in the doe. Wilson (1958) reported a twinning incidence of 12.7 per cent in the East African goat found in Eastern Uganda. Sacker and Trail (1966) on the other hand reported a 30 per cent twinning rate in the Mubende goats (a type of the East African goat) kept in Western Uganda. Mason and Maule (1960) and Hutchison (1964) have reported incidences of twinning of similar magnitude in the East African goat type found in Tanzania. Devendra and Burns (1970) have reported the findings on the incidences of multiple births in some tropical and temperate breeds of goats when they were all reared in tropical environments. The results indicate that there are differences in the incidences of multiple births

Table 2.6 . Recent reports on reproduction in female goats in the tropics

Breed	Locality	No. of animals	Traits studied	Findings	References
Tropical (not specified)	India		Physiological and biochemical changes of cervix during oestrus	No change	Datta <u>et al.</u> (1969)
Criollo	Mexico		Flushing before mating	No effect on conception rate No effect on litter size	Carrera and Diego (1971)
Criollo	Guadeloupe		Average litter size	2.33	Cognie <u>et al.</u> (1971)
French Alpine	Guadeloupe		Season on sexual activity	No effect (Criollo) Affected (French Alpine)	
Anglo Nubian	Venezuela	567	Season on sexual activity	Of all heats 82.2% occur in summer Of all conceptions 89.0% occur in summer	Gonzalez and Castillo (1971)
French Alpine					
Saanen					
Toggenburg					
Criollo and their Crosses					
Gujarat	India		Induction of ovulation in immature goats using pregnant donkey serum + HCG	All the treated ovulated	Shukla <u>et al.</u> (1971)

Table 2.6 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	References																									
Malabar	India	85K	Age of dam on frequency of multiple births	<table border="1"> <tr> <td><2</td> <td>2-3</td> <td>3-4</td> <td>4-5</td> <td>>5</td> </tr> <tr> <td>40</td> <td>.18</td> <td>8</td> <td>4</td> <td>15</td> </tr> <tr> <td>32</td> <td>4</td> <td>4</td> <td>0</td> <td>0</td> </tr> <tr> <td>8</td> <td>12</td> <td>3</td> <td>3</td> <td>10</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>5</td> </tr> </table>	<2	2-3	3-4	4-5	>5	40	.18	8	4	15	32	4	4	0	0	8	12	3	3	10	0	0	1	1	5	Mukundan and Rajagopalan (1971)
<2	2-3	3-4	4-5	>5																										
40	.18	8	4	15																										
32	4	4	0	0																										
8	12	3	3	10																										
0	0	1	1	5																										
			Age (years)																											
			No. of kiddings																											
			Singles																											
			Twins																											
			Others																											
			Sex ratio in single births	♂ 50	♀ 50																									
			Sex ratio in twin births	54.2	45.8																									
			Sex ratio in triplet births	40.7	59.3																									
Barbari	India		Incidence of multiple births	Highest at 4th kidding	Prasad <u>et al.</u> (1972)																									
Nubian x Criollo	Venezuela	25	Oestrus synchronization using Fluorogestone Acetate (FGA)	48 hrs. after sponge withdrawal 72 hrs. after sponge withdrawal does exhibited oestrus after mating 60 NR Kidding % Kids/goat	Fuenmayo <u>et al.</u> (1973)																									
				65.2%																										
				100.0%																										
				95.6%																										
				81.8																										
				1.78																										

Table 2.6 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	References	
Criollo Criollo cross- bred	Venezuela	285	Pregnancy diagnosis using	8th-9th week of gestation	Gonzalez (197	
				14th correct diagnoses		66.6%
				14th non-pregnancies		98.2%
				8th-9th week of gestation	40.0%	
				14th " "	92.9%	
				Correct diagnoses for twins	91.6%	
				Correct diagnoses for singles	78.8%	
				Accurate diagnosis from 100 days of gestation		
Tanzanian	Tanzania		Macroscopic and microscopic examination of vaginal contents during oestrus cycle	Time of oestrus could be predicted to nearest day	Sarson (1974) Thesis for M.Agr.Sci. Univ. of Reading (unpublished)	
Jamunapari	India	339	Kidding % (6 years study) Range	79.65	Singh and Singh (1974)	
				57.58-100.0		
				44.81:55.19		
				54.81:45.18		
				Singles:Twins		
				Twinning for does >54 months of age	62.0%	
				Twinning for does <36 months of age	27.37%	

Table 2.6 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	References
Red Sokoto	Niger	850	Time of kidding High incidence of kidding Litter size 1st kidding Litter size 2nd kidding Litter size 3rd kidding Overall Age at 1st kidding (days) Kidding interval (kid Sept.-April) Kidding interval (kid May-June) Kidding interval (kid July-Aug.)	Throughout the year Feb.-April (spring) 1.20 1.72 1.47 1.08 332.4 ± 6.2 343.2 302.3 266.1	Haumesser (1975)

between breeds. The authors have also indicated that the trait tends to increase with age of the dam up to five or six years and it then decreases. Within a breed, the trait is positively correlated with the weight of dam. These workers have also reported three studies which estimated the heritability and seven studies on repeatability of multiple births in tropical breeds of goats. These estimates vary between 0.09 and 0.25 for heritability and between 0.06 and 0.29 for repeatability. Similar low estimates of heritability have been reported in sheep (Bowman, 1966; Doane, 1971; Gjedrem, 1971; MLC, 1972). However, the reliability of the data on estimates of heritability in goats based on a few studies is questionable. Bowman (1966) has pointed out that application of heritability estimates depends on the source of data, method, accuracy and result of calculations. Furthermore, there is need to work out the heritability estimates of the number of kids born at different kiddings as against a single heritability estimate of multiple births (Young et al., 1963). This is because fertility seems to be affected by the age of dam. However, although litter size has a fairly low heritability, relatively large selection differentials are possible (MLC, 1972). Therefore selection for increased litter size should produce a greater response in number of lambs reared per ewe than practicing no selection. Similar response might be obtained if selection for litter size was practiced in goats. Devendra and Burns (1970) have reported that there

is a paucity of data on selection for various traits in meat goats in the tropics and that studies need to be undertaken if the reproductive and other production traits in the goat are to be improved.

Barrenness in does would be another factor which would affect reproductive efficiency. Factors which might cause barrenness in the East African goat do not seem to have been studied to any great extent. In ewes, sexual immaturity, fertilisation failure and embryonic and foetal mortality were some of the factors which caused barrenness (MLC, 1972). Devendra and Burns (1970) have cited a study in Angora goats in South Africa in which cases of widespread abortions were attributed to the regression of the corpus luteum during pregnancy. Hafez (1969) has reported on studies made in Australia which showed that estrogenic substances in some leguminous plants, especially the subterranean clover (Trifolium subterranean) interfere with the hormonal interactions in the animal's body and therefore cause reproductive failure. Although barrenness is important in a meat goat enterprise, it has been shown by the studies made in sheep by Young et al. (1963), Turner (1968) and MLC (1972) that the trait has low heritability. It is recommended, therefore, that selection for multiple births in sheep is more likely to be successful than selection against barrenness.

2.3.2.3 Kidding interval

With a gestation period of only 150 days, it is theoretically possible for the tropical goat breeds which breed throughout the year to kid at least twice per year. In practice this reproductive rate is rarely achieved. Although the Black Bengal in India is able to kid twice per year, other breeds of tropical goats, including the East African goat, commonly kid three times in two years (Devendra and Burns, 1970). These workers have also reported that meat breeds have shorter kidding interval than dairy breeds, presumably due to the influence of lactation in the latter. For breeds not specialising in milk production it is advantageous to breed them as often as possible to obtain a maximum number of kids. The major factor which, according to the workers above, seems to affect kidding interval is service period. Its duration depends on how soon the doe conceives again after kidding which in turn depends on the resumption of the oestrus cycles. The breed, environment, and other factors such as abortion seem to affect this trait.

In cases where artificial insemination is used, the need to know the time of ovulation in the doe is important so that high conception rates can be achieved, and semen and labour used in undertaking inseminations are not wasted. Ovulation in the doe takes place towards the end of oestrus, which lasts between 24 and 36 hours (Devendra and Burns, 1970). It is recommended, therefore, that insemination should take place towards the end of heat, i.e. at least

12 hours after oestrus is first observed. Fougner (1976) obtained good conception rates after inseminating temperate goats 12 hours after the detection of oestrus.

2.3.2.4 Mortality and longevity

It is important that mortality in the flock is kept as low as possible. Devendra and Burns (1970) have reported that birth weight, parity of the doe, season of the year, breeding history of the flock and management affect mortality. They cite studies which show that lighter kids were more susceptible than heavier kids to disease and early death. However, mortality was also high in very heavy kids, especially those from does kidding for the first time. They cite a study by Sacker and Trail (1966) involving an East African goat type in which an overall mortality of 45.3 per cent was observed between birth and weaning among single kids from first kidding dams. A study by Minett (1950) in India in which mortality of the kids was higher during the colder seasons than in other seasons was cited. In Ghana mortality was highest during the wet season and lowest during the dry season. However, in this latter study, the flock was highly inbred and might have been atypical of the herds found in the area (Devendra and Burns, 1970). The same workers have reported studies in which respiratory diseases seemed to cause mortality in kids, while good management seemed to lower it. Recent reports on mortality in goats in the tropics have been shown in Table 2.7. Although mortality is an

Table 2.7. Recent reports on mortality in goats in the tropics

Breed or Type	Locality	No. of Animals	Traits studied	Findings	References
Indigenous types	Sri Lanka	2530	Kid mortality % on two Government farms		Ranatunga (1971)
			<u>Farm A</u>		
			<u>Foetal deaths</u>	4.75	
			Neonatal (up to 1 month from birth)	8.44	
			Perinatal (foetal + neonatal)	23.74	
	<u>Farm B</u>				
	<u>Neonatal</u>		5.61		
	Post natal (birth to weaning)		32.19		
	Overall mortality		28.42		
Criollo x Nubian, Criollo and Nubian	Venezuela	65 66 152	Kid mortality %	17.8	Castillo <u>et al.</u> (1972)
			Birth-weaning	2.2	
			Weaning-6 months 6 months-1 year	8.9	

important trait, it has been pointed out that direct selection against it in a species like sheep might not have much effect (MLC, 1972). This is because heritability for the trait is expected to be below 5 per cent. It is therefore recommended that indirect methods of selection such as selecting rams for extreme cold may prove more useful.

Another important factor in meat production is the productive life span or longevity of the dam. Since it has been shown from the studies reviewed by Devendra and Burns (1970) that reproductive efficiency in goats increases with the age of the dam up to five or six years, it is very worth while to maintain for this length of time in a commercial flock highly productive dams. However, in breeding herds, where rapid turnover of breeding dams can lead to a faster genetic gain, retention of dams for a long time may not be desirable. Some possible causes of mortality in the East African goat will be reported in this thesis.

2.3.2.5 Maternal care of the kids

From birth to the time when rumination starts, the kid is completely dependent on its dam for milk, without which it would not survive. The licking, cleaning and massage carried out by the dam as soon as the kid is born are supposed to be important aspects of maternal care. Spedding (1970) has cited studies which indicate that sight is the main source by which ewes recognise their lambs and that it is supplemented by other sensory cues as

well. A small proportion of ewes which exhibit aberrant maternal behaviour have been observed. This varies from erratic or even deliberate movement of the ewe aimed at preventing suckling to desertion or butting. This behaviour is more common in ewe lambs and ewes being bred as yearlings or soon thereafter. Similar behaviour in the East African goats has not been reported. Loss of kids dying from lack of maternal care is expected where goats are reared in large flocks with a restricted kidding period.

2.4 Mature Size in the East African Goat

The knowledge of the mature size of any particular breed of goat may help the producer to estimate the rate at which the young animals will grow. Brody (1945) showed that live growth was strongly influenced by a potential for the mature weight to be attained. It can be stated in another way, namely, that growth can be expressed as a percentage of a potential mature weight. The Meat and Livestock Commission of the United Kingdom (MLC, 1975) has discussed the usefulness of the knowledge of mature size of different breeds of sheep and how the slaughter weight of a crossbred grown without check can be estimated from the mature size of the parent breeds. It has been pointed out also (MLC, 1972) that in markets where fatty carcasses are undesirable, progeny from parents of large mature size seem to grow to heavier weights before starting to put on fat. In addition to the relationship between size and

each of the factors: rate of growth and meat yield, it has been observed that size is also linked to feed for maintenance (Spedding et al., 1972; Baker et al., 1973; Spedding et al., 1976). These workers have also shown that these three main factors which are related to size interact with each other and with a range of other factors such as breeding frequency, number of offspring, birth weight, longevity and food conversion efficiency.

Devendra and Burns (1970) have classified various tropical breeds of goats according to mature weight and body height at the withers, and have placed the majority of the types of the East African goat, namely the Mubende, Tanzania, Kenya and others, into the dwarf group. According to these workers only the East African goat type found in Kigezi in Western Uganda would qualify for the next group of larger tropical goat breeds, namely, the small breeds. Mason and Maule (1960) disagreed with Epstein (1956) and Wilson (1958) who called the goat found in East Africa a Dwarf East African goat. Mason and Maule argue that, although average liveweight of mature goats found in East Africa was around 25 kg and height at the withers was around 60 cm, some adults could reach 45 kg when fattened and would therefore achieve a size similar to that being achieved by the large breeds of goats. They therefore recommended that the term "dwarf" be restricted to the West African Dwarf and the Nilotic breed types which were less than 50 cm in height at the withers and weighed up to 20 kg only at maturity. They (Mason and Maule, 1960) argued

that these were the types which would qualify for the term short-legged achondroplastic types. For reasons which have been discussed in Section 2.2.1, the East African goats' present small mature size might not be due to genetically determined "pituitary hypoplasia" as Epstein (1956) described it, but to scarcity of feed and water (Devendra and Burns, 1970; McDowell, 1972). If it is the environment which limits the size of the East African goat, then improved management should assist it in growing to larger size. Selection for large size, if there is genetic variation for size, could be effective. However, it would also be interesting to study the response of this goat to pituitary therapy in order to establish whether or not it is achondroplastic. If the doe continues to live in the range areas of East Africa where the growth of forage is limited by the lack of adequate rain, and only the kids will be grown or fattened in areas with higher rainfall, then small mature size might be an advantage. The livestock owners should, therefore, be interested in providing improved management which will lead to improved reproductive performance and longevity. Unfortunately, no studies have been undertaken to improve these two traits in the East African goat.

Fast growing and larger mature size in the progeny can be obtained by crossbreeding with larger breeds. Devendra and Burns (1970) suggested the Boer from Southern Africa, the Jamnapari from India, the Ma T'ou from China, the Kambing Katjang from Malaysia and the Fijian from Fiji

as improver tropical breeds of goats for meat production. They also suggested the Malabar from India; the Barbari from India and Pakistan, the Ma T'ou from China and the Damascus from the Middle East as improvers for prolificacy. Some preliminary reports on crossbreeding studies involving the Boer and the East African goat in Tanzania (Hutchison, 1964, also cited by Devendra and Burns, 1970) indicate that improvement in growth rate can be achieved. However, if at the same time improvement is made on litter size (through crossbreeding) then it must be demonstrated that the doe can produce enough milk for the kids. Artificial rearing or suckling on foster mothers of surplus kids increases the cost of rearing kids and should not be encouraged especially where good management and good stockmanship are lacking.

Ease of kidding is another very important factor which needs to be taken into account when crossbreeding between small and large breeds of goats is being undertaken. Aiding does with kidding difficulties under any system of production, whether it be extensive or intensive system of goat production, would be impracticable, not only due to lack of experienced stockmanship, but also due to the increased cost.

It would be useful to know the relationship between mature weight and various external body measurements, such as heart girth, length of body, height at the withers and width of the hind quarters. A character which is highly correlated with liveweight could be used in estimating the

weights of the mature animals in the villages where weigh scales might be unavailable. Devendra and Burns (1970) have cited one study on the Beetal goat in India in which there was a highly significant correlation between the log (logarithm) body weight and log length (0.63 - 0.85) and between log body weight and log heart girth (0.59 - 0.87) for non-pregnant and pregnant does, including goats of less than one year of age to above five years. Recent reports on mature size in goats in the tropics have been shown in Table 2.8. A measuring stick or tape which had a scale of conversion of body measurements to liveweight would be of great practical value. The relationship between body weight and external body measurements will be reported later in this thesis.

2.5 Birth Weight

It has been shown that there is a positive correlation between birth weight and adult size in tropical breeds of goats (Devendra and Burns, 1970). These workers also showed that there is variation between breeds for this trait. The latter observation is to be expected, since there is a wide variation in mature size between breeds and there is a high correlation between these two traits. Devendra and Burns (1970) showed also that sex tends to affect birth weight, in that male kids are heavier at birth than females. Similarly, type of birth seems to affect birth weight, in that within one sex kids born as singles are heavier than kids of the same sex from multiple births.

Table 2.8. Recent reports on mature size in goats in the tropics

Breed or Type	Locality	No. of Animals	Traits studied	Findings	References
Criollo	Mexico	40 ♀	Mature wt. (kg) Range	39.6 38.4-41.9	Carrera and Sevilla (1971)
Criollo	Guadeloupe		Mature wt. (kg)	25.0	Cognie <u>et al.</u> (197)
Criollo	Venezuela		Mature wt. (kg)	30.0-45.0	Garcia <u>et al.</u> (197)
Dwarf West African	Ghana	♀	Wt. (kg) for animals > 3 yrs. of age Height at withers (cm)	24.81 46.17	Sada and Vohradsky (1973)
Boer	Zambia	12 ♂	Mature wt. (kg)	54.1 ± 2.0	Igboelli (1974)
Zambian		11 ♀	Mature wt. (kg) Height at withers (cm) Boer Zambian	27.1 ± 1.8 67.1 ± 1.64 52.5 ± 0.7	
Malawi	Malawi	6 ♂	Mature wt. (kg) Height at withers (cm)	29.31 ± 2.89 61.61 ± 2.56	Owen (1975)
Botswana	Botswana	3 C 22 ♀	Mature wt. (kg) Mature wt. (kg)	52.73 38.65	Owen <u>et al.</u> (1976)

C = Castrates

Variation in birth weight is due to both genetic and environmental factors. The genetic factors are inherited from both the dam and the sire, while environmental factors would be those such as nutrition, disease and others which affect the mother during gestation.

Birth weight is automatically improved in a cross-breeding programme where the aim is to get fast growing progeny and large mature size. Crossbreeding between the East African goat - a small breed type - and the Boer - a large meat type - in Tanzania resulted in increased birth weight in the progeny (Hutchison, 1964, also cited by Devendra and Burns, 1970). It is stated (MLC, 1972) that although crossbreeding in sheep increases birth weight, if such lambs are going to be used as replacement animals in poor environments, then increasing birth weights may mean reduced adaptability to those environments.

A correlation between birth weight and kid mortality was observed in the Mubende goats - a type of the East African goat - in Uganda (Sacker and Trail, 1966). Mortality was high in kids with small birth weights and in those with above average birth weights. This observation supports the conclusion made in a study in sheep (MLC, 1972), namely that caution should be exercised in planning production systems which are aimed at achieving high birth weights, since larger lambs may cause more lambing problems. Some recent reports on birth weights in goats in the tropics have been shown in Table 2.9.

Table 2.9. Recent reports on birth weight in goats in the tropics

Breed	Locality	No. of Animals	Traits studied	Findings	References
Black Bengal	India	1,375	Birth wt. (kg) Summer Monsoon Winter Overall Heritability	1.12±0.01 1.08±0.02 1.15±0.01 1.13±0.01 0.01	Moulick and Syrestad (1970)
Criollo	Venezuela		Birth wt. (kg)	2.2 - 2.8	Garcia <u>et al.</u> (1972)
Black Bengal	Bangladesh	9 ♂ 100 ♀	Birth wt. (kg)	0.73	Ali <u>et al.</u> (1973)
Saanen Chamois Coloured	Guadeloupe	75	Birth wt. (kg)	3.0 - 3.6	Chenost and Geoffroy (1973)
Dwarf West African	Ghana	20 ♂ 20 ♀	Birth wt. (kg) Range	1.40 0.54±2.48	Sada and Vohradsky (1973)
Boer	South Africa	33 ♂	Birth wt. (kg)	3.7	Skinner (1974)

a = Effect of year on birth weight was significant
Effect of season on birth weight was not significant

b = Interaction year x season was significant

2.6 Growth Rate

2.6.1 Studies on Growth in General

Most of the recent studies on growth in farm animals have been made in relation to the pioneering work done by Brody (1927), Hammond (1932), Palsson (1940) and Verges (1952). These workers have shown that growth has two aspects. Firstly, there is increase in mass (weight) per unit time, and secondly, there is change in form and composition (development) resulting from differential growth of the component parts of the body (Berg and Butterfield, 1976). Interest in growth in meat animals is centred on the growth of three major tissues of the carcass, namely, muscle (lean), fat and bone. The nutritional status seems to have considerable effects on liveweight gain and external measurements (Wilson, 1958a, b, 1960). The kids in these experiments were divided into three groups and were fed different rations. Those on a high plane of nutrition grew faster than those on either medium or low plane. Although female kids on a good plane grew at 0.2 kg and male kids at 0.5 kg per head per week (or about 0.03 and 0.07 kg per head per day, respectively), it is pointed out by Devendra and Burns (1970) that this growth rate is too low for meat animals. Since very few studies have been made on growth in meat animals in the tropics, these workers must have been comparing the growth rate of kids in this study with those of other meat animals found in the temperate countries. If this is the case, it can

be argued that there is little or no justification in comparing growth rate of animals grown in contrasting environments. This statement is supported by the findings of Sacker and Trail (1966) in Uganda, when studying the growth rate of lambs belonging to the Blackhead Persian breed type of sheep which is indigenous to Eastern Africa. The growth rates obtained in this study were very low (Table 2.10) compared with those from lambs under temperate conditions. Recent studies on growth rate in goats in the tropics are shown in Table 2.11.

Crossbreeding between the indigenous East African goat and the large Boer in Tanzania resulted in crossbred kids which had an advantage of approximately 25 to 40 per cent over the indigenous kids in weight for age at 1 - 1½ years (Hutchison, 1964, also quoted by Devendra and Burns, 1970). Devendra (1966) reported on a study in which crossbred kids resulting from the matings between the Anglo-Nubian (a British breed) and Jamnapari (an Indian breed) grew at almost twice the rate of the indigenous Kambing Katjang (a Malaysian breed) kids. The advantage that crossbred kids show in growth rate over indigenous kids indicates the value of improver breeds in meat production. Table 2.12 shows some recent studies on crossbreeding in relation to birth weight and growth in goats in the tropics.

There are very few reports in the literature to show the effects of castration on growth in goats. Brooks and Asdell (quoted by Mackenzie, 1967) have shown that Toggenburg kids (a British dairy goat breed) which were castrated

Table 2.10. Growth Rate (kg per head per day) of Lambs and Kids belonging to Tropical and Temperate Breeds of Sheep and Goats

Breed or breed type of animal	Type of birth	Workers			Country	
		Wilson (1958a,b, 1960)	Sacker and Trail (1966)	Spedding (1970)		
Blackhead	Single lambs	(c)	(a)	(b)	(c)	Uganda
Persian sheep	Twin lambs		0.07	0.04		Uganda
East African goat	Single kids		0.08	0.04		Uganda
	Twin kids		0.06	0.04		Uganda
	or Male kids	0.07	0.05	0.04		Uganda
British breeds of sheep	Female Kids	0.03				Uganda
					0.16-0.26	United Kingdom

(a) = Birth to weaning at 16 weeks

(b) = Weaning to 1 year old

(c) = Growth rate before reaching maturity

Table 2.11. Recent studies on growth of goats in the tropics

Breed or Type	Locality	No. of Animals	Traits studied	Findings	References
Beetal	India	60 ♂ 6 ♀	Growth rate (g/day) Hormone Ia Hormone I & II ^a Control	63 53 37	Narang <u>et al.</u> . (1969)
Criollo	Guadeloupe		Growth rate (g/day)	45	Cognie <u>et al.</u> . (1971)
Black Bengal	Bangladesh	9 ♂ 100 ♀	Growth rate (g/day) Birth-19 wks. (B.-weaning)	62	All <u>et al.</u> . (1973)
Dwarf West African	Ghana	20 ♂ 20 ♀	Growth rate (g/day) Birth-1 yr.	35	Sada and Vohradsky (1973)

a = Hormone I (Chlorotetracycline or Aurolfac 2A) - Growth hormone
 II (Stilboestrol or Clineestrol) - Growth hormone

Table 2.12. Recent reports on crossbreeding in goats in the tropics

Breed	Locality	No. of Animals	Traits studied	Findings						References												
Nubian x Criollo	Venezuela	65	Birth wt. Weaning wt. Wt. at 6 mth. Wt. at 1 yr.	S	3.5	3.1	13.7	12.9	19.9	16.8	33.7	30.0	Castillo and Garcia (1971)									
														T	3.3	3.0	11.7	10.8	17.8	16.3	32.9	30.3
Nubian x Criollo	Venezuela	66	Birth wt. Weaning wt.	Sa	3.6	3.1	13.2	12.4	18.2	16.8	33.2	30.1	Castillo et al. (1972)									
														b	2.6	2.4	8.0	6.6	9.5	7.5	24.6	18.2
														c	3.3	2.9	12.9	11.4	16.3	13.3	31.2	28.7
Nubian		152	Wt. at 6 mth. Wt. at 1 yr.	Ta	3.2	3.0	11.3	10.1	16.8	14.9	22.7	21.0										
														b	2.3	2.0	7.2	6.4	10.3	7.9		
														c	2.9	2.7	12.1	11.5	15.0	14.2		
				Wt. at 3 mth. (kg)																		
Jannapari	d Sri Lanka	Groups of 10	Birth wt.	d	3.5	1.9	12.8	12.1	17.0	13.1			Buvanendran and Jalatge (1974)									
Kottukachchiya	e		Wt. at 3 mth.	e	1.9	2.1	9.9	10.5	13.5	14.4												
Jannapari x Kottukachchiya	f		Wt. at 6 mth.	f	2.1	2.0	10.8	10.0	19.0	16.2												

Table 2.12 (cont'd)

Breed	Locality	No. of Animals	Traits studied	Findings	References
Malabar g	India	40 & 101K	Age at 1st kidding Kidding interval	g Age at 1st kidding h Age at 1st kidding	Raja and Mukundan (197
Jamnabari x Malabar h		52 & 144K	Effect of season on kidding	g Kidding interval h Kidding interval Season affected kidding rate in g only	
Pygmy x Normal Gat	Oregon (USA)		Height over withers Concentration of growth hormone (GH) in serum	F ₂ Intermediate in height F ₁ Single ♀ (mature) had higher GH than normal mature ♀	Simms (1974)

S = Single kids
T = Twin kids
K = Kiddings

at birth grew faster than either the intact male or female kids of the same breed. Devendra and Burns (1970) have cited one study in which castration led to better feed utilisation. More recently, Louca et al. (1977) have reported a study in which entire male kids grew faster and used feed more efficiently up to nine months of age than castrates in the Damascus breed of goat in Cyprus. After this age, however, the intact male kids ceased to grow and this was attributed to strong sexual activity which these kids exhibited from this age onwards. If sexual activity is manifested at this late age of 9 months, there would be need to take advantage of fast growth of intact male kids and slaughter them between 6 and 9 months of age, before the onset of sexual activity. However, since a taint of varying intensity was reported in the meat from intact male kids, there would also be a need to study how discriminating the consumers are against meat with such flavour. If there is no strong dislike for such meat it would be economical to raise intact male kids to take advantage of fast growth and better feed utilisation. In breeds where intact males exhibit sexual activity at an early age, raising them as intact males might cause some problems in management, and one would need to study the whole picture, including growth rate, efficiency of feed utilisation and management, to see which category of kids, entire or castrates, have an overall advantage.

2.6.2 Compensatory Growth

The phenomenon by which growth usually proceeds at enhanced rates during re-alimentation following periods of restricted nutrition or malnutrition is termed compensatory growth (Bohman, 1955). Wilson and Osbourn (1960) have reviewed the early studies made on this subject. One of the studies with East African goat kids (Wilson, 1957a,b, 1958, 1960) involved the comparison in body composition between, on the one hand, restricted versus unrestricted feeding and, on the other, restriction followed by re-alimentation and unrestricted feeding followed by restriction. The body compositions of the kids were compared on equal fatless weight when slaughtered at 7.3 kg (near to point of deceleration of the growth curve) and at 13.6 kg (roughly at the stage of full sexual maturity, but not of full adult size). The unrestricted kids had slightly more muscle in their body than restricted kids, but this difference was not significant at 7.3 kg. At 13.6 kg the only significant difference due to treatment was in the urino-genital organs, where the re-alimentated kids possessed heavier gonads than the unrestricted controls. It was concluded that this was an indication of the marked resilience of the individual body tissues to undernutrition and support for the principle of homeostasis or constancy in the internal environment of living organisms described by Cannon (1929). In agricultural systems, the principle of compensatory growth has been used to restrict animals

to achieve their normal sizes and conformation and then feeding them liberally. However, periods of prolonged or excessive restriction can lead to permanent stunting and therefore to permanent modification of the adult body form and composition. Wilson and Osbourn (1960) have suggested that, in explaining the effects of restriction on recovery, it would be better to divide the former into categories of (a) severe restriction, resulting in a loss of body weight, (b) restriction resulting in maintenance of constant body weight, and (c) mild restriction allowing small but subnormal increases in body weight. The degree of ultimate recovery increased as the restriction category passed from (a) to (b), but the degree of compensatory growth exhibited during the early period of re-alimentation decreased in the same order. They conclude that the imposition of a restraint at or near the point of inflexion of the sigmoid growth curve of an animal was likely to result in the greatest inhibition of growth.

The knowledge of compensatory growth would be useful in planning animal production systems in East Africa where animals go through periods of food shortage during the dry seasons and periods of abundance during the rainy seasons. It would be interesting to find out about the type of animal which was suited to this type of environment. Wilson and Osbourn (1960) have suggested that in such an environment a slow maturing animal rather than a fast maturing one might be more desirable. Lodge (1970),

however, has recommended a small but fast maturing animal for such an environment. He arrived at this conclusion after surveying the studies which had been made on carcass yield and composition in farm animals. He found that at a common age animals of a larger breed produce a heavier and leaner carcass than those of a smaller breed, and that therefore the larger late maturing types of animals are best suited to systems allowing rapid daily gain, while the smaller early maturing types are more suited to the less intensive systems. Wiener (1967) (also cited by Lodge, 1970) observed that, although British breeds of sheep ranged widely in mature size (46 kg for the Welsh ewes to about 96 kg for Lincolns), there was little or no variation in rates of maturity when raised in the same environment. Growth rates were such that all breeds reached their maximum weight at about 2 years of age. This observation is very interesting. Similar studies in tropical meat goats were not found in the literature.

2.6.3 Diseases Affecting Growth Rate

Domestic livestock are expected to convert their feed into building up and maintaining their body tissues and in producing useful products such as milk, wool, eggs etc. An animal production system can therefore be compared with an industrial process in which there is an input of raw material, a central processing system, and an output of a processed or completed product (Payne, 1972). An endogenous condition that results in sub-optimal growth,

production or reproduction or death, has been defined by Ellis (1976) as disease. In the production system defined above, disease would interfere with output. Ellis has further pointed out that, when a physiological function is impaired, productivity may be severely affected although no clinical signs of disease are apparent. Worm infestation reducing growth rates has been given as an example of such a condition. Hutchison (1964) listed the causes of death in goat kids in Tanzania and the list included internal parasites and pneumonia. The kids with a high proportion of the Boer blood were more susceptible to various diseases than the kids from the indigenous East African goat parents. Deaths of kids due to haemorrhagic septicaemia were also reported. McCulloch and Kasimbala (1968) studied the distribution of gastro-intestinal nematodes in goats and sheep in the North-Western part of Tanzania and those with a wide distribution included Haemonchus contortus, Trichostrongylus colubriformis and Oesophagostomum columbianum. McCulloch and Tungaroza (1967) reported that demodicosis was a major skin disease in goats in the area of Tanzania mentioned above. Incidences of psoroptic and sarcoptic mange, streptothricosis, ringworm, eczema and damage by ecto-parasites were reported to be low. Lowe (1943) working in Tanzania observed that goats did not suffer as much as other domestic livestock from trypanosomiasis, and that this was the reason for goats' presence where this disease occurred. Data assembled by the British Veterinary Association on

animal diseases in the tropics tend to confirm this fact, in which goats are more tolerant to trypanosomes than cattle. Species of tape worms (Moniezia spp.), liver flukes (Fasciola spp.) and coccidiosis have also been known to affect goats (FAO, 1967). Goat pox (synonym: Variola caprina), contagious agalactia (caused by Mycoplasma agalactiae), contagious caprine pleuropneumonia (CCPP), Nairobi Sheep Disease transmitted by the brown tick Rhipicephalus appendiculatus, and Heart-water, a non-contagious tick-borne rickettsial infection, affect goats in East Africa (Brit. Vet. Assoc., 1968). It has, however, been pointed out that little attention has so far been paid to the health of indigenous sheep and goats in East Africa (FAO, 1967). The economic importance of diseases in meat goat production systems in Tanzania and elsewhere in the tropics has not been assessed. This information would be very useful in planning management systems which aim at getting the maximum growth rates and in reducing mortality in goat kids.

2.6.4 Mineral Requirements

French (1957) (also quoted by Devendra and Burns, 1970) showed that most tropical forages were low in mineral contents, particularly calcium and phosphorus, and that therefore animals depending on grazing alone for their mineral nutritional requirements were likely to suffer from various mineral deficiencies. Chamberlain (1959), and Chamberlain and Searle (1963) have also reported a wide

occurrence of shortages of cobalt and copper in the Rift Valley areas of Kenya and Tanzania. The deficiency of cobalt in cattle and sheep is recognised by loss of appetite, emaciation, anaemia and often death; and the disease is known as "Nakuruitis" after the name of a farming district in Kenya. Walker (1954) has reported deficiencies of cobalt and copper in pastures found in some parts of Iringa Region in Tanzania. Naik (1965) reported the deficiency of cobalt in pastures in the Mbulu area of Northern Tanzania. Kategile (1976) reported the deficiency of iodine in goats in the Kilosa area of Morogoro Region in Tanzania. Specific studies aimed at studying the mineral requirements of goats in the tropics do not seem to have been undertaken. The improvement of meat goats through breeding can be larger if the nutritional and management factors limiting reproductive and growth performances are corrected. Although Devendra and Burns (1970) have suggested that the wide browsing habits of the goat might enable it to avoid mineral deficiencies, the mineral content in the browse does not seem to have been widely studied. FAO (1967) reported that not much was known concerning the availability of minerals in pastures in East Africa. FAO (1967) therefore suggested that more studies be undertaken in this field. Since browse forms part of the diet of the goat in range areas of East Africa, knowledge of their mineral contents would be valuable in assessing the contribution to the goats' diet by this feed source.

2.7 Carcass Yield and Quality

The knowledge of yield and quality of the goat carcass is important, not only in comparing various goat production systems with other agricultural enterprises, but also in marketing a product which has consistent and definable quality. Devendra and Burns (1970) have reviewed the studies undertaken on the dressing percentage (the ratio of warm or cold carcass weight to liveweight at slaughter x 100) in goats. They conclude from these studies that the range is between 43 and 53 per cent and that therefore goats compared very favourably in this trait with other species of domestic livestock, namely, beef cattle, where the range for this trait is between 50 and 60 per cent (Preston and Willis, 1970), and in sheep, where the range is between 45 and 50 per cent (Spedding, 1970; Owen, 1976). Berg and Butterfield (1976) have pointed out that it is important that standardised procedures and definitions on dressing percentage be made in order to have meaningful comparisons between carcasses from different animals. They point out that this trait could be influenced by access to feed and water prior to weighing, transport prior to weighing, use of hot or cold carcass weight and dressing procedure. The latter would vary depending on whether or not the kidney and pelvic fat were kept or removed from the dressed carcass. Boer et al. (1974) have discussed how the Cattle Commission of the European Association for Animal Production set up a working party to try and standardise the methods for the assessment

of carcass characteristics in the member countries. Whether this objective will be achieved is not known. However, from the questionnaires which were sent by the working party to member countries, information on beef cutting and dissection techniques has been summarised by Pomeroy and Williams (1975) and later reported by the same workers (Williams and Pomeroy, 1976). These workers have stated that the objective of publishing the summary in the form of a document is to make available to interested workers sufficient detail of the various techniques so that the methods adopted in different countries can readily be compared. An attempt has not been made to collect and publish similar information on other meat livestock (Elder, 1977).

2.7.1 Carcass Composition

To determine the economic value of the carcass, it is important to know the proportions of saleable to unsaleable and edible to inedible parts of the carcass. The knowledge of lean, bone and fat in the goat carcass would also be important when comparing the biological efficiency of protein production with other species of livestock (Homb and Joshi, 1972).

2.7.1.1 Assessment by tissue separation

Cuthbertson et al. (1972) have reported on the technique of tissue separation in beef and lamb. Berg and Butterfield (1972) suggested the use of the term total fat for total dissectible fat and non-dissectible fat as

intramuscular fat. Cuthbertson et al. (1972) described how, after subjective scoring of lamb carcasses for characteristics such as fat content and conformation, the carcass was divided into two halves by splitting it down the vertebral column from top to bottom. The left side was cut into standardised commercial joints after the kidney and the perinephric and retro-peritoneal fat, sometimes known as kidney knob and channel fat, respectively, had been removed. The lean meat, various separable fat depots and bone trimmings within each of the joints were weighed separately. When the weights of these tissues were added together, the composition of the whole carcass was obtained. These workers pointed out the possible sources of error in this technique. These included inaccuracies in splitting the carcasses into sides and inherent differences between the sides. However, after removing the kidney knob and channel fat depots, evidence of bilateral asymmetry had not been reported. Also differences between technicians, although few differences existed if these were experienced in dissection work. Finally loss of moisture from the carcass between the time the animal was killed and the time tissue separation was completed. They point out that some errors can be avoided if tissue separation is undertaken in surroundings where humidity and temperatures are controlled. However they doubt if the extra accuracy achieved justifies the expense involved in putting up such facilities.

In studying carcass composition and factors which may affect it, animals are slaughtered at either equal weight

or equal age (Carroll, 1976). Wilson (1958a,b, 1960) stated that slaughter at equal weight would be preferred when one wished to determine the stage of killing, since the rates of growth of the carcass constituents changed during the growing period. Animals killed at equal ages but different weights would naturally differ in composition according to the respective stage of growth which had been reached at the arbitrary age. He (Wilson, 1958,a,b, 1960) points out, however, that quantitative growth analysis on the basis of equal fatless empty body weights is artificial and the results obtained by this method have no direct application for the agriculturalist. He points out that the farmer is concerned with the entire animal, and not with that part of the carcass which remains after all the dissectible fat has been removed. In order to contribute to the knowledge on carcass composition, he nevertheless proceeded to compare the East African goat kids on the basis of equal fatless empty body weight, after they had been slaughtered at birth, and at the weights of 4.1, 7.3, 11.3, 13.6 kg, and at maturity. Table 2.13 shows the results from this study and some data from Malaysia reported by Devendra and Burns (1970). The proportions of meat and edible offals were at their highest at birth or soon thereafter and then decreased. The edible fat, however, increased until the stage of 11.3 kg liveweight. The higher percentages of edible and saleable portions of the animal in the study from Malaysia are because the head and some bone fractions were included in the portions

Table 2.13. Carcass Composition, Saleable and Edible Portions of the Carcass

Stage at Slaughter	Proportion of tissues as % of total live weight					
	Meat (a)	Edible offals (b)	Edible fat (c)	Skin (d)	Total saleable a+b+c+d	Total edible
Birth	24.5	6.4	2.6	12.4	45.9	-
4.1 kg	37.5	- ^e	- ^f	- ^e	61.8	-
7.3 kg	- ^e	- ^e	- ^f	- ^e	60.8	-
11.3 kg	- ^e	- ^e	12.5	- ^e	57.5	-
13.6 kg	34.9	4.8	- ^e	7.2	-	-
15.0 kg	-	-	8.6	7.5	-	-
Maturity	-	-	-	-	55.5	48.3
					81.5 ^g	61.2 ^g

e = decreasing values

f = increasing values

g = based on data from Malaysia (Devendra and Burns, 1970)

Rest of data based on study in Uganda (Wilson, 1960)

falling under these categories (Devendra and Burns, 1970). These results in which kids slaughtered at small weights had a higher proportion of lean meat than those slaughtered at larger weights would tend to support the view that maximum economic efficiency does not coincide with maximum biological efficiency (Bowman, 1972). This is because farmers very rarely slaughter kids at young ages and low weights. In sheep, farmers have to ascertain that the weight and condition reached would make the carcass acceptable to consumers, and they wish to take lambs to the heaviest weight possible if cheap feed is available and if the lambs will not put on too much fat (Newton et al., 1974).

2.7.1.2 Assessment by chemical analysis of carcass tissues

Apart from physical separation of either the whole or parts of the carcass into their component parts to study composition, other methods have been used. One of them involves the chemical analysis of part or the whole of the carcass (Read et al., 1968; Robelin, 1976). It involves the grinding of part or the whole of the carcass to produce a uniform sample for analysis into fat, protein and mineral matter. The results from the analyses are then interpolated to provide information on the proportions of muscle, fat and bone in the whole carcass. This method is useful when attempting to obtain an inventory of food nutrients in the body. Berg and Butterfield (1976) and Owen (1976) have stated that the main disadvantages of this

method include high costs of labour and carcasses for experiments, especially for large livestock such as cattle, difficulties in getting representative samples, inability to apply the knowledge obtained from such analyses to particular parts of the carcasses, and the time it takes to carry out. Berg and Butterfield (1976) have cited studies in cattle which show that the fraction of each major chemical component (water, protein and fat) which is found in the muscle, varies with age, weight of the animal, and also with other factors. Thus this method has some shortcomings when attempting to relate the findings from it to edible tissues of the carcass.

2.7.1.3 Assessment by the specific gravity method

This method is based on the Archimedean principle that a body immersed in water displaces a volume equal to its own. Thus by weighing in air and weighing in water carcass density can be determined. Berg and Butterfield (1976) have pointed out that it is normal to consider carcass as comprising fat and fat-free components. They state further that, since the fat has a density of 0.90 and muscle has about 1.10, a change of 0.002 in density would be about equal to a 1 per cent change in carcass fatness. The main advantages of this method are that it is simple and easy to determine, and there is no loss in value of the carcass (Berg and Butterfield, 1976; Owen, 1976). Berg and Butterfield (1976) have pointed out that although this method has high standard errors of estimate

to be very precise in predicting the composition of individual carcasses, it can be useful in experiments where replications are possible. Thus differences between groups of animals in body composition can be worked out. They point out, however, that it is not known whether specific gravity estimates are independent of sex and breed type. If they were, the method could have quite general application to any kind of carcass.

2.7.2 The Role of Indirect Methods of Predicting Carcass Composition

2.7.2.1 Measurements taken on the carcass

The backfat thickness over the longissimus dorsi (rib-eye or eye muscle) has proven to be a useful predictor of total percentage of fat and indirectly of muscle in sheep carcasses (Bowman, 1966; Timon, 1968; Cuthbertson et al., 1972; Owen, 1976) and cattle carcasses (Berg and Butterfield, 1976). Berg and Butterfield (1976) point out that, since breed differences exist in the ratio of intermuscular to subcutaneous fat, one can suspect that the above method of measuring carcass composition would not be independent of breed effects.

The area of the rib-eye has been used in estimating muscling in cattle (Berg and Butterfield, 1976) and sheep (Bowman, 1966; Timon, 1968; Cuthbertson et al., 1972; Owen, 1976). Berg and Butterfield (1976) have stated that, although it accounts for only a small amount of variation in total or per cent muscle, it continues to be

used due to its simplicity and the lack of better, simpler and direct methods of predicting muscling.

Kidney fat weight or per cent and various linear measurements, such as length, width, depth or combinations of these, have been used in estimating carcass composition. It has, unfortunately, been shown (Berg and Butterfield, 1976) that they have no value in predicting total carcass composition.

Subjective estimates of carcass composition have formed the basis for carcass grading in several countries. Berg and Butterfield (1976) point out that these estimates are difficult to quantify and they have not stood up to objective assessment. Conformation has been the main basis for subjective assessment. It has been proved to be more influenced by fat than by muscle (Bowman, 1966; Berg and Butterfield, 1976). Berg and Butterfield (1976) have suggested that it would be useful if studies on the subject were aimed at estimating fatness subjectively, followed by subjective estimates of muscling within fat classes.

2.7.2.2 Measurements taken on the live animal

Indirect techniques for predicting carcass composition in the live animal would be very useful to breeders in breeding superior strains of livestock and to the market by pinpointing the most desirable slaughter animals for particular situations (Berg and Butterfield, 1976; Kallweit, 1976; Owen, 1976). Effective live appraisal techniques must account for differences in dressing per cent

and differences in composition of the resulting carcass. Berg and Butterfield (1976) have stated that, whereas dressing percentage is involved only with the weight of the carcass, composition influences its ultimate value. They state further that the objective in live animal appraisal should thus be to estimate both weight and composition of the carcass and weight of muscle in the carcass.

2.7.2.2.1 Types of live animal measurements

Numerous measurements (Berg and Butterfield, 1976; Owen, 1976), including length, width, height etc., have been made on live animals and have been correlated with measures of carcass merit. Berg and Butterfield (1976) have reported on a study which showed that body measurements added only 2 to 4 per cent of the variation to slaughter weight in accounting for the differences in edible product. They conclude, after citing other studies, that these measurements have little value in predicting carcass composition. Bowman (1966), Timon (1968) and Owen (1976) arrived at similar conclusions when examining studies made on the value of live measurements in predicting carcass composition in sheep.

2.7.2.2.2 Ultrasonic probes

These work on the principle that the speed of transmission of sound waves above the frequency audible to the human ear is sensitive to density of material and changes in density reflect the waves back to the instrument. Thus

interphases between tissues etc. can be recorded and mapped and an assessment of depth or cross-sectional area of material obtained. This technique is used in measuring backfat as a measure of fatness and on the depth or cross-sectional area of the longissimus dorsi muscle (rib-eye or eye muscle) as a measure of muscling in cattle (Berg and Butterfield, 1976; Cuthbertson, 1976) and sheep (Bowman, 1966; Timon, 1968; Owen, 1976). These workers cite studies in which ultrasonic fat measurements or longissimus dorsi area correlate well with measurements made directly on the carcass. Berg and Butterfield (1976) have concluded that, because the technique is non-destructive and non-harmful to the animal or product and it can be used on the live animal at any age or stage of development, more research should be done to develop more precision and accuracy in ultrasonic predictions of carcass composition. Similar observations have been made by Bowman (1966), Timon (1968) and MLC (1972).

2.7.2.2.3 Potassium 40 counting

Whole-body counting of the naturally occurring radioactive isotope of potassium (^{40}K) has been studied as a possible method of predicting the amount of muscle in the live animal (Lohman et al., 1968; Berg and Butterfield, 1976). ^{40}K has a long half life (3×10^9) and it occurs at a relatively constant proportion of total potassium. It is found in the body predominantly within the cells. Berg and Butterfield (1976) have cited studies in cattle in which whole body counting has correlated fairly well

with total muscle mass. They, however, observe that it is an expensive equipment to build and operate and it lacks portability and that cheaper and more accurate equipment would be more useful.

2.7.2.2.4 Dilution techniques

These methods of estimating body composition are based on the assumption of reasonable constancy of the fat-free body. A non-toxic substance, which can be distributed quickly and uniformly in the body, remain stable for a long time to permit sampling, and whose excretion from the body is slow, can be used in estimating body water. A sample of fluid, usually blood, is drawn and analysed for the chemical from which a total fluid volume can be estimated as :

$$\text{volume (ml)} = \frac{\text{g added}}{\text{g (ml in solution)}}$$

Radioactive substance can also be used and the volume measured as :

$$\text{volume (ml)} = \frac{\text{counts/minute added}}{\text{counts/minute/ml}}$$

Antipyrone and several of its derivatives, including radioactive (I-131) antipyrone or the combination of this substance with creatine, have been used in predicting body composition. Berg and Butterfield (1976) cite studies in which the use of dilution techniques to estimate body composition have yielded reliable estimates. They conclude that, although the use of radioactive diluents for commercial use may not be acceptable, dilution techniques

in conjunction with other live evaluation techniques could provide useful estimates of body composition.

2.7.3 Combined Methods of Predicting Carcass Composition

Multiple regression techniques allow the possible use of several predictions in one equation. Timon (1968) developed some equations for predicting carcass composition in sheep. The equations combine caul fat weight, gigot width, cannon bone weight, carcass weight, back flesh depth (probe), weight of four feet and eye muscle area as follows :

$$Y_1 = 46.88 + 3.63X_1 - 1.21X_2 - 0.33X_3 + 0.66X_4 - 0.61X_9 \pm 2.01 \quad (R^2 = 0.86)$$

$$Y_2 = 65.60 - 2.29X_1 + 0.36X_3 - 0.56X_4 - 5.59X_7 + 0.83X_8 \pm 2.04 \quad (R^2 = 0.78)$$

$$Y_3 = 4.46 - 1.22X_1 + 0.56X_2 - 2.28X_5 + 3.45X_7 + 0.26X_9 \pm 1.01 \quad (R^2 = 0.78)$$

where Y_1 , Y_2 and Y_3 denote carcass fat, muscle and bone respectively; and X_1 = caul fat weight, X_2 = gigot width, X_3 = cannon bone weight, X_4 = carcass weight, X_5 = back flesh depth (probe), X_7 = weight of four feet and X_8 and X_9 denote eye muscle areas at the 6th-7th rib and 12th-13th rib interfaces, respectively. Berg and Butterfield (1976) have cited the USDA yield-grade formula, where the edible portion of the primal cuts in cattle carcasses is estimated from a linear combination of backfat thickness, rib-eye area, carcass weight and kidney fat percentage. They point out that it would be desirable if prediction equations could be used for all breed types and perhaps for all sexes over a wide age and weight range. They add, however, that carcass

weight does not satisfy this requirement. Late maturing breeds will have lower levels of fat at equal carcass weights than early maturing breeds. Similarly, heifers are generally fatter than steers and bulls at the same carcass weights. They add that predictions might be useful for each breed and sex only. It has been pointed out by Berg and Butterfield (1976) that carcass evaluation as a routine process for grading or classification scheme must be economical, rapid and not too disruptive of routine procedures. Specific gravity, average backfat thickness and individual muscle weights are some of the most promising predictors of carcass composition. These workers state that rib-eye area contributes in a small but positive way to overall precision if weight of selected muscles is not obtained. Table 2.14 shows some of the recent reports on carcass characteristics in goats in the tropics.

Table 2.14. Recent reports on carcass characteristics in goats in the tropics

Breed or Type	Locality	No. of Animals	Age or	Dressing %	Reference
Baladi	Egypt	50 (♂ ^c)	8-18 mth. 8-18 mth.	48.7 65.2	Lofti and Youssef (1968)
Feral	New Zealand	18 ♂ ^c 18 ♀	Birth-3 yrs.	44.6 42.2	Kirton (1970)
Jamnapari	India	5 ♂ ^c 2 ♀	9½-18½ mth.	46.9	Johri and Talapatra (1971)
Boer	South Africa	70	31.8 kg. " " 45.4 kg.	54.6a 51.8b 49.4d 56.5a 56.3b 52.4d	Skinner (1972)
Malawi	Malawi	1 ♂ ^c 1 ♂ ^c 1 ♀ ^c 1 ♂ ^c 1 ♀ ^c 1 ♀	Mature Immature Mature Mature Immature Mature	44.5e 41.8e 45.6e 53.0f 50.0f 54.7f	Owen (1974)

Table 2.14 (cont'd)

Breed or Type	Locality	No. of Animals	Age or Weight	Dressing %	Reference
Malawi	Malawi	7 ♂ 8 ♂	4-8 mth. 9-14 mth.	52.11 ± 3.00 ^f 56.70 ± 2.14 ^f	Owen (1975)
		6 ♂	15-24 mth.	57.21 ± 1.06 ^f	
Sudan	Sudan	36 ♂	10 kg. EBW 20 kg. EBW 30 kg. EBW	48.1 52.0 54.5	Gailli (1976)
Sudan Desert	Sudan	11 ♂ 6 C	6-15 mth.	48.2 51.2	Wilson (1976)

♂ = Entire male
 ♀ = Female
 C = Castrate
 a = Fed ratio containing 60% concentrate
 b = Fed ratio containing 60% roughage
 d = Fed ratio containing all roughage
 e = Dressing % (gut full)
 f = Dressing % (gut empty)
 EBW = Empty body weight
 mth = Month

CHAPTER 3

MATERIAL AND METHODS

3.1 Introduction

The objectives of this study were :

- a. To study the reproductive patterns of the indigenous Tanzania goats and use this knowledge in proposing suitable mating times.
- b. To use crossbreeding as a tool in increasing growth rate and therefore shorten the time to market animals.
- c. To cross the Tanzania goat with larger exotic breed types of tropical meat goats to raise the mature size and therefore increase slaughter weight.
- d. To develop true-breeding types of meat-producing goats suited to Tanzania conditions which will breed regularly, produce a high proportion of twins, have adequate milk to rear the twins, and be able to possess good carcass characteristics.
- e. To derive estimates of heritability of commercial characteristics of meat goats under Tanzania conditions.

3.2 Sources of Breeding Animals

The data used in this thesis came from a flock of Tanzania, Boer and Kamorai goats kept between 1972 and 1977 at the University Farm belonging to the Faculty of

Agriculture, Forestry and Veterinary Science of the University of Dar-es-Salaam. The Faculty is located at the foot of the Uluguru Mountains at an elevation of 400 m above sea level about latitude 7°S and longitude 38°E. It is 5 kilometres from Morogoro town and about 200 kilometres west of Dar-es-Salaam, the capital city of Tanzania. All the foundation females and some males belonged to the indigenous Tanzania goat - a type of the East African goat - and they were purchased from around Morogoro and Dodoma Regions of Tanzania. In the Morogoro Region the precipitation is about 900 mm per annum, while the Dodoma Region, which is in the centre of the country and at an elevation of about 1,200 m above sea level, gets about 750 mm of rain. Both Regions have definite rainy and hot, and dry and cool seasons, but there is considerable variation in rainfall from year to year. Daylength in both places is about 12 hours and it varies only by ±30 minutes during the various seasons of the year. The maximum temperatures vary between 27.7 and 34.0°C during the rainy and hot season, and between 26.3 and 33.6°C per day during the dry and cool season. The minimum temperatures can be as low as 13.9°C and 18.1°C during the dry and cool season and the rainy and hot season, respectively. The sunshine hours can be as few as 4.6 per day during the rainy and hot season, and as many as 9.9 per day during the dry and cool season. The data on environmental factors found in Morogoro during the period of this study have been

presented in Tables A3.1.1 to A3.1.6 and Figures A3.1 to A3.4. Morogoro is different from Dodoma, however, in that the former is only about 200 kilometres from the Indian Ocean and therefore tends to be more humid than the latter, which is about 350 kilometres away from the ocean. Both regions, however, are known to be quite suitable for ruminant livestock farming (Ayre-Smith, Skerman and Beale, 1968) and apart from the under nutrition which goats and other ruminant livestock might suffer during the dry season due to lack of conservation of feed for them, no obvious nutritional deficiencies have been observed. Some indications of iodine deficiency in goat kids in Morogoro Region have, however, been observed in some flocks (Kategile, 1976).

The Boer and Kamorai male goats came from Malya and West Kilimanjaro Government Livestock Breeding Stations, located in the North-Western and Northern parts of Tanzania, respectively. West Kilimanjaro has an elevation and climate similar to that of most of the Dodoma Region described above. Although Malya has about the same elevation as Dodoma, it differs in having slightly more rain of about 889 mm per annum than the two places described above. It is again similar to these other places in day-length, minimum and maximum temperatures, and in having definite dry and cool, and rainy and hot seasons. Malya, which is only about 100 kilometres south of Lake Victoria, the second largest lake in the world, tends to be more

humid than West Kilimanjaro, which is about 400 kilometres from the nearest large body of water, which in this case is the Indian Ocean.

3.3 The Morogoro Environment

Various measurements were collected on environmental factors occurring at the University Farm on which the breeding goats and their progeny were raised. These included the daily maximum and minimum temperatures, total rainfall, total sunshine hours and maximum and minimum relative humidities. These data have been presented in Tables A3.1.1 to A3.1.6 and in Figures A3.1 to A3.7. According to climatic factors, the Morogoro Region falls into the part of Tanzania where four seasons occur. The season of short rains which is normally hot and humid starts at the beginning of November and lasts till the end of January. It is followed by a hot and dry period which normally occurs during the month of February. The rainy season starts at the beginning of March and lasts till the end of May. Rainfall during this period is more certain than during that of short rains. The dry season which starts at the beginning of June and lasts till the end of October is normally divided into two sub-seasons,

namely, the cool and dry period which covers the months of June, July and August, and the hot and dry which covers the months of September and October. It was not possible in the given time to discover what species of grasses, legumes and browse goats ate most frequently. The description of the vegetation found in various geographical regions of East Africa, including the coastal belt in which Morogoro Region is found, have been described by Milne (1940), van Rensburg (1960), Napier (1965) and Lind and Morrison (1974). More recently, Wingfield (1975) has made a study of the indigenous and introduced species of flora found at the University Farm at Morogoro and the list of the major species of grasses, legumes and browse includes the following :

- a. Grasses: Giant panicum or Guinea Grass (Panicum maximum), Bracharia spp., African foxtail (Cenchrus citiaris), Chloris gayana, Guatamala grass (Tripsacum laxum), elephant grass (Pennisetum purpureum), Hyparrhenia spp., Arundinacea spp., Sporobolis spp., Digitaria spp., Eragostis spp., and Aristida spp.

- b. Legumes: Glycine javanica, Centrosema pubescens,
Stylosanthes spp. and Phaseolus spp.

The main species of trees and shrubs on whose branches and saplings the goats browsed included :

Lantana camara, Leucaena glauca, Acacia albida,
Acacia robusta, Brachystegia spp., Cassia
abbreviata, C. burtii, Tamarindus indica, Crotolaria
laburnifolia, and Hibiscus spp.

In addition, the animals had access to various crop residues such as sorghum heads and stover, maize stover, sweet potato hulms, cowpea hulms and cassava leaves. It was intended that the management of the experimental animals would be as similar as possible to those obtaining in the ranches. However, in order to ensure that nutrition would not be limiting to growth of the animals in any way, a concentrate ration (Ration A in Table 3.2), comprising maize bran (80 per cent), cottonseed cake (18 per cent) and mineral supplements (2 per cent), in the form of mineral licks and bone meal, were provided during the period 1972-75 in addition to hay, and fresh elephant and guatamala grasses. The concentrate ration was changed (Ration B in Table 3.2) during 1976 to include ground maize cob (50 per cent), maize bran (28 per cent), cottonseed cake (20 per cent), and bone meal and mineral supplement (2 per cent). The chemical composition of the basic ingredients in the concentrate rations has been presented in Table 3.1.

Table 3.1. Chemical Composition of the Basic Ingredients used in Goat Ration

Ingredient	CF %	CP %	EE %	Ca %	P %
Maize bran	10.0	10.0	9.5	0.02	0.58
Cottonseed cake	23.0	32.0	5.0	0.17	0.64
Bone meal	-	18.0	-	30.00	13.90
Maize cob	34.3	3.0	1.0	-	-

Table 3.2. Nutritive Values of the Rations

Ingredient	Proportion in the ration %	CP %	EE %	TDN %	ME Mcal/kg
<u>Ration A</u>					
Maize bran	80	10.0	9.5	84	2.400
Cottonseed cake	18	32.0	5.0	63	0.414
Bone meal	2	18.0	-	-	-
In composite ration Digestibility 75%		14.12	8.5	78	2.814 ≡ 12.0 MJ/kg
<u>Ration B</u>					
Maize cob	50	3.0	1.0	46	1.700
Maize bran	30	10.0	9.5	84	3.000
Cottonseed cake	18	32.0	5.0	63	2.300
Bone meal	2	18.0	-	-	-
In composite ration Digestibility 60%		10.56	4.25	66	2.164 ≡ 12.0 MJ/kg

The grazing management was such that sheep and goats were not confined to paddocks like cattle. The former were herded from one part of the farm to the other. Because of this management practice, it was not possible to work out an accurate estimate of the mean stocking rate. However, the land allocated for grazing to the three classes of livestock comprised about 280 hectares. The adult stock carried on this land were nearly 200 goats, 200 cattle and 100 sheep. If one grazing stock unit is considered to be equal to one mature cow, five goats or five sheep, the land carried about 260 stock units or one beast to 1.08 hectares per year. Under herding system just as in paddocking, visual observation to estimate the amount of herbage available to the animals is one of the methods employed in deciding whether or not the animals needed moving to a fresh area. During the rainy season, a period of about three weeks was considered to be sufficiently long to keep grazing animals out of an area or paddock in order to allow grass to grow. During the dry season when grass growth does not take place, however, the decision to move animals from one paddock to another or from one unfenced area to the other is undertaken to protect the grass from being overgrazed to the point where it will not grow again when the rains come back. The other important consideration is that overgrazing is normally avoided because it leaves the soil bare and therefore makes it liable to soil erosion during the rains.

Routine disease control measures were based on the recommendations made by the Tanzania Veterinary Service. Dosing against internal parasites was done once per month by alternating the use of drugs for the control of nematodes, trematodes, and cestodes. External parasites were controlled by spraying the animals with acaricides once per week. Anthrax and Blackquarter were controlled by using a combined vaccine which was administered once per year. Goats were also vaccinated against various strains of Foot and Mouth Disease twice per year. Foot-rot, which became a problem during the rainy season, was controlled by walking the goats, every morning when being taken for grazing and every evening when returning from grazing, through a foot-bath containing a solution of formaldehyde.

3.4 Description of the Genotype

3.4.1 The Tanzania Goat

Mason and Maule (1960) have described the Tanzania goat as a small, very hardy animal. It has usually a fine, short and smooth coat which may be of any colour, including black, brown, white bi-coloured or multi-coloured. The males often have a pronounced mane of long coarse hair running the full length of the back, and a lesser ridge of long hair is sometimes seen on the females, but less frequently than in males. Some long-haired individuals, more usually bucks, are seen in which the hairs, which may be 9-10 cm long, are carried on the

back, flanks and shoulders. Horns on both sexes vary and may be very short (2.5-5.0 cm only), medium (about 15 cm) or long (about 25 cm). Tassels are seen in perhaps 30-40 per cent of the animals but this proportion may vary widely between local populations. Adult live-weight is about 25-30 kg. Mason and Maule (1960) state further that there is a good deal of variation in body size and some adults can reach 45 kg or more. The height at the withers in adult animals is about 60 cm. They are known to breed throughout the year and twinning occurs in about 10-15 per cent of the births (Plates 3.1 & 3.2)

3.4.2 The Boer Goat

The Boer goat or Africander goat has been described by Mason and Maule (1960) as a breed which was evolved by the Dutch settlers at the Cape in South Africa from local Bantu goats, and possibly with additional European and Indian blood. Ueckermann et al. (1974), however, have postulated that the Dutch settlers acquired these from the Hottentot stock and later during the early nineteen-twenties started, with the support of animal scientists of the South African Government's Department of Agriculture, to improve through selective breeding the meat conformation of their local stock. Whatever its historical background, the animal is described as being compact, well-proportioned and short-haired. It has a straight facial profile, medium-size lop ears and short backward horns. The ears vary enormously in size and may be vestigial ("mouse-eared"). The colour of the coat

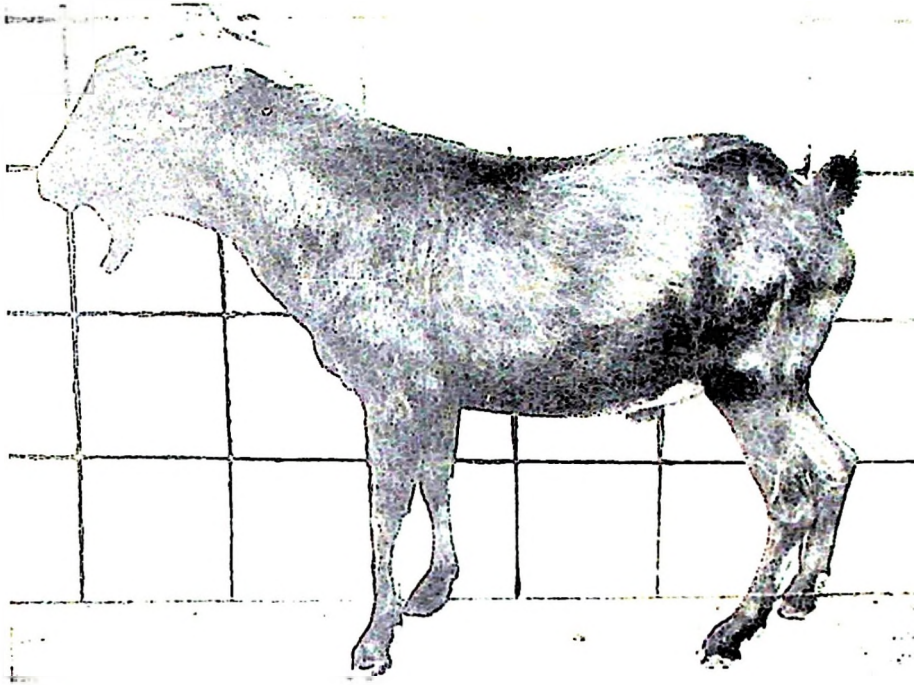


Plate 3.1. Tanzania male goat

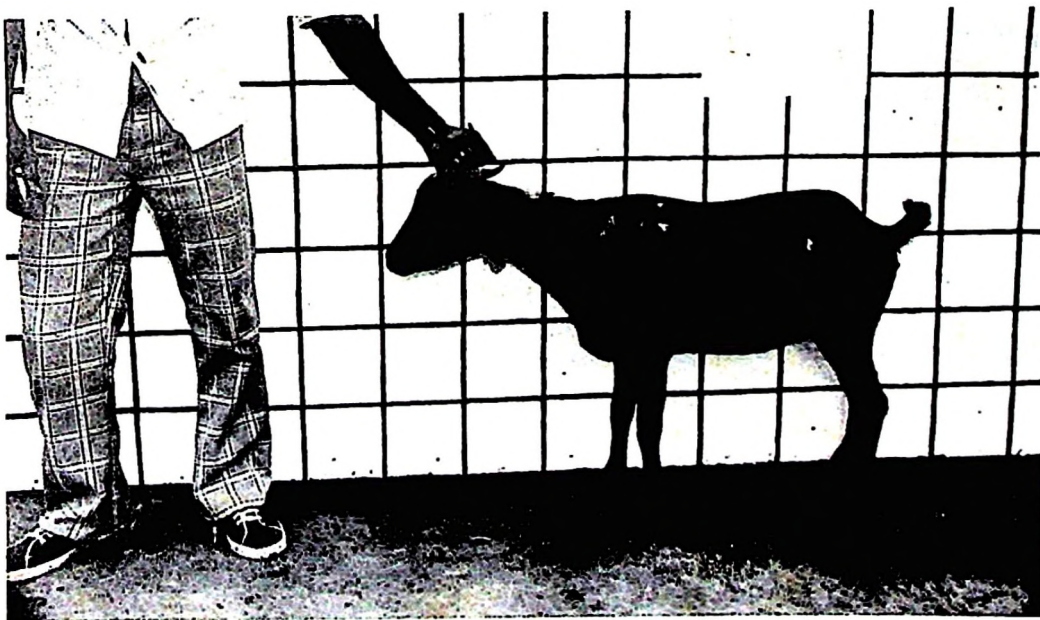


Plate 3.2. Tanzania female goat

also varies, common colours being speckled brindled with yellow and brown spots on the face, white and white (skilder) with brown (briekwa) head and neck. There is a variety of the Boer which has long hair. Head, horns and shoulders are all heavy; skin, legs and flesh are coarse. A second variety is polled and has long ears, derived from imported dairy breeds. It has a fine head and roman nose. Most herds are a mixture of these types. Those introduced in Tanzania between 1930 and 1960 seem to resemble the variety with horns. Ueckermann et al. (1974) have reported that the typical mature Boer goat does can have a mean weight of 54 kg. The males would most likely weigh more (Plates 3.3 and 3.4).

3.4.3 The Kamorai Goat

The Kamorai or Kamori goat was introduced to Tanzania in the 1950s, from Pakistan. Devendra and Burns (1970) have described this type of goat as large, lop-eared and with brown coat colour which sometimes has black or grey markings. They are found in the semi-arid and arid areas of Sind. They yield good carcasses and crops of hair. The does have well developed udders, yielding 2-4 kg of milk per day, and have a reputation of producing a high proportion of twins (Plates 3.5 and 3.6).

3.4.4 Crossbred Goats

Plates 3.7 and 3.8 show the crossbred goats obtained while carrying out the experiment.

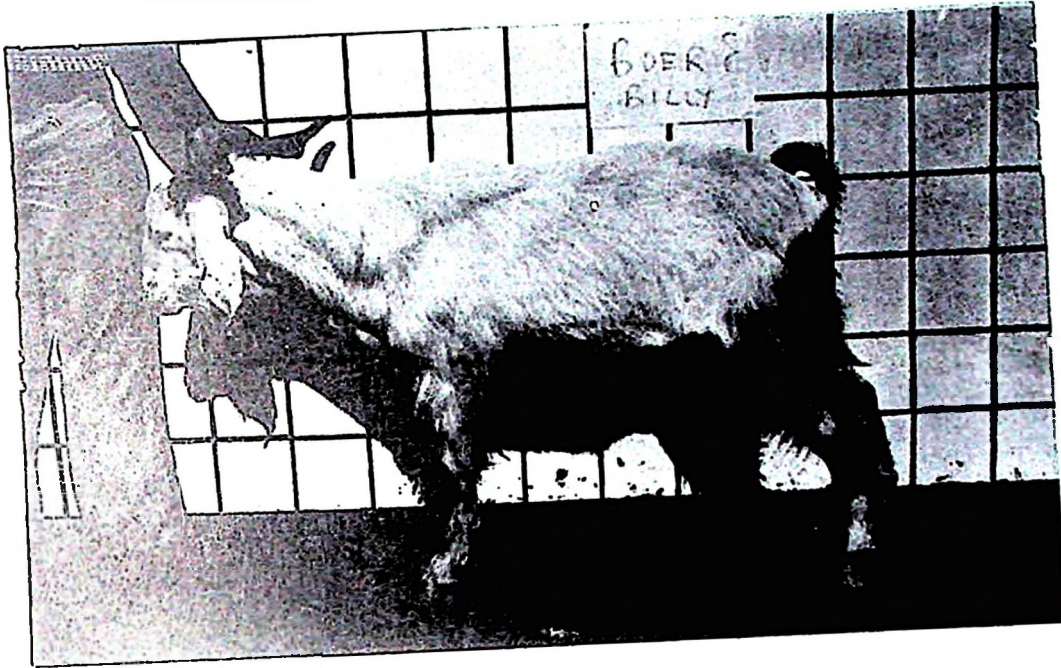


Plate 3.3. Boer male goat

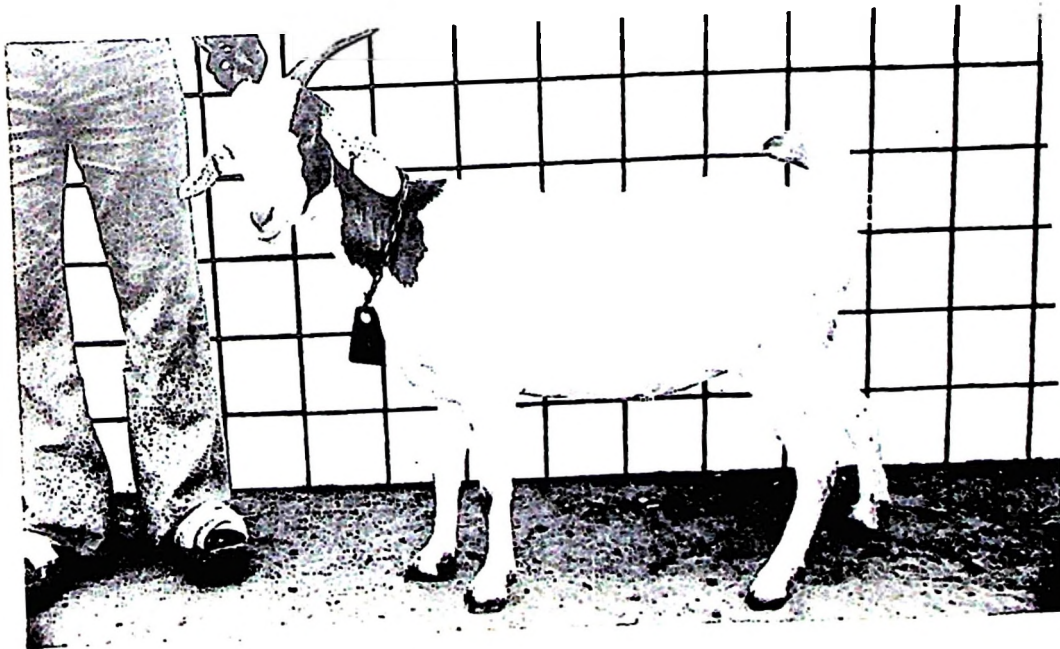


Plate 3.4. Boer female goat

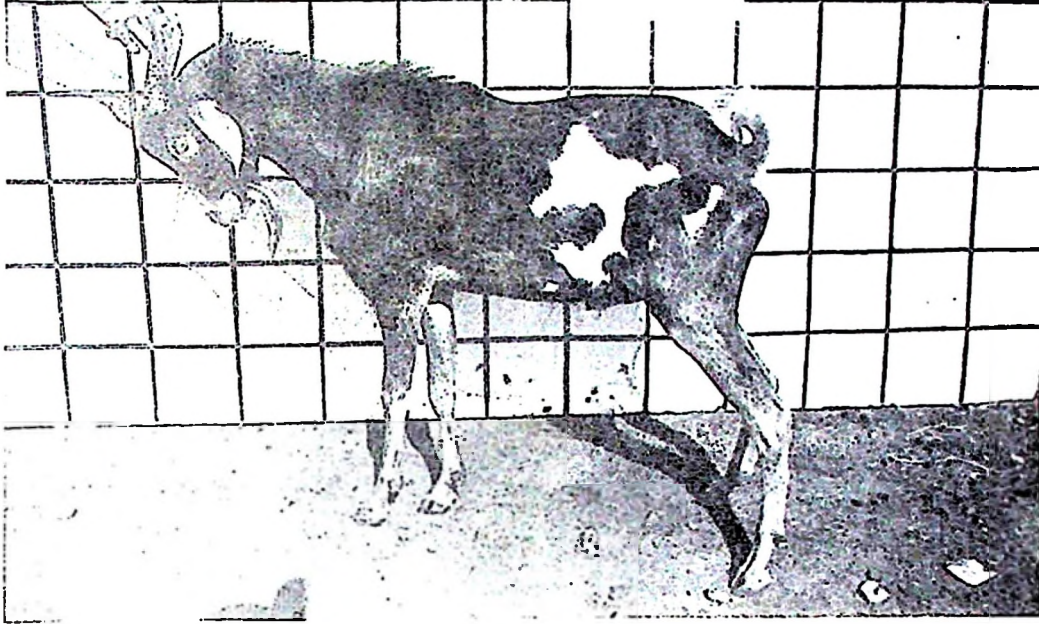


Plate 3.5. Kamorai male goat

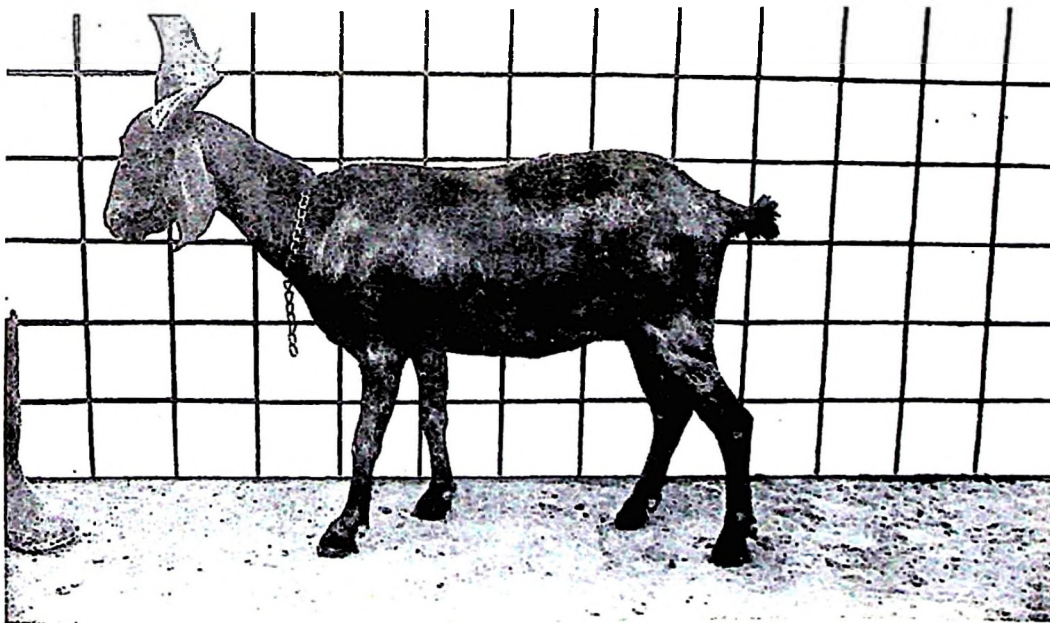


Plate 3.6. Kamorai female goat

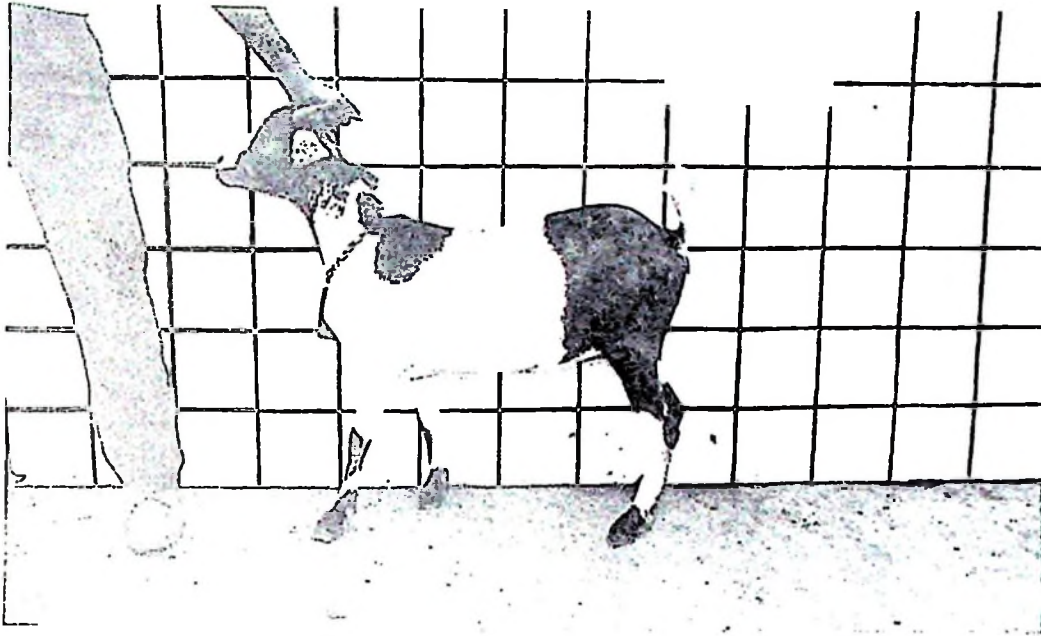


Plate 3.7. Boer-Tanzania Crossbred female goat

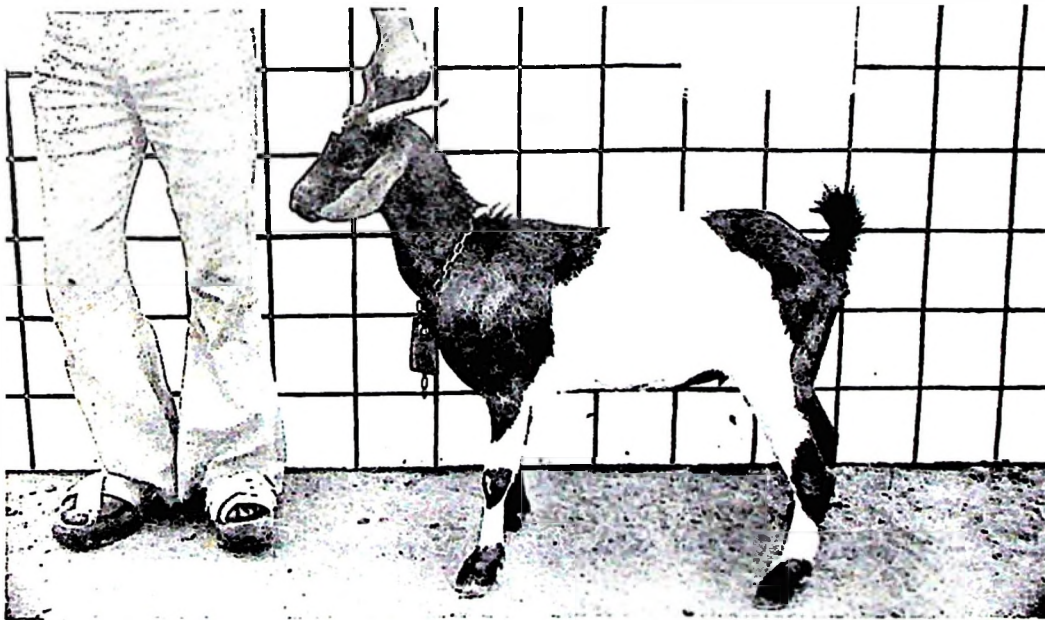


Plate 3.8. Boer-Kamorai Crossbred female goat

3.5 Experimental Layout

3.5.1 Collection of Data on Reproductive Performance

The foundation female goats described above were divided at random into seven groups, each of which comprised between 15 and 25 animals. Seven bucks, two per breed type of Boer and Kamorai and three Tanzania types, were allocated at random to the groups of females. All the animals used in this experiment were identified individually at birth or at the time of acquisition if brought in from outside the farm, by fixing in both ears of each animal numbered metal ear-tags. In addition, a tattoo of the same number was imprinted inside each ear to ensure that if the eartag came out the animal could still be identified. The female animals carried neck chains to which coloured and numbered plastic tallies were fixed to identify the mating groups to which they belonged. To save expenses on shepherding, the bucks and does grazed in separate flocks during the day between 08.00 and 18.00 hours. As soon as they returned from grazing, they were all sorted out into their mating groups and kept in separate large looseboxes between 18.00 and 08.00 hours. This meant that mating could take place at night only. Hayracks were placed in each of the looseboxes and in them hay and green fodder were placed in order to enable the animals to have access to them whenever they liked. Portable metal watering troughs were also placed in each of the

looseboxes in order to enable the animals to have access to water throughout the night. It is normal in Tanzania to shut small stock (sheep and goats) into looseboxes or some other enclosures at night in order to protect the animals from predators, especially leopards, jackals and hyaenas. The management of experimental animals described above was followed throughout the period the experiment was run. Because of the continuous mating system, it was expected that kidding would also take place throughout the year (see also Plates 3.9, 3.10 and 3.11).

3.5.2 Collection of Growth Data

After recording the birth type, sex, breed, and the sire's and the dam's numbers (Appendix 2), the birth weights of all live kids were taken within 18 hours after birth, but weights of dead kids were not recorded. After weighing, each kid was identified by fixing numbered metal eartags in both ears. Every other male kid born in each mating group was castrated by the use of an elastrator and a rubber ring at one week of age, and in the case of twin births only one member of the pair was castrated. In the case of all male triplets one or two members of this type of birth would be castrated depending on the method of allocation to the two groups of either castrate or entire described above. The kids of all sexes (males, females and castrates) were weighed every fourth week until they reached the age of 72 weeks. Weaning took place at 16 weeks of age and from this age



Plate 3.9. Mixed flock of pure and crossbred Boer, Tanzania and Kamorai female goats grazing and browsing in unimproved pastures



Plate 3.10. Goat kids and adult male goat eating concentrate feed

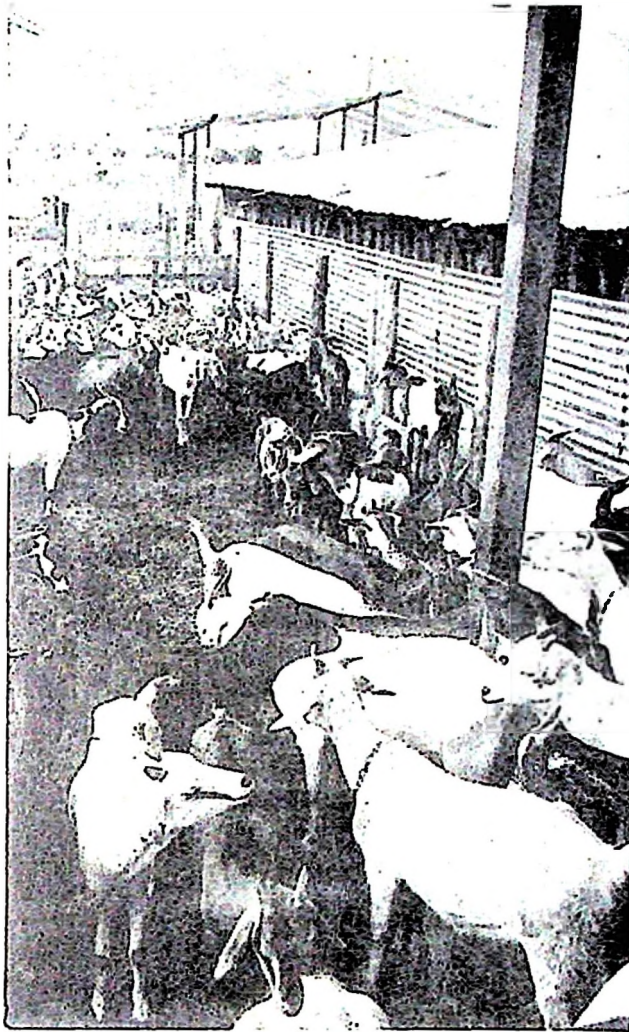
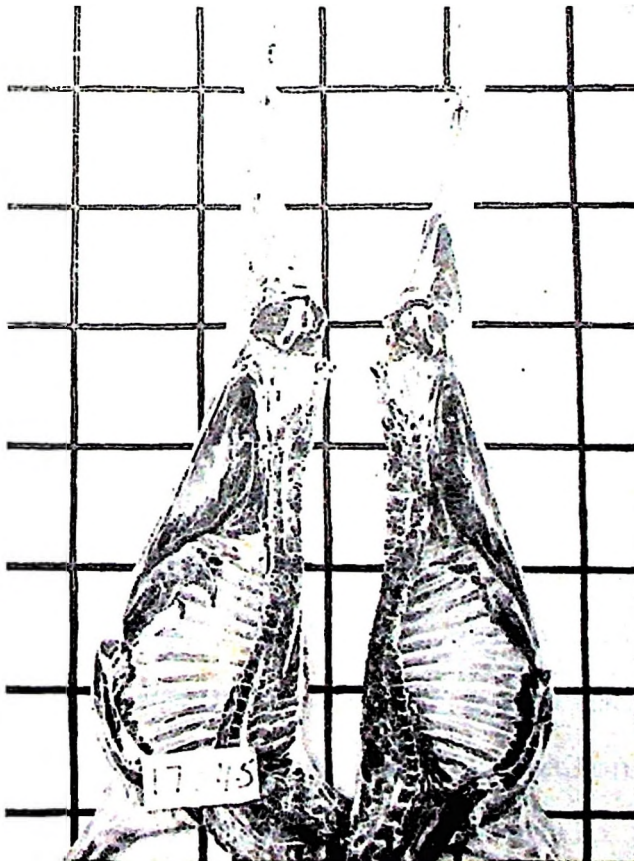


Plate 3.11. Female pure and crossbred Boer, Tanzania and Kamorai female goats before being sorted into mating groups



until 72 weeks male and castrated kids were run as a separate flock from that of the female kids. At 72 weeks of age, all males and castrates were slaughtered for carcass studies. The female kids were drafted into the mating groups when they reached this age of 72 weeks. To avoid inbreeding, the female kids were not allocated into the mating groups of their individual sires. From the twelfth week after birth and at twelve week intervals thereafter up to 72 weeks, body measurements were taken on all the kids. These included height at the withers, length from the pin bones to the point of shoulder, heart girth, and width of the hindquarters between the centre point of both haunches, using a metal tape for heart girth and a caliper-like graduated metal rod for the rest of the body measurements. Table 3.3 shows the summary of the total number of animals contributing to the study and other characteristics of the data.

3.5.3 Collection of Carcass Measurements

The method developed in Tanzania by Hutchison (1962) was used in collecting carcass data (Appendix 3). Slaughter was fixed at 72 weeks of age because, according to Hutchison, the Tanzania goat kids would have grown to large enough sizes to provide large enough carcasses for commercial use. An animal which had reached an age of 72 weeks was weighed off the experiment and then starved for 24 hours. During the starvation period only water was provided. It was weighed again at the end of this period and then slaughtered (see Plate 3.12).

Table 3.3. Summary of the Total Number of Animals Contributing to the Study and Other Characteristics of the Data

Types of animals and other characteristics	Breed of Animals								Total	
	Boer		Kamorai		Tanzania			3		
Sires	1	1	1	1	1	1	1	1	7	
No. of Dams Tanzania	16	14	15	14	23	19	20		121	
No. of Dams Crossbred	a 32		a 24						56	
Total births	57	92	52	68	51	55	62	69	53	559
No. of parities										7
No. of sexes ^b										3
Type of births ^c										2
Duration of study (in years)										5

a = Crossbred dams were distributed among all sires in different proportions

b = Sexes included entire males, castrates and female kids

c = There were single and twin births - only one set of triplets was recorded from a Boer crossbred dam but it was not included in the study

3.5.3.1 Slaughtering procedure

Slaughtering was done by severing the carotid artery between the occipital bone (Os occipitale) and the first cervical vertebra (atlas) after stunning the animal with a captive bolt pistol. Each carcass was bled by hanging it from the hind legs and the free draining blood was collected in a bucket and weighed to the nearest 25 g. The skin, the pluck (lungs, trachea, heart, pericardial fat and parts of the diaphragm), the liver, the full gastrointestinal tract (gut) with its associated fat, the sexual organs, the spleen, the bladder, the gall bladder, the thyroid gland, the head and the limb extremities after the hind feet had been severed between the tarsus and metatarsus and the fore feet between the carpus and metacarpus, were removed and weighed separately. The carcass minus these tissues was weighed for the purpose of finding the hot dressed carcass weight. The gut was immediately stripped of all fat and weighed. It was then emptied by hand, washed and weighed again. The weight of its contents was estimated by difference. Subtracting the weight of the gut from the weight of the kid just before slaughter (taken to the nearest 50 g) gave the empty body weight (EBW). The weight of the contents added to the overnight loss in weight of the kid gives gut fill. The carcass was then chilled for 24 hours in a cooler at 4°C and weighed again to find the "chilled" or cold carcass weight.

3.5.3.2 Collection of various external measurements

The measurements shown in the chart (Appendix 3) were taken on the whole carcass for the purpose of correlating them with other carcass components. Before jointing started, demarcation lines between wholesale cuts or commercial joints were marked on the left side clearly, by using a knife and following the chart.

3.5.3.3 Quartering

The carcass was split by hand by sawing through the caudal vertebrae and along the remainder of the vertebral column. The left half was retained for complete anatomical dissection, while the right half was jointed and sold. Before jointing the left half, the eye muscle (longissimus dorsi) of the 10th, 11th and 12th ribs were exposed by cutting with a knife from their posterior sides. Tracing the edges of these muscles was undertaken by using transparent paper and the portion indicating the size of the muscle was shaded with black ink. The shaded portions were passed through an electric planimeter. The instrument works on the principle of light and the area of the opaque part of any flat material fed into it is automatically shown on a panel in square centimetres. Cutting through the carcass on the posterior part of the 10th rib and continuing the cut through the ventral tissues divides the half carcass into the hind and fore quarters. To ensure the repeatability of the results, splitting of the carcass into its component parts was undertaken by an experienced operator.

3.5.3.4 Jointing procedure

The flank and abdominal muscles were separated from the leg by cutting with a knife. A cut was then made following a straight line from the symphysis of the pubis to the posterior end of the 11th rib. The hind quarter was then removed from the rail and cutting was completed by sawing through the 11th rib. By separating the last lumbar and the first sacral vertebrae, the loin was detached, leaving behind the chump and the hind leg. The hind leg, which comprised the femur, the patella, tibia and distal limb bones, was separated from the chump by following the earlier marked demarcation lines. The fore quarter was jointed by first freeing various muscles at their regions of either origin or insertion attachment. The shoulder, together with the shin, were separated from the thorax and breast by cutting and freeing the superficial pectoral muscle from its attachment. The fore limb was then subdivided into a scapula and humerus portion of the shoulder point and shin. The breast was separated from the thorax by severing each of the ribs in turn along the demarcation line already marked. The separation of the neck from the thorax was done by cutting between the 4th and the 5th cervical vertebrae.

3.5.3.5 Dissection

Each joint was physically dissected into muscle or lean, bone and depot fat, using sharp knives, scalpels and forceps. The muscle component was free of connective tissue, while the bone included only the cartilage and

tendon which were attached to it. The fat component included tendons removed from muscle, connective tissue, sheaths, blood vessels, glands and nerves. These tissues were weighed to the nearest 50 g. During dissection the separate tissues were covered with a damp piece of hessian cloth to avoid water loss before they were weighed.

3.6 Analysis of Data

3.6.1 Reproductive Performance

The relationships between time of kidding and environmental factors such as rainfall, temperature, relative humidity and sunshine hours were computed by the method of regression analysis similar to that described by Lees (1966). The analysis of variance was done to test the differences between does of different breed types in kidding interval and between young female kids of different breed types in time between birth and first kidding, using the standard statistical methods of analysis of variance described by Steel and Torrie (1960) and Snedecor and Cochran (1967).

3.6.2 Growth of Progeny

The data on growth of progeny were analysed by using the programme for Model Type 3 (MTY = 03) of the Department of Applied Statistics of the University of Reading. The programme is an adaptation of the Least Squares and Maximum Likelihood General Purpose Programme (MSMLMM) developed by Harvey (1960). It undertakes the fitting of individual constants for interaction effects so that

weighted squares of means can be obtained directly. The computation of adjusted or least squares sums of squares in this programme makes use of the constant estimates and segments of the inverse of the variance-covariance matrix. The fitting of partial regression constants, both for individual classes or subclasses or on a pooled basis for continuous independent variables, is done. The systematic computation of sums of squares for single degree of freedom orthogonal comparisons with the use of simple transformation matrices is also undertaken by the same programme. Finally, it undertakes the application of mean separation procedures to the correlated least-squares means. The Mixed Model type of statistical analysis as described by Steel and Torrie (1960), Steel (1962) and Snedecor and Cochran (1967) with one set of non-interacting random nested effects fitted these data. An observation on progeny was made up of various components as shown in the formula below.

$$Y_{ijklm} = U + b_i + S_{ij} + p_R + \text{sex}_l + bt_m + (p\text{Sex})_{kl} + (\text{Sex}bt)_{lm} + E_{ijklm}$$

where U = the population mean for the character

b_i = effect of i th breed

S_{ij} = effect of j th sire of i th breed

p_R = effect of R th parity

Sex_l = effect of l th sex

bt_m = effect of m th birth type

$(p\text{Sex})_{kl}$ = interaction between k th parity and l th sex

$(\text{Sex}bt)_{lm}$ = interaction between l th sex and m th birth type

E_{ijklm} = random error

The programme produced an estimate of heritability for weight at birth, weaning, one year of age, and genetic and phenotypic correlations at these ages.

The regression of weight on age and body measurements on age, and multiple correlations between weight and body measurements at various ages, and the analysis of variance to compare breed types and sexes for weight and body measurements were undertaken using GENSTAT Programme of the Rothamsted Experimental Station as described by Wilkinson (1970) and James and Wilkinson (1971).

3.6.3 Carcass Characteristics

The Mixed Model type already described fitted these data and the equation this time was :

$$Y_{ijkl} = U + b_i + s_{ij} + \text{sex}_k + bt_l + E_{ijkl}$$

where U = the population mean for the character

b_i = effect of i th breed

s_{ij} = effect of j th sire of i th breed

sex_k = effect of k th sex

bt_l = effect of l th birth type

E_{ijkl} = random error

The correlations between different carcass traits were calculated using programme ASF2 of the Department of Applied Statistics of the University of Reading. The comparison between breed types in carcass characteristics was undertaken using the standard analysis of variance methods already described.

CHAPTER 4RESULTS AND DISCUSSION4.1 Reproductive Performance

4.1.1 Results

4.1.1.1 Incidence of kidding in relation to time of the year

Table 4.1 shows the incidence of kidding in relation to the time of the year. Although it is demonstrated that kidding takes place throughout the year, there are definite peaks when several does kid. This pattern of kidding might be in response to some factor or factors, environmental or otherwise, which influenced conception. An attempt was made to relate the time of conception to various environmental factors: The date of conception was calculated by subtracting 150 days - the gestation length in goats - from the date of kidding. The total number of conceptions resulting in live births in any peak kidding period were tested against either total rainfall for that month or period, mean daily maximum and minimum temperatures, mean daily maximum and minimum relative humidities, or mean number of sunshine hours, using the method of regression analysis similar to the one used by Lees (1966). The test for significance of the regression coefficients shows that there is a relationship between conception resulting in live births and total rainfall in the month or period in which conception occurs (Table 4.2). The mean daily rainfall

Table 4.1. Number of does kidding in relation to time of the year

Year	M o n t h												Total kiddings per year		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.			
1972															39
1973	20	14	1	1	14	3	1	27	1	4	13	3		102	
1974	0	19	1	19	4	3	17	25	10	4	9	11		122	
1975	8	11	0	17	6	35	5	15	1	7	7	9		119	
1976	1	28	7	1	0	8	4	31	8	1	5	1		95	
Total within month	29	72	9	38	24	47	53	102	21	23	34	25		477	

Table 4.2. Relationship between number of kiddings and total rainfall at the time of kidding

Time of kidding	No. of kiddings (X)	Time of conception	Total rainfall in mm (Y)
July - Aug. 1972	30	Feb. - Mar. 1972	10.0
Jan. - Feb. 1973	34	Aug. - Sep. 1972	0.8
May - June 1973	17	Dec.72 - Jan. 1973	11.2
Aug. - Sep. 1973	28	Mar. - Apr. 1973	11.0
Nov. - Dec. 1973	16	July - Aug. 1973	0.6
Feb. - Mar. 1974	20	Sep. - Oct. 1973	0.7
Apr. - May 1974	23	Nov. - Dec. 1973	5.5
July - Sep. 1974	52	Feb. - Mar. 1974	3.2
Nov.74 - Mar. 1975	39	July - Oct. 1974	0.8
Apr. - May 1975	23	Nov. - Dec. 1974	0.4
June - July 1975	38	Jan. - Feb. 1975	3.6
Aug. - Sep. 1975	16	Mar. - Apr. 1975	10.2
Feb. - Mar. 1976	35	Sep. - Oct. 1975	0.9
Aug. - Sep. 1976	31	Mar. - Apr. 1976	9.0
Oct. - Dec. 1976	20	May - July 1976	3.3

$$t = \frac{b}{s_b} = 6.7 \quad P < 0.001$$

within months and years are shown in Table A3.1.1 to Table A3.1.6 and Figures A3.1 to A3.4. The superimposition of the figure on kidding incidence (Figure 4.1) on the figure representing mean daily rainfall (Figure A3.1) resulted in Figure 4.2. This figure shows that the rainy periods and the periods when most kiddings occur are out of phase with each other and that this pattern is very regular. It is worth noting that although the total annual rainfall and the peak mean daily rainfall were decreasing between 1974 and 1976, the sizes of the peak kidding incidences were not reduced. The relationship between time of conception and other environmental factors already discussed were not significant.

4.1.1.2 Age at first kidding

The female progeny were drafted into breeding groups after they had attained an age of 72 weeks. Inbreeding was avoided by ensuring that they did not join their respective sires' mating groups. The mean lengths in days from the date of drafting them into the mating groups to the date of first kidding are shown in Table 4.3. The crossbred female kids produced their first kids at an earlier age (238 ± 9.43 days for the Boer crosses and 240 ± 16.93 days for the Kamorai crosses) than the Tanzanian kids which kidded for the first time after 269 ± 25.82 days from the time they were drafted into the mating groups. The difference in age at first kidding between the Boer

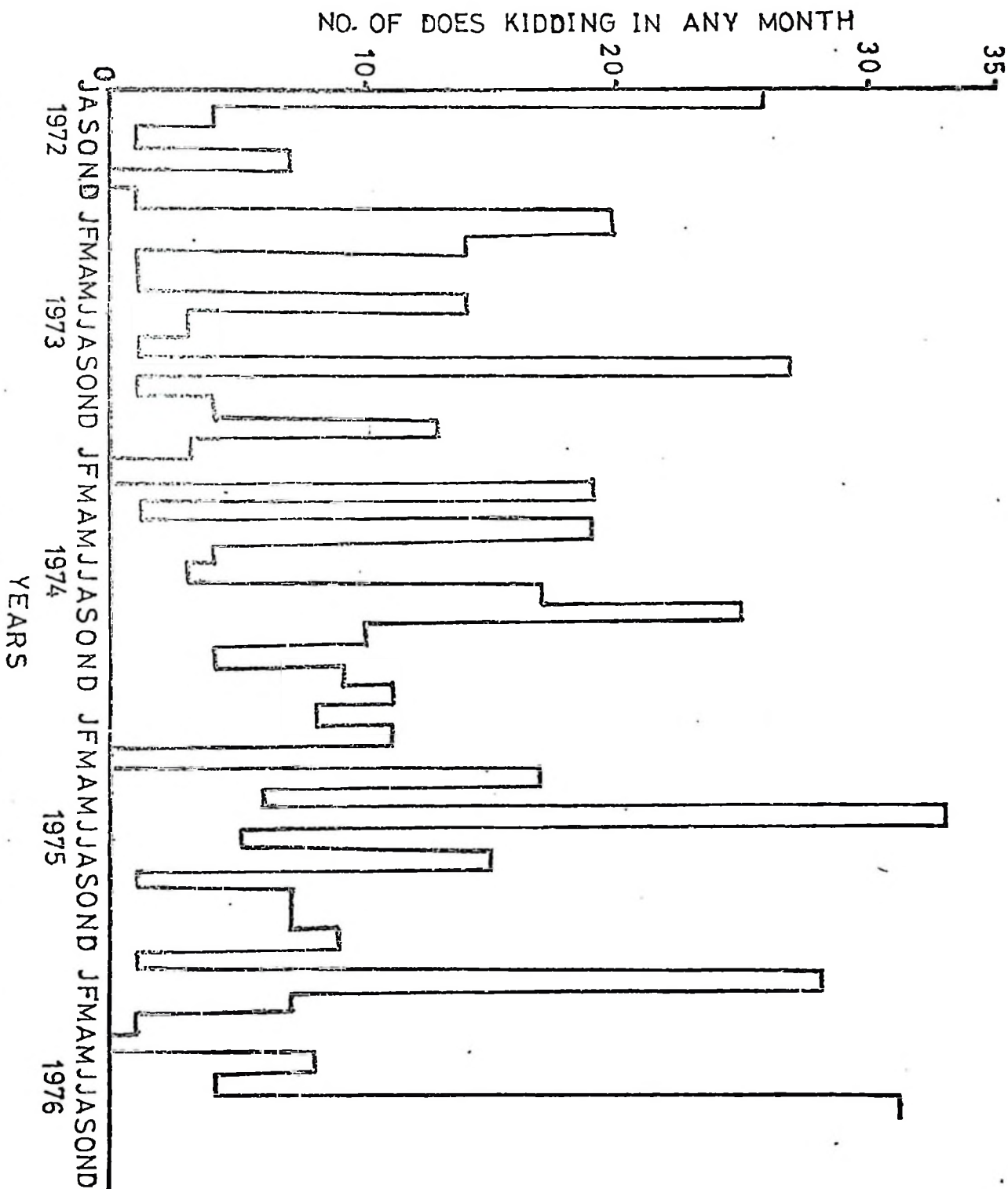


Fig. 4.1 INCIDENCES OF KIDDING IN RELATION TO TIME OF THE YEAR.

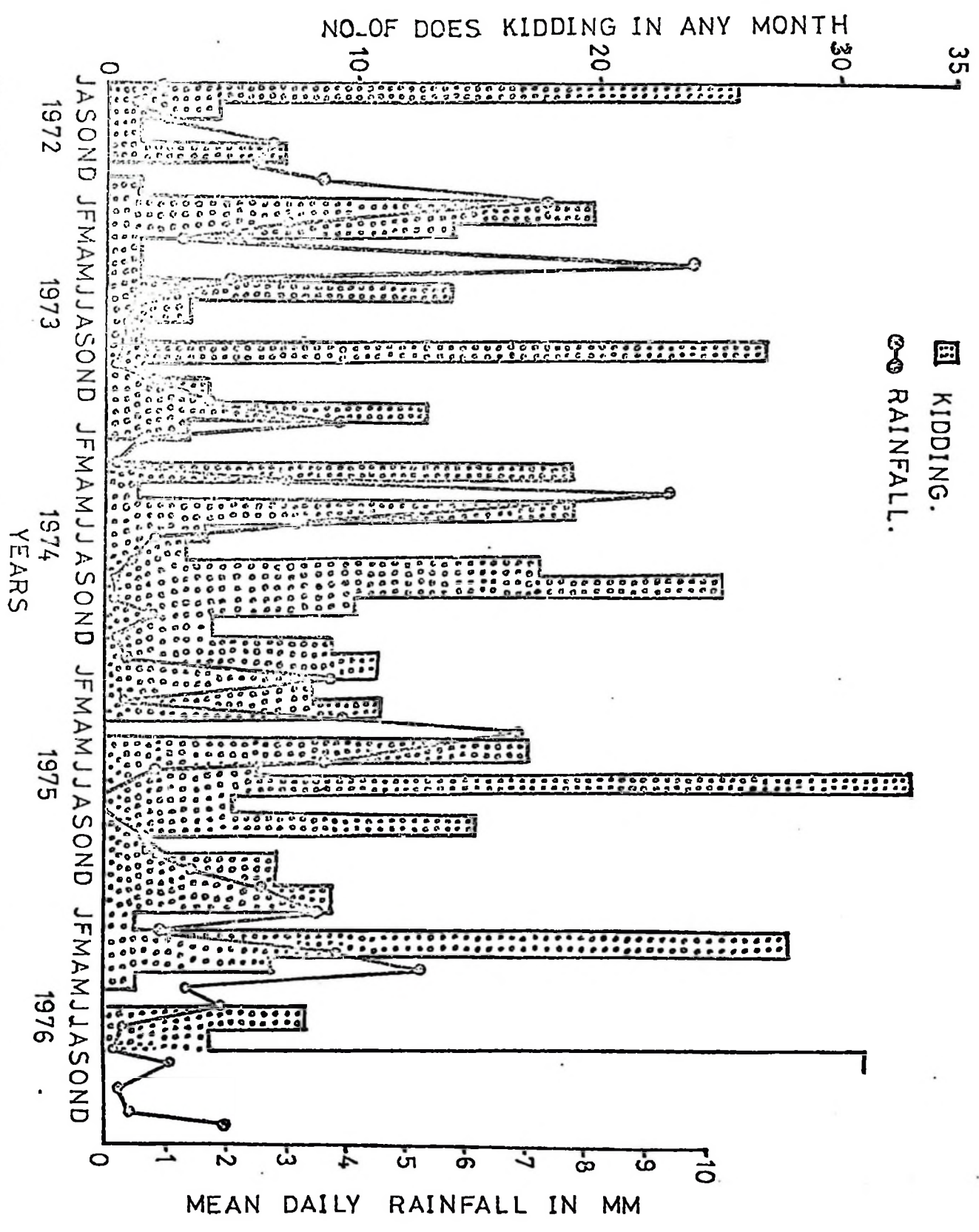


Fig. 4.2 INCIDENCES OF KIDDING IN RELATION TO THE TIME OF THE YEAR AND TO MEAN DAILY RAINFALL AT MOROGORO

Table 4.3 Mean length (in days) from drafting into breeding groups at 72 weeks of age to first kidding

Character	Breed type of progeny			Differences between means
	Tanzania	Boer crosses	Kamorai crosses	
No. of animals	14	17	20	
Average length (in days)	269 ± 25.82	238 ± 9.43	240 ± 16.93	
Tanzania vs Boer Crosses				***
Tanzania vs Kamorai Crosses				NS
Boer Crosses vs Kamorai Crosses				**

The levels of significance are indicated as

NS = Not significant at $P < 0.05$

** = Significant at $P < 0.01$

*** = Significant at $P < 0.001$

crosses and the Tanzania purebred kids was highly significant ($P < 0.001$), while that between the Boer and the Kamorai crossbred kids was significant at $P < 0.01$. The difference between the Kamorai crossbred kids and the Tanzania kids in this trait was not significant.

4.1.1.3 The kidding interval

The kidding intervals in days between parities of dams are shown in Table 4.4. The differences in average kidding intervals between various breed types were not significant.

4.1.1.4 The rate of twinning

The average kidding and twinning rates at various parities are shown in Table 4.5. There was a tendency for the twinning rate to increase with parities in Tanzania purebred and Boer crossbred does. The latter tended to have higher incidences of twinning at most parities than the other breed types used in the study. The births which produced twins were very few in the Kamorai crossbred does. Only one birth resulted in birth of triplets from a Boer-Tanzania crossbred doe. The overall twinning percentages for the Tanzania purebred, and Boer and Kamorai crossbred does (Table 4.6) were 16.4, 31.5 and 3.9, respectively.

Table 4.4 Kidding intervals in days

No. of kidding interval	Indigenous does		Boer crosses		Kamorai crosses		Analysis of variance to test differences in kidding interval between breed types
	Mean length of kidding interval	No. of does	Mean length of kidding interval	No. of does	Mean length of kidding interval	No. of does	
1 - 2	315 ± 9.71	93	342 ± 18.05	27	305 ± 19.38	17	NS
2 - 3	294 ± 10.89	68	300 ± 27.10	14	306 ± 30.18	8	NS
3 - 4	284 ± 10.50	50	258 ± 22.16	9			
4 - 5	324 ± 17.70	39	308 ± 48.89	7			
5 - 6	325 ± 23.98	14	288 ± 34.71	5			
6 - 7	275 ± 26.84	5					

Table 4.5 Kidding performance of crossbred Boer and Kamorai does and purebred Tanzania does at different parities

Character	Breed type	P a r i t y n u m b e r						
		1	2	3	4	5	6	7
Total no. of births	Tanzania	128	105	71	53	38	16	5
	Boer crosses	31	27	13	8	7	4	2
	Kamorai crosses	22	19	8	2	-	-	-
Total no. of births resulting in twin births	Tanzania	14	13	13	8	13	4	3
	Boer crosses	7	8	5	3	3	2	1
	Kamorai crosses	-	2	-	-	-	-	-
Twinning %	Tanzania	10.9	12.4	18.3	15.1	34.2	26.0	60.0
	Boer crosses	22.6	29.6	38.5	37.5	42.5	50.0	50.0
	Kamorai crosses	-	10.5	-	-	-	-	-

Table 4.6 Overall reproductive performance of Boer and Kamorai crossbred and Tanzania does

Characteristics	Breed type			Total
	Tanzania	Boer crosses	Kamorai crosses	
Total no. of of births	416	92	51	559
Births resulting in twins	68	29	2	99
Twinning %	16.4	31.5	3.9	17.7
Ratio, % Twinning at 1st Parity : % Twinning at remaining parities	1.7	1.6	-	1.7

4.1.1.5 Kid mortality

The kid mortality rates are shown in Table 4.7. There was an average mortality rate of 35.6 per cent during the five year period. It was higher among the male kids, 39.4, as against 31.3 per cent among the female kids. The mortality rates were relatively higher during the years of 1974 and 1975, being 46.8 and 44.8 per cent, respectively, than other years in which mortalities were below 30.1 per cent. Mortality rates between birth and weaning were higher than those which occurred between weaning and one year of age. The reverse was true during 1976 only. When the data for all the five years were combined, the average mortality rates before weaning and after weaning were 22.7 and 12.9 per cent, respectively. Table 4.8 shows the mean birth weights of kids dying before reaching one year of age and the mean birth weights of all the kids within respective breed types. Most of the kids which died and which were born by does kidding for the first time had slightly lighter birth weights than the average birth weights for all kids in their respective breed types. Those which died and had come from parities other than the first, had similar average birth weights to those of other kids in their respective breed types. Table 4.9 shows some of the causes of death in goat kids. Apart from the causes of death which were not easy to diagnose, pneumonia caused higher percentages of deaths in kids than other causes.

Table 4.7 Number of kids born during the various years and mortality rates

Character	Year												All years	
	1972		1973		1974		1975		1976					
	M ^a	F ^b	M	F	M	F	M	F	M	F	M	F	M	F
No. of births	24	27	71	61	75	64	76	58	51	52	297	262		
No. of deaths	3	4	18	18	31	34	48	12	17	14	117	82		
Deaths as % of births	12.5	14.8	25.4	29.5	41.3	53.1	63.2	20.7	33.3	26.9	39.4	31.3		
Total no. of births	51		132		139		134		103		559			
Total no. of deaths	7		36		65		60		31		199			
Deaths as % within years	13.7		27.3		46.8		44.8		30.1		35.6			
No. of deaths before weaning	7		29		49		28		14		127			
No. of deaths after weaning	-		7		16		32		17		72			
% deaths before weaning	13.7		22.0		35.3		20.9		13.6		22.7			
% deaths after weaning	-		5.3		11.5		23.9		16.5		12.9			

a = Male (M); b = Female (F)

Table 4.8 Mean birth weights of kids dying before reaching 1 year of age (A) and mean birth weights of surviving kids (B)

Group	Breed	No. of Parity	Type of birth and sex of kids							
			Singles				Twins			
			Male	No.	Female	No.	Male	No.	Female	No.
A	Boer	First	2.0 ± 0.22	(7)	1.9 ± 0.43	(4)	2.0	(1)	1.5	(1)
	Kamorai	"	2.1 ± 0.21	(9)	2.1 ± 0.16	(6)	2.0	(1)	2.0	(2)
	Tanzania	"	1.6 ± 0.18	(8)	1.9 ± 0.12	(8)	2.0	(2)	0.0	(0)
	Boer	Others	2.5 ± 0.15	(20)	2.0 ± 0.20	(4)	2.5 ± 0.26	(9)	1.9 ± 0.19	(13)
	Kamorai	"	2.3 ± 0.15	(21)	2.0 ± 0.18	(13)	2.1 ± 0.12	(11)	2.0 ± 0.14	(9)
	Tanzania	"	2.1 ± 0.12	(20)	1.9 ± 0.11	(23)	2.3 ± 0.20	(6)	1.5 ± 0.16	(5)
B	Boer	ALL	2.3 ± 0.09	(92)						
	Kamorai	"	2.1 ± 0.09	(79)						
	Tanzania	"	2.0 ± 0.08	(123)						

Table 4.9 Some causes of kid mortality recorded during the various years

Causes of kid mortality	Year					Total deaths
	1972	1973	1974	1975	1976	
General weakness and non-specific causal diseases	7	32	31	37	22	129
% of total	100	88.9	47.7	61.7	71.0	64.8
Crushed at night by older animals	-	1	8	7	-	.16
% of total	-	2.8	12.3	11.7	-	8.0
Pneumonia	-	2	19	11	6	38
% of total	-	5.6	29.2	18.3	19.4	19.1
Plant poisoning	-	-	3	1	-	4
% of total	-	-	4.6	1.7	-	2.0
Food poisoning	-	-	1	-	-	1
% of total	-	-	1.5	-	-	0.5
Enteritis	-	-	2	3	2	7
% of total	-	-	3.1	5.0	6.5	3.5
Septicaemia	-	-	-	1	-	1
% of total	-	-	-	1.7	-	0.5
Snake bite	-	-	1	-	-	1
% of total	-	-	1.5	-	-	0.5
Strangulation by fencing wire & other mechanical injuries	-	1	-	-	1	2
% of total	-	-	-	-	3.2	1.0
Total deaths	7	36	65	60	31	199

4.1.1.6 Reproductive failure and mortality in does

The incidences of reproductive failure and deaths among the does are shown in Table 4.10. Abortions and still births were very few (less than 4 per cent) among the does of all breed types. There was only one case of failure to conceive. Deaths among does were very few - less than 3 per cent of the total does. The main causes of deaths were - loss of condition after abortion or kidding, and deliberate disposal by slaughter of very weak and emaciated does.

4.1.2 Discussion

4.1.2.1 Incidence of kidding in relation to time of the year

The results in Table 4.1 confirm the observations by other workers (Mason and Maule, 1960; Hutchison, 1962; Devendra and Burns, 1970), namely, that the Tanzania goat breeds throughout the year. However, peak kidding periods do occur during certain periods of the year. The total monthly rainfall is related to conception rate. One of the ways rainfall could influence conception would be indirectly through the stimulation of forage growth. The availability of feed would improve the condition of does and thereby enable them to ovulate, conceive and carry the foetus to term. Similar studies in which kidding time was associated with rainfall were undertaken in India (Devendra and Burns, 1970). The possible reason for lack of relationship between conception and other environmental

Table 4.10 Incidences of reproductive failure
and deaths among the does

Character	Breed type		
	Tanzania	Boer	Kamorai
Total does started with	428	94	53
Total births	416	92	51
Abortions and still births	11	2	2
Abortions and still births as % of all does	2.6	2.1	3.8
Failed to conceive	1	0.0	0.0
Does failing to conceive as % of total does	0.2	0.0	0.0
Deaths of does	5	2	0.0
Deaths of does as % of total does	1.2	2.1	0.0

factors such as daily sunshine hours, would be that the variations in these factors between the different periods of the year are not large enough. In tropical countries, namely Ghana and India with hotter summers than Morogoro, temperatures affect time of kidding (Devendra and Burns, 1970).

4.1.2.2 Age at first kidding

The time from birth to first kidding tended to be very long in all the breed types. Hutchison (1962) recommended that, although Tanzania female kids were sexually mature before they attained the age of one year, delaying mating until after 72 weeks of age would enable the kids to attain heavier body weights and hence be able to breed without getting stunted. It was expected, therefore, in the present study, that the purebred Tanzania female kids would conceive and carry foetuses to term soon after joining the mating groups at 72 weeks (504 days) of age. However, they took 269 ± 25.82 extra days, while the Boer and the Kamorai crossbred kids took 237.8 ± 9.43 and 240.3 ± 16.93 extra days, respectively, before kidding for the first time. These periods are longer by 205 days for the Tanzania kids, 174 and 177 days for the Boer and the Kamorai crossbred kids, respectively, when compared with the age at first kidding of the Mubende goats of 567 ± 11.6 days reported by Sacker and Trail (1966). The Tanzania and the Mubende goats both belong to the East African breed type of goat and they would be expected to

have similar ages at first kidding when raised in a similar environment. The Mubende goats were kept at Mbarara near the Equator only $0^{\circ} 31'$ S latitude and the dry periods occur in June, July, August and four weeks in January and February, otherwise there is rain most of the time. This rainfall pattern resembles that which occurs at Morogoro, which is 7° S. The only differences are that the dry season at Morogoro is longer by about three months - June to November - and the rainy period between November and January is very unreliable in that it can either be long or short (Figure A3.1). These differences could make the East African goat kids kept in the Morogoro environment take longer to reach age at first kidding than those at Mbarara. Furthermore, the rainfall data (Table A3.1.1) indicate that 1974, 1975 and 1976 were generally very dry years, and for the whole of Tanzania these were regarded as drought years. The dry period affected the availability of forage for the goats and might, indirectly, have been responsible for delaying the full growth, conception and first kidding of the female kids. The first kidding at a younger age by the Boer crossbred kids, compared with the Tanzania kids, would seem to indicate that crossbreeding can shorten the age at first kidding. Raja and Mukundan (1974), however, reported that the crossbred progeny of the Jamnapari and Malabar tropical goats in India took longer to reach age at first kidding than the Malabar purebred female kids. The relatively long periods between

birth and first kidding observed in the present study in Boer and Kamorai crossbred and in Tanzania purebred goat kids were, however, shorter than those reported in the study in Puerto Rico (Devendra and Burns, 1970). In this study the local and crossbred goats kidded for the first time between 13 and 49 months of age. Dýrmundsson (1973) has cited studies in sheep which show that ewe lambs behavioural signs of oestrus are weak and incomplete and that the intensity of oestrus is less marked than in adult ewes. Some studies reported by this author showed that ewe lambs in oestrus made little or no attempt to approach the ram but accepted service when the latter made sexual advances. Similar behaviour might be occurring in female goat kids, and if bucks failed to detect oestrus, this could lead to long periods between the joining of the mating groups and first kidding by young does. More study is needed to see if age at first kidding cannot be shortened by keeping young does with fertile bucks in their own mating groups instead of mixing them with older does.

4.1.2.3 Kidding interval

The lengths of the kidding intervals and their standard errors between various parities (Table 4.4) were very similar to those reported by Sacker and Trail (1966) for the Mubende goats in Uganda. They were also similar to those reported by Raja and Mukundan (1974) for the Malabar and the Jamnapari-Malabar crosses in India, and those observed in the Red Sokoto in Niger by Haumesser (1975). Since the period between two consecutive kiddings is made

up of the service period and the gestation period, shortening the former could reduce the kidding interval. In the present study, the service period (kidding interval minus the gestation period of 150 days) was 170 days between the first and second kiddings and 146 days between the latter kiddings. Devendra and Burns (1970) have, however, cited one study in Malaysia in which the service period in indigenous goats was 92 days, while in the Anglo-Nubian - a temperate based - it was 327 days, and 204 days in the Anglo-Nubian-Malaysia crossbred goats. From the results of these studies, the length of the kidding interval seems to be a breed characteristic. There seems, however, to be need to re-examine the effects of some environmental factors, such as nutrition of the doe and early weaning of kids, on kidding interval if we wish to reduce the latter and therefore obtain kids at shorter intervals.

4.1.2.4 The rate of twinning

The overall twinning percentage of the Tanzania goats of 16.4 is close to the earlier findings on this trait in the East African goats, namely, that of 10 to 15 per cent (Mason and Maule, 1960), but higher than that of 12.7 per cent reported by Wilson (1958). It was, however, lower than the twinning percentage of 30 reported by Sacker and Trail (1966) in the Mubende goats which, like the Tanzania goat, belong to the East African goat breed type. The twinning rate in the Mubende goats was as high as that which was observed in the present study in the Tanzania-Boer

crossbred does. Devendra and Burns (1970) have, however, reported conflicting results on the effects of crossbreeding in improving twinning rate. In the present study, twinning percentage increased with the age of the doe in both the Tanzania and the crosses between this breed type and the Boer. Devendra and Burns (1970), Prasad et al. (1972), and Singh and Singh (1974) have reported similar relationship between the age of doe and the rate of twinning. It was demonstrated in some of these studies, especially that of Prasad et al., that the increase in twinning rate with the age of the doe was up to the 4th parity only. Thereafter the rate of twinning started to decline. The fewer number of does at the 6th and 7th parities in the present study would not make such comparison valid. Nevertheless, the trend was such that the twinning rate was highest at the 5th parity than at lower parities. But to prove whether it would have continued to increase with the parity of the dam will await the running of the experiment for a longer period than five years.

4.1.2.5 Kid mortality

The overall kid mortality between birth and weaning of 22.7 per cent was lower than that of 31.8 per cent reported by Sacker and Trail (1966) in the Mubende goats in Uganda. General weakness and non-specific causes accounted for more deaths than other causes. There was no opportunity to study these cases of mortality and therefore pinpoint the actual causes. Starvation due to lack of milk from the dams might have been one of the major causes of death. The

poor rainfall in 1974, 1975 and 1976 might have led to poor nutrition of the dams and hence to lower milk yield for the kids. Availability of good animal health facilities at the time would have determined the proportion of mortality caused by an outbreak of a skin disease in 1974. The symptoms were fever and the development of papules around the lips, mouth and nostrils. These papules, or pimples, later became umbilicate and exuded a watery fluid. These symptoms could apply either to the viral infection caused by the Goat Pox (Variola caprina) disease as described by the Br. Vet. Assoc. (1968) or to another viral infection caused by Contagious Pustular Dermatitits disease as described by Mackenzie (1970), and Blood and Henderson (1974). According to these authors, the former disease can cause between 3 and 40 per cent mortality in kids, while Contagious Pustular Dermatitits can cause between 25 and 75 per cent mortality. The high mortality rates due to pneumonia in the present study would tend to support the widely held view that, when goats are kept together in large groups, incidences of pneumonia increase. Protection of the kids from the cold by keeping them in well ventilated and warm loose boxes would probably reduce the incidence of the disease. High incidences of pneumonia do not seem to occur to as great an extent in the traditional flocks in the villages in Tanzania. This is probably because, in most cases, goats, sheep and calves are accorded special care in that they are housed in the warmest parts of buildings, compared with pigs and mature cattle. Mackenzie

(1970) has attributed the susceptibility of the goat to pneumonia to lack of protective coat from the cold environments except the heat generated in the rumen during digestion. . If high mortality rates caused by pneumonia have to be reduced in commercial goat production systems, there will be need to pay particular attention to the design of goat houses. Devendra and Burns (1970) have cited studies in India and Egypt in which pneumonia, like the findings in the present study, was one of the main causes of mortality in goat kids between birth and weaning. These authors also advocate proper housing for kids to be one of the ways of reducing mortality in kids.

4.1.2.6 Reproductive failure and mortality in does

The causes of abortions and still births which represented 4 per cent of all the does drafted into mating were, because of lack of animal health facilities at the time, not identified. Although these and the mortality rate in does of about 2 per cent were very low, finding and eliminating the causes for them can lead to bigger improvements in the health and productivity of the flock.

4.2 Weight at Birth, Weaning, One Year and 72 Weeks of Age

4.2.1 Results

4.2.1.1 Birth weight

The total number of kids giving records in the different breed types, parities of dams, sexes and birth types are shown in Table 4.11. The correction factors for adjusting birth weight for the above categories (breed types, etc.) were calculated by the method of least squares analysis described in Chapter 3.6. These factors, together with the least squares means and standard errors for the means, have been shown in Table 4.12. The analysis of variance to test the differences in birth weight due to breeds, sires, parity of dam, sex of kid, birth type whether single or twin, years, seasons and interactions between parity and sex, and sex and birth type, are shown in Table 4.13. The Boer crosses were heavier at birth than the Kamorai crossbred and the Tanzania kids by about 0.3 and 0.2 kg, respectively. These differences were, however, not significant. There were also no differences in birth weights of kids from different sires and parities. Male kids were, however, heavier than the female kids by 0.3 kg ($P < 0.01$), and there were differences in birth weight between kids born as singles and those born as twins ($P < 0.001$). The years had influence on birth weight ($P < 0.001$). The differences between kids in birth weight were not influenced by seasons. There were no interactions between parity and sex, and between sex and birth type.

Table 4.11 Total number of kids giving records in each category

Name of Category	Birth wt.	Weaning wt.	Weight at one year	Weight at 72 weeks
Boer crosses ^a	92	92	92	92
Kamorai crosses ^b	79	79	79	79
Tanzania ^c	123	123	123	123
Parity ^d 1 all breeds	58	58	58	58
2 all breeds	94	94	94	94
3 all breeds	65	65	65	65
4 all breeds	39	39	39	39
5 all breeds	27	27	27	27
6 all breeds	11	11	11	11
Sex:				
Males 1 all breeds	76	76	76	76
Castrates 2 all breeds	87	87	87	87
Females 3 all breeds	131	131	131	131
Birth type:				
Singles 1 all breeds	210	210	210	210
Twins 2 all breeds	84	84	84	84
Total*	294	294	294	294

* Total = a + b + c

d = Parity 7 had one animal a castrate, and in some tables where this animal was included the total number of castrates appears as 88 instead of 87.

Table 4.12 Correction factors, least squares means and standard errors for birth weight

Independent variable	No. of Observations	Correction Factor	Least Squares Means	SE
Overall Mean	294	2.16	2.16	0.06
Boer crosses	92	0.13	2.29	0.09
Kamorai crosses	79	-0.02	2.14	0.09
Tanzania crosses	123	-0.11	2.05	0.08
Parity 1	58	-0.04	2.12	0.10
" 2	94	0.06	2.22	0.07
" 3	65	0.03	2.19	0.08
" 4	39	-0.12	2.04	0.10
" 5	27	0.01	2.17	0.11
" 6	11	0.05	2.20	0.18
Males	76	0.16	2.32	0.09
Castrates	87	0.01	2.17	0.10
Females	131	-0.17	1.98	0.07
Singles	210	0.19	2.35	0.06
Twins	84	-0.19	1.96	0.08
Parity 1 x Males	8	-0.27	2.01	0.20
" 1 x Castrates	18	0.13	2.27	0.14
" 1 x Females	32	0.14	2.09	0.11
" 2 x Males	21	-0.08	2.30	0.13
" 2 x Castrates	32	0.06	2.29	0.11
" 2 x Females	41	0.02	2.07	0.10
" 3 x Males	20	0.03	2.38	0.13
" 3 x Castrates	18	-0.04	2.17	0.13
" 3 x Females	27	0.01	2.02	0.11
" 4 x Males	12	0.04	2.24	0.16
" 4 x Castrates	11	0.02	2.07	0.17
" 4 x Females	16	-0.06	1.80	0.14
" 5 x Males	11	0.18	2.51	0.17
" 5 x Castrates	6	-0.01	2.17	0.22
" 5 x Females	10	-0.17	1.82	0.17
" 6 x Males	4	0.10	2.46	0.27
" 6 x Castrates	2	-0.16	2.05	0.39
" 6 x Females	5	0.07	0.09	0.24
Male singles	54	-0.06	2.46	0.09
Male twins	22	0.06	2.18	0.13
Castrate singles	66	0.08	2.44	0.10
Castrate twins	21	-0.08	1.90	0.14
Female singles	90	-0.02	2.15	0.08
Female twins	41	0.02	1.81	0.10

Table 4.13 The analysis of variance to test at various ages the differences due to breeds, sires within breeds, parity, sexes (males, females and castrates), birth type, years, seasons and interaction, parity x sex, and sex x birth type

	Birth wt.	Weaning wt.	Wt. at 1 year	Wt. at 72 weeks
Breed type	NS	NS	NS	NS
Sire/breed	NS	*	NS	*
Parity	NS	NS	***	***
Sex	**	*	**	**
Birth type	***	*	NS	NS
Years	***	***	***	***
Seasons	NS	***	***	***
Parity x Sex	NS	NS	NS	NS
Sex x Birth type	NS	NS	NS	NS

NS = Not significant at $P < 0.05$

* = Significant at $P < 0.05$

** = Significant at $P < 0.01$

*** = Significant at $P < 0.001$

4.2.1.2 Weight at weaning

Factors for adjusting the weaning weight to a mean weight for the sample used in the study, the least squares means and the standard errors of the means are shown in Table 4.14. The analysis of variance to test the differences in weaning weight between the different breeds, sexes, types of birth and parity of dams are presented in Table 4.13. The Boer crossbred kids were heavier at weaning than either the Kamorai crossbred or the Tanzania kids by 0.7 kg and 1.3 kg, respectively. The Kamorai crossbred kids were only 0.6 kg heavier than the Tanzania kids at this age. These differences between breed types were, however, not significant. There were also no significant differences in weaning weight, between parities of dams, in the interaction between parities and sex, and between sex and birth types of kids. There were, however, differences in weaning weight between kids from different sires and sexes ($P < 0.05$), and those born in different years ($P < 0.001$) and seasons ($P < 0.001$). The castrated kids were on the average 0.3 kg heavier than the entire male kids. This difference was, however, not significant.

4.2.1.3 Weight at one year of age

The correction factors, least squares means and the standard errors of the means for weight at one year of age are shown in Table 4.15. The analysis of variance to test the differences in weights at one year of age between breed types, sexes, types of birth and parity of dams are presented in Table 4.13. The Boer crossbred kids were heavier than

Table 4.14 Correction factors, least squares means and standard errors for birth weight

Independent variable	No. of Observations	Correction Factor	Least Squares Means	SE
Overall Mean	294	9.25	9.25	0.35
Boer crosses	92	0.68	9.93	0.51
Kamorai crosses	79	-0.06	9.19	0.52
Tanzania	123	-0.62	8.62	0.45
Parity 1	58	0.40	9.65	0.49
" 2	94	0.19	9.44	0.40
" 3	65	-0.21	9.03	0.42
" 4	39	-0.21	9.03	0.42
" 5	27	-0.48	8.77	0.57
" 6	11	-0.47	8.78	0.86
Males	76	0.19	9.44	0.45
Castrates	87	0.47	9.72	0.52
Females	131	-0.66	8.59	0.40
Singles	210	0.41	9.65	0.36
Twins	84	-0.41	8.84	0.42
Parity 1 x Males	8	-0.83	9.01	0.94
" 1 x Castrates	18	0.42	10.54	0.66
" 1 x Females	32	0.41	9.40	0.55
Parity 2 x Males	21	-0.48	9.15	0.65
" 2 x Castrates	32	0.19	10.11	0.54
" 2 x Females	41	0.28	9.06	0.49
" 3 x Males	20	0.00	9.22	0.62
" 3 x Castrates	18	-0.12	9.39	0.66
" 3 x Females	27	0.11	8.49	0.56
" 4 x Males	12	0.85	10.85	0.76
" 4 x Castrates	11	-0.48	9.80	0.82
" 4 x Females	16	-0.37	8.78	0.68
" 5 x Males	11	0.33	9.29	0.80
" 5 x Castrates	6	-0.24	9.01	1.06
" 5 x Females	10	-0.10	8.01	0.82
" 6 x Males	4	0.12	9.09	1.27
" 6 x Castrates	2	0.22	9.48	1.81
" 6 x Females	5	-0.34	7.78	1.14
Male singles	54	-0.12	9.72	0.48
Male twins	22	0.12	9.15	0.63
Castrate singles	66	0.16	10.29	0.50
Castrate twins	21	-0.16	9.16	0.70
Female singles	90	-0.05	8.95	0.44
Female twins	41	0.05	8.23	0.49

Table 4.15 Correction factors, least squares means and standard errors for weight at 1 year of age

Independent variable	No. of Observations	Correction Factor	Least Squares Means	SE
Overall mean	294	12.62	12.62	0.84
Boer crosses	92	1.48	14.11	1.22
Kamorai crosses	79	1.35	13.97	1.26
Tanzania	123	-2.84	9.79	1.08
Parity 1	58	2.80	15.42	1.29
" 2	94	3.80	16.43	1.00
" 3	65	1.86	14.48	1.08
" 4	39	1.79	14.44	1.30
" 5	27	-3.49	9.14	1.54
" 6	11	-6.76	5.86	2.42
Males	76	-0.43	12.19	1.18
Castrates	87	2.59	15.22	1.39
Females	131	-2.17	10.46	0.99
Singles	210	-0.70	11.92	0.87
Twins	84	0.70	13.32	1.08
Parity 1 Males	8	-0.99	14.00	2.66
" 1 Castrates	18	0.40	18.42	1.83
" 1 Females	32	0.59	13.84	1.48
" 2 Males	21	-1.64	14.36	1.80
" 2 Castrates	32	-0.16	18.86	1.45
" 2 Females	41	1.80	16.06	1.29
" 3 Males	20	1.65	15.70	1.70
" 3 Castrates	18	-1.66	15.41	1.82
" 3 Females	27	0.02	12.34	1.51
" 4 Males	12	1.58	15.56	2.13
" 4 Castrates	11	-1.97	15.03	2.30
" 4 Females	16	0.39	12.64	1.87
" 5 Males	11	-0.22	8.48	2.23
" 5 Castrates	6	1.85	13.58	3.01
" 5 Females	10	-1.62	5.35	2.31
" 6 Males	4	-0.37	5.06	3.63
" 6 Castrates	2	1.55	10.00	5.19
" 6 Females	5	-1.18	2.51	3.24
Male singles	54	0.64	12.13	1.26
Male twins	22	-0.64	12.26	1.73
Castrate singles	66	-0.54	13.98	1.31
Castrate twins	21	0.54	16.46	1.95
Female singles	90	-0.10	9.66	1.15
Female twins	41	0.10	11.26	1.30

either the Kamorai crossbred or the Tanzania goat kids by 0.1 and 4.3 kg, respectively. The Kamorai crossbred kids were in turn heavier than the Tanzania goat kids by 4.2 kg. These differences were, however, not significant. The differences in weight due to parity, years and seasons were highly significant ($P < 0.001$), while the differences in weight due to sex of kid were significant at $P < 0.01$. The differences in weights of kids due to sire, birth type and the interaction between parity and sex, and between sex and birth type at this age were not significant. The castrate kids were on the average heavier than the entire male kids by 3.0 kg at one year of age. This difference was close to significance.

4.2.1.4 Weight at 72 weeks of age

Factors for adjusting weight of kids to a common sample mean at 72 weeks of age, the least squares means and their standard errors are presented in Table 4.16. The analysis of variance to test the differences in weights of kids due to breed types, sires, parity of dam, sex, birth type, years, seasons and the interactions between parity and sex and between sex and birth type are shown in Table 4.13. At this age, the Kamorai crossbred kids were heavier than the Boer crossbred and the Tanzania goat kids by 0.3 and 6.1 kg, respectively. The Boer crossbred kids were in turn heavier than the Tanzania goat kids by 5.9 kg. However, these differences were not significant. The differences in weight due to parities, years and seasons were highly significant ($P < 0.001$), while that due to sex

Table 4.16 Correction factors, least squares means and standard errors for weight at 72 weeks

Independent variable	No. of Observations	Correction Factor	Least Squares Means	SE
Overall mean	294	15.63	15.63	1.30
Boer crosses	92	1.87	17.50	1.89
Kamorai crosses	79	2.12	17.75	1.92
Tanzania	123	-3.98	11.65	1.68
Parity 1	58	4.14	19.78	1.75
" 2	94	3.87	19.51	1.46
" 3	65	2.55	18.18	1.53
" 4	39	2.71	18.34	1.76
" 5	27	-4.20	11.43	2.12
" 6	11	-9.07	6.56	3.00
Males	76	-0.65	14.99	1.64
Castrates	87	3.29	18.93	1.86
Females	131	-2.65	12.99	1.45
Singles	210	-1.01	14.63	1.33
Twins	84	1.01	16.64	1.53
Parity 1 Males	8	-1.77	17.36	3.28
" 1 Castrates	18	1.15	24.22	2.33
" 1 Females	32	0.62	17.75	1.95
" 2 Males	21	-1.61	17.25	2.30
" 2 Castrates	32	-0.92	21.89	1.92
" 2 Females	41	2.53	19.39	1.75
" 3 Males	20	1.73	19.26	1.20
" 3 Castrates	18	-2.04	19.43	2.32
" 3 Females	27	0.31	15.85	1.98
" 4 Males	12	2.60	20.30	2.67
" 4 Castrates	11	-2.77	18.86	2.86
" 4 Females	16	0.17	15.87	2.38
" 5 Males	11	-0.90	9.89	2.78
" 5 Castrates	6	3.41	18.13	3.69
" 5 Females	10	-2.51	6.28	2.88
" 6 Males	4	-0.05	5.86	4.40
" 6 Castrates	2	1.18	11.03	6.24
" 6 Females	5	-1.12	2.79	3.95
Male singles	54	1.32	15.30	1.72
Male twins	22	-1.32	14.67	2.22
Castrate singles	66	-1.05	16.87	1.77
Castrate twins	21	1.05	20.98	2.46
Female singles	90	-0.27	11.71	1.60
Female twins	41	0.27	14.27	1.76

was significant at $P < 0.01$. The influence of birth type, and the interaction between parity and sex, and between sex and birth type were not significant. The castrated kids were heavier than the entire male kids by 3.9 kg, but this difference did not reach significance.

4.2.1.5 Correlation between weights at different ages

The correlations between birth weight and weight at various ages are presented in Table 4.17. The correlations between birth weight and weight at each of the other ages, namely, weaning, one year and 72 weeks, were 0.3, 0.1 and 0.2, respectively. The former correlation of 0.31 between birth weight and weight at weaning was significant at $P < 0.01$. The correlation between weaning weight and yearling weight was 0.4, while that between weaning weight and weight at 72 weeks was 0.5. Both these correlations were significant; the former at $P < 0.01$ and the latter at $P < 0.001$. The correlation between yearling weight and weight at 72 weeks of age was 0.9, and this was significant at $P < 0.01$.

4.2.1.6 Heritability estimates for weight at birth, weaning, one year and 72 weeks of age

The heritability estimates for weight of kids at various ages are shown in Table 4.17. These were obtained from paternal half-sib analyses and were estimated as four times the half-sib correlation.

Table 4.17 Heritabilities (on), phenotypic (below), environmental (below in parenthesis) and genetic (above diagonal) correlations between birth weight, weights at weaning, one year and 72 weeks of age

	BWT	SE ^a	WWT	SE ^a	WAT 1Y	SE ^a	WAT 72	SE ^a
Birth wt. (BWT)	0.07	0.10	1.43	0.72	-1.00	0.85	-0.41	0.88
Weaning wt. (WWT)	0.31	0.10	0.14	0.14	0.02	1.03	0.39	0.68
Wt. at 1 year (WAT 1Y)	0.14	(0.23)	0.44	(0.48)	0.07	0.11	1.06	0.13
Wt. at 72 weeks (WAT 72)	0.15	0.15	0.46	(0.47)	0.93	0.17	0.16	(0.93)

a = SE of heritabilities and genetic correlations only

4.2.1.7 Mature size of the foundation goats

The weights and body measurements of the mature bucks and does used in the mating groups are shown in Table 4.18. The Tanzania male and female goats had lighter weights than either the Boer or the Kamorai crossbred goats of similar sex. The former had also smaller body measurements except for width of the hind quarters in which the Tanzania goat bucks and does exceeded the Boer goats. The Tanzania bucks were as wide as the Kamorai bucks while the does belonging to the former breed type had larger width measurements by 0.5 cm than the Kamorai does.

4.3 Growth of Kids

4.3.1 Results

4.3.1.1 Increase in weight

The growth rates of kids from birth to various ages are shown in Tables 4.19 and 4.20. The average growth rate between birth and weaning was 64.3 g per day while that between weaning and 72 weeks of age was 24.3 g per day. The Boer kids grew faster before and after weaning than either the Kamorai or the Tanzania kids. The Kamorai kids in turn grew faster at these two periods than the Tanzania kids. The rate of growth of 65.8 g per day for single kids was higher than that of 60.4 g per day for twins between birth and weaning. After weaning the kids from the two birth types grew at almost the same rate. Tables 4.21 and 4.22 show the differences in the rates of growth between various periods. The growth rate of kids

Table 4.18 Mature size of the foundation bucks and of samples of does taken at the commencement of mating

Character	B r e e d t y p e							
	Tanzania		Boer		Kamorai			
	Male	Female	Male	Female	Male	Female	Male	Female
Weight (kg)	37.0 (2)	30.0 (25)	40.8 (2)	33.4 (9)	44.0 (2)	31.0 (5)		
Height at withers (cm)	57.8 (2)	61.3 (25)	74.8 (2)	65.8 (3)	67.3 (2)	65.1 (5)		
Heart girth (cm)	73.0 (2)	73.3 (25)	80.6 (2)	69.3 (3)	84.4 (2)	74.3 (5)		
Width of hind quarters between widest points (cm)	16.5 (2)	16.1 (25)	14.5 (2)	15.1 (3)	16.9 (2)	15.6 (5)		
Length from pin bones to point of shoulder (cm)	57.7 (2)	57.6 (25)	67.5 (2)	63.5 (3)	60.6 (2)	60.4 (5)		

Table 4.19 Mean daily growth rates in g/day at various ages
In parenthesis is the numbers of goats

Age	Grand Mean	Breed				Birth type			Sex		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates		
Birth - 4 wks	116.6 (295)	115.8 (124)	111.2 (79)	122.3 (92)	121.5 (211)	104.1 (84)	122.6 (164)	109.0 (131)	-		
Birth - 12 wks	75.3 (295)	71.6 (124)	73.0 (79)	82.2 (92)	78.2 (211)	68.0 (84)	75.8 (76)	72.1 (131)	79.6 (88)		
Birth - 16 wks	64.3 (295)	60.2 (124)	64.1 (79)	69.9 (92)	65.8 (211)	60.4 (84)	63.5 (76)	61.7 (131)	68.8 (88)		
Birth - 24 wks	49.8 (295)	46.1 (124)	50.6 (79)	54.1 (92)	49.8 (211)	49.8 (84)	49.4 (76)	47.6 (131)	53.4 (88)		
Birth - 36 wks	43.9 (295)	41.8 (124)	43.9 (79)	46.9 (92)	44.4 (211)	42.7 (84)	43.3 (76)	41.9 (131)	47.6 (88)		
Birth - 48 wks	40.2 (295)	37.4 (124)	40.4 (79)	43.6 (92)	40.7 (211)	38.8 (84)	40.6 (76)	37.7 (131)	43.5 (88)		
Birth - 60 wks	38.1 (295)	34.9 (124)	39.5 (79)	41.0 (92)	38.2 (211)	37.7 (84)	38.4 (76)	36.0 (131)	40.8 (88)		
Birth - 72 wks	36.6 (295)	33.0 (124)	38.2 (79)	40.1 (92)	36.8 (211)	36.4 (84)	37.4 (76)	34.4 (131)	39.3 (88)		

Table 4.20 Comparison of the rates of growth (g/day) of goat kids at various intervals in the growth period

Age	Grand Mean	Breed \pm 1.262			Birth type \pm 1.228		Sex \pm 1.277		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates
Birth - 4 weeks	116.60	115.8 (124)	111.2 (79)	122.3 (92)	121.5 (211)	104.1 (84)	122.6 (164)	109.0 (131)	-
4-12 weeks	54.47	49.4 (124)	53.7 (79)	62.0 (92)	55.4 (211)	52.1 (84)	54.5 (76)	52.1 (131)	57.9 (88)
12-24 weeks	24.36	20.5 (124)	28.7 (79)	25.9 (92)	21.2 (211)	32.3 (84)	23.3 (76)	23.3 (131)	26.6 (88)
24-36 weeks	27.73	26.5 (124)	28.6 (79)	28.6 (92)	27.7 (211)	27.7 (84)	25.1 (76)	26.5 (131)	31.9 (88)
36-48 weeks	28.33	23.5 (124)	30.0 (79)	33.3 (92)	29.3 (211)	25.9 (84)	29.8 (76)	24.8 (131)	32.3 (88)
48-60 weeks	28.79	24.6 (124)	34.4 (79)	30.4 (92)	27.4 (211)	33.0 (84)	28.1 (76)	29.2 (131)	29.5 (88)
60-72 weeks	30.84	26.5 (124)	32.8 (79)	35.0 (92)	29.9 (211)	33.2 (84)	34.6 (76)	27.1 (131)	33.1 (88)

Table 4.21 Differences in rates of growth (g) of goat kids between the birth to 4 week period and other periods

Age	Grand Mean	Breed			Birth type		Sex		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates
Birth - 4 wks	0								
Birth - 12 wks	41.3	44.2	38.2	40.1	43.3	36.1	46.8	36.9	-
Birth - 16 wks	11.0	11.4	8.9	12.3	12.4	7.6	12.3	10.4	10.8
Birth - 24 wks	14.5	14.1	13.5	15.8	16.0	10.6	14.1	14.1	15.4
Birth - 36 wks	5.8	4.3	6.7	7.2	5.3	7.1	6.1	5.7	5.9
Birth - 48 wks	3.8	4.4	3.4	3.3	3.7	3.9	2.7	4.2	4.1
Birth - 60 wks	2.1	2.5	0.9	2.6	2.5	1.1	2.3	1.6	2.6
Birth - 72 wks	1.4	1.9	1.3	0.9	1.5	1.4	1.0	1.6	1.6

Table 4.22 Differences in mean growth rates g/day of goat kids between the rate at any one period and that at the preceding period

Age	Grand Mean	Breed		Birth type		Sex			
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates
Birth - 4 wks	62.1	66.4	57.5	60.3	66.1	52.0	68.1	56.9	-
12 - 24 wks	30.1	28.9	25.0	36.2	34.2	19.9	20.8	28.9	31.4
24 - 36 wks	-3.4	-6.1	0.1	-2.7	-6.6	4.6	-1.4	-3.2	-5.3
36 - 48 wks	-0.6	3.0	-1.4	-4.8	-1.6	1.8	-4.7	1.7	-0.4
48 - 60 wks	-0.7	-1.0	-4.3	3.0	1.9	-7.1	1.7	-4.4	2.8
60 - 72 wks	-1.9	-2.0	1.5	-4.6	-2.5	-0.3	-6.5	2.1	-3.7

was high after birth and then it decreased as they grew older. This is confirmed by the slope of the growth curves shown in Figures 4.3 and 4.4, and by the regression lines obtained by computing weight in kg against age in weeks shown in Figures 4.5 to 4.10.

The analysis of variance to test the differences in growth rates between various groups of kids (Table 4.23) showed a highly significant difference ($P < 0.001$) between breed types and for the interaction between age of kids and parity. The differences in growth rates between the male and the female kids and between the kids from different parities were significant at $P < 0.05$ only.

4.3.1.2 Increase in body measurements

The rate of increase in height above the withers (mm per day) in kids of various categories is shown in Table 4.24, while the mean height in centimetres at various ages is shown in Table 4.25 and Figures 4.11 to 4.15. There was a tendency for the Kamorai crossbred kids to increase in height at the withers faster than other breed types at all ages. The Boer crossbred kids in turn tended to increase faster than the Tanzania kids in this characteristic. The analysis of variance to test the differences between various groups of kids in the increase in height at the withers (Table 4.26) showed a significant breed difference ($P < 0.05$), and a difference between single and twin kids ($P < 0.05$).

Table 4.23 Analysis of variance to test the differences in growth rate between breeds, birth type (singles, twins), sexes (males, females and castrates), years, seasons and parity

Period	Breeds	Birth types	Sexes		Years	Seasons	Parity
			Males + Castrates vs Females	Castrates vs Rest			
Birth - 4 wks	NS	**	*	NS	*	*	NS
Birth - 12 wks	*	**	*	NS	***	***	NS
Birth - 16 wks	**	*	*	NS	***	***	*
Birth - 24 wks	***	NS	*	NS	***	***	NS
Birth - 36 wks	*	NS	*	*	***	***	NS
Birth - 48 wks	***	NS	***	NS	***	***	NS
Birth - 60 wks	***	NS	**	NS	***	***	NS
Birth - 72 wks	***	NS	***	NS	***	***	NS
4 - 12 wks	*	NS	NS	NS	***	***	NS
12 - 24 wks	*	***	NS	NS	***	***	NS
24 - 48 wks	*	NS	*	NS	***	***	NS
48 - 72 wks	***	NS	NS	NS	***	***	NS

* = Significant at P < 0.05
 ** = Significant at P < 0.01
 *** = Significant at P < 0.001
 NS = Not significant at P < 0.05

Table 4.24 Rate of increase in height at withers (mm per day) in goat kids at various ages

Age Periods	Grand Mean	Breed \pm 0.0225			Birth type \pm 0.0221			Sex \pm 0.0230		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates	
4 - 12 wks	1.0	0.9 (124)	1.1 (79)	1.0 (92)	1.0 (211)	1.0 (84)	1.0 (76)	1.0 (131)	1.0 (88)	
12 - 24 wks	0.5	0.4 (124)	0.5 (79)	0.5 (92)	0.4 (211)	0.5 (84)	0.4 (76)	0.4 (131)	0.5 (88)	
24 - 36 wks	0.4	0.3 (124)	0.4 (79)	0.4 (92)	0.3 (211)	0.5 (84)	0.3 (76)	0.4 (131)	0.4 (88)	
36 - 48 wks	0.3	0.2 (124)	0.3 (79)	0.3 (92)	0.2 (211)	0.3 (84)	0.2 (76)	0.2 (131)	0.3 (88)	
48 - 60 wks	0.3	0.2 (124)	0.2 (79)	0.3 (92)	0.2 (211)	0.3 (84)	0.3 (76)	0.2 (131)	0.2 (88)	
60 - 72 wks	0.2	0.1 (124)	0.2 (79)	0.2 (92)	0.1 (211)	0.3 (84)	0.2 (76)	0.2 (131)	0.2 (88)	

Table 4.25 Mean height (cm) at the withers at various ages

Age in weeks	Grand Mean	Breed			Birth type		Sex		
		Tanzania	Kamorai	Boer	Singles	Twins	Male	Female	Castrate
4	36.1 SE ± 0.29	35.2	36.0	37.2	36.5	35.0	36.3	35.4	36.8
		± 0.21	± 0.21	± 0.21	± 0.21	± 0.20	± 0.21	± 0.21	± 0.21
12	41.7	40.4	42.4	42.9	42.0	40.8	41.8	41.0	42.5
24	45.5	43.7	46.6	46.9	45.9	44.6	44.9	44.7	47.0
36	49.3	47.5	50.6	50.5	49.4	48.9	48.5	48.7	50.9
48	51.4	49.5	52.9	52.6	51.4	51.4	50.1	50.6	53.6
60	53.5	51.6	54.8	55.1	53.5	53.5	53.0	52.6	55.3
72	54.8	52.5	56.5	56.5	54.6	55.4	53.9	54.2	56.5

Table 4.26 Analysis of variance to test the differences in increase of body measurements when ages were pooled

Source of variation	Characteristic			
	Height at withers	Heart girth	Width of hind quarters	Length of point of shoulder to pin bones
Age	***	***	***	***
Breed	*	*	NS	*
Sex	NS	NS	NS	NS
Birth type	*	*	NS	NS
Parity	NS	NS	*	NS
Age x breed	NS	**	NS	NS
Age x sex	NS	**	NS	NS
Age x type of birth	NS	*	NS	*
Age x parity	NS	***	*	*

NS = Not significant at $P < 0.05$

* = Significant at $P < 0.05$

** = Significant at $P < 0.01$

*** = Significant at $P < 0.001$

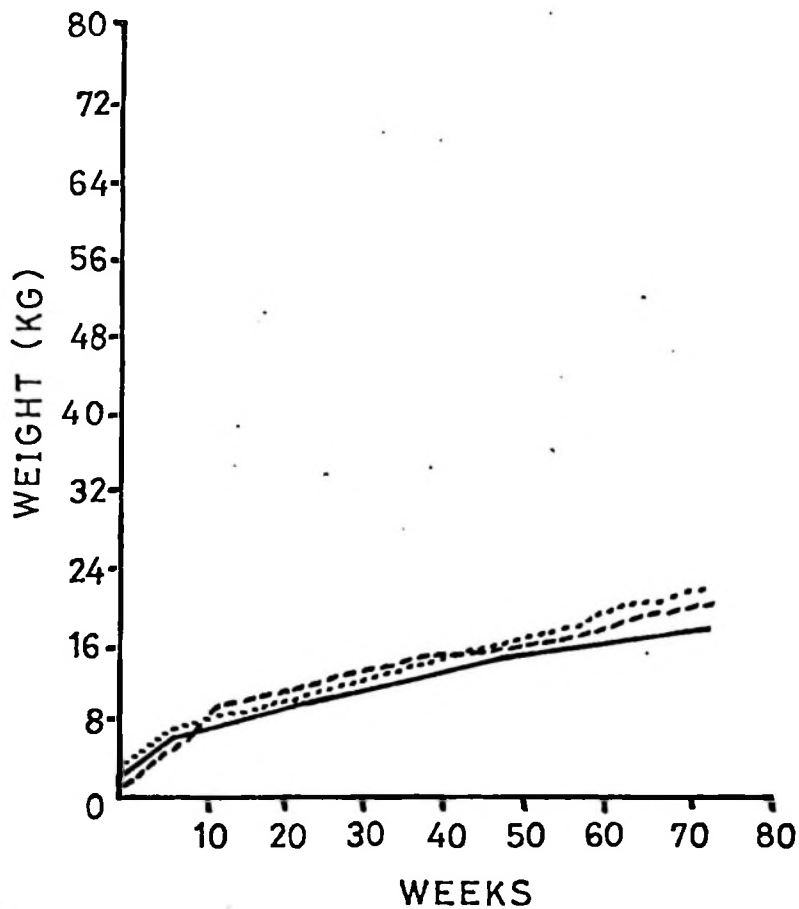
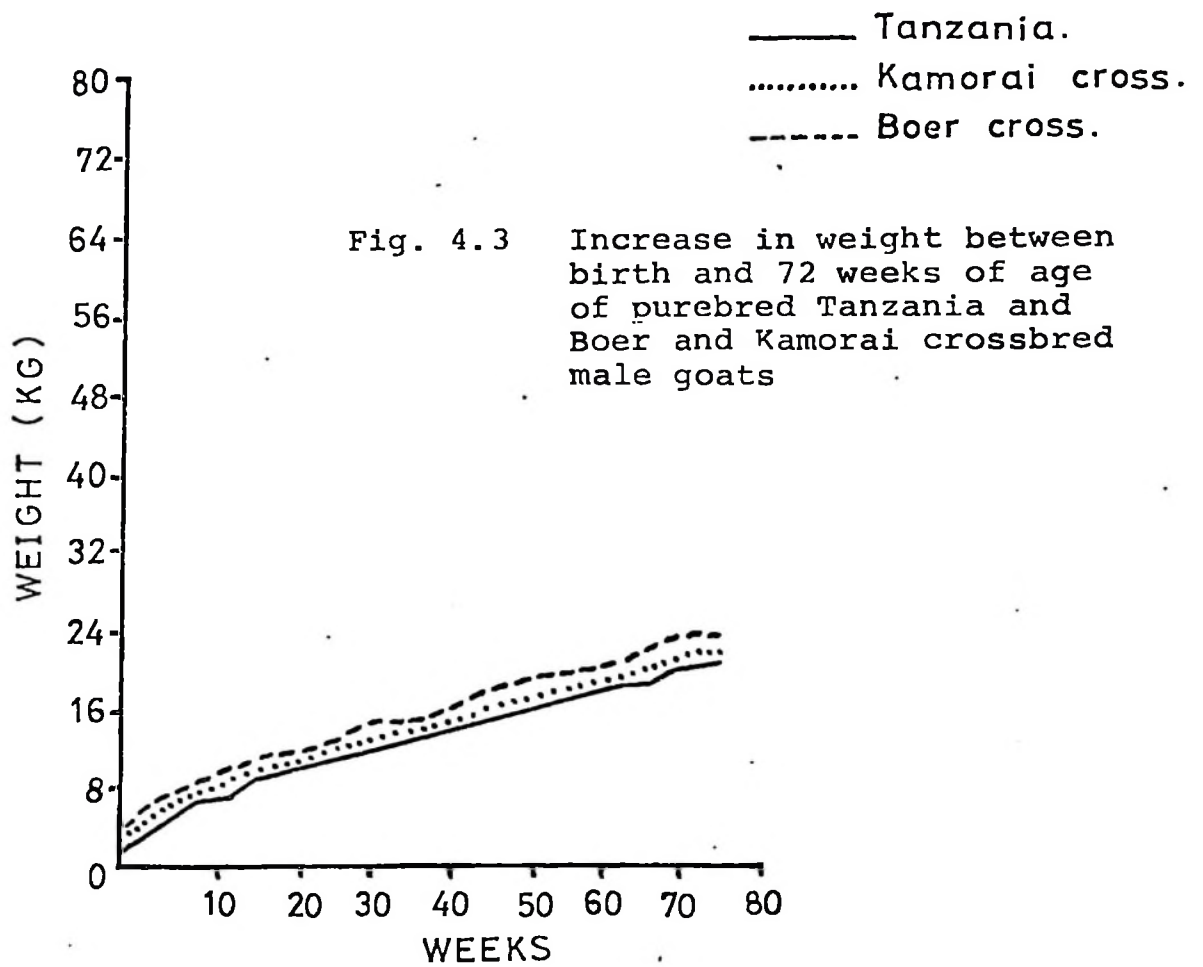
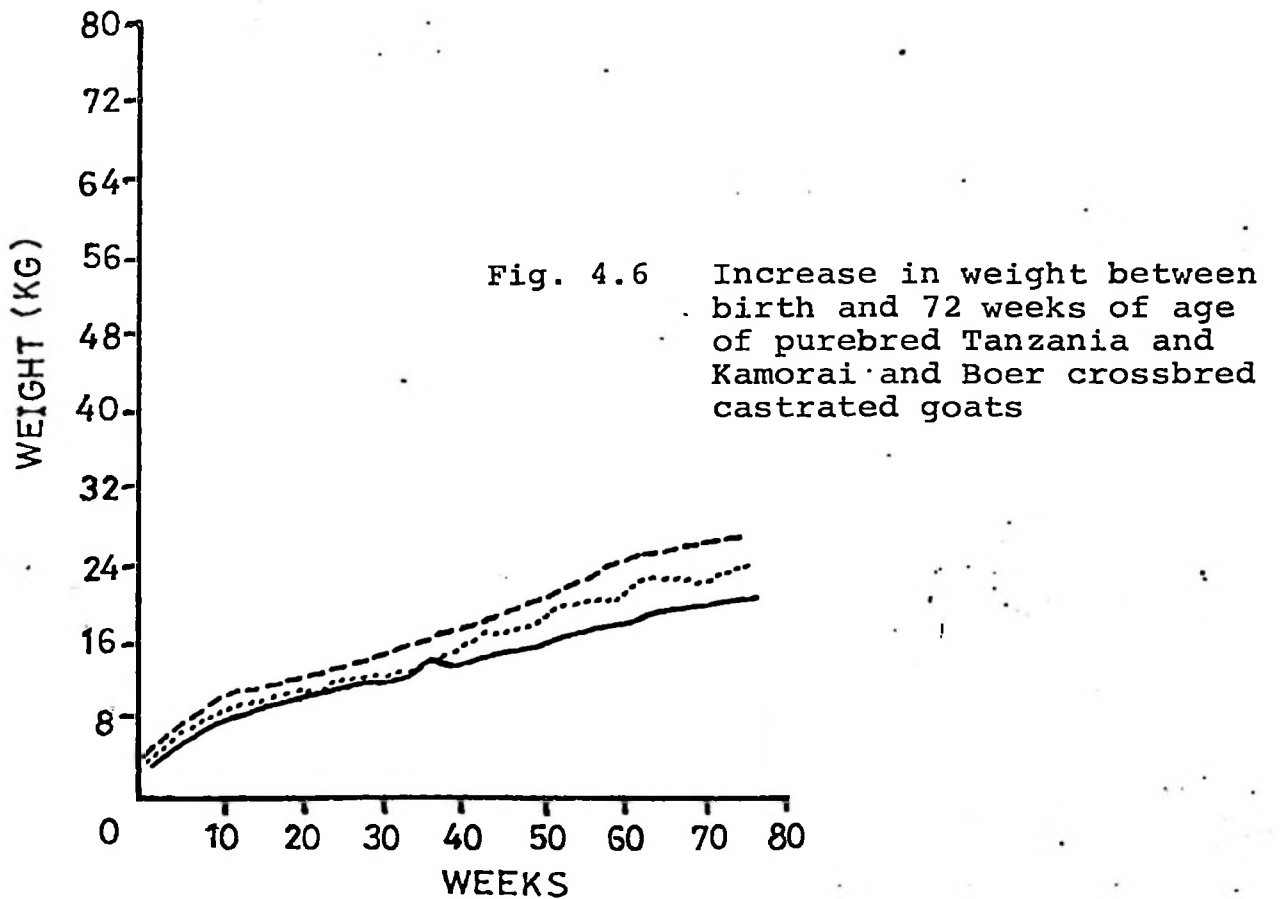
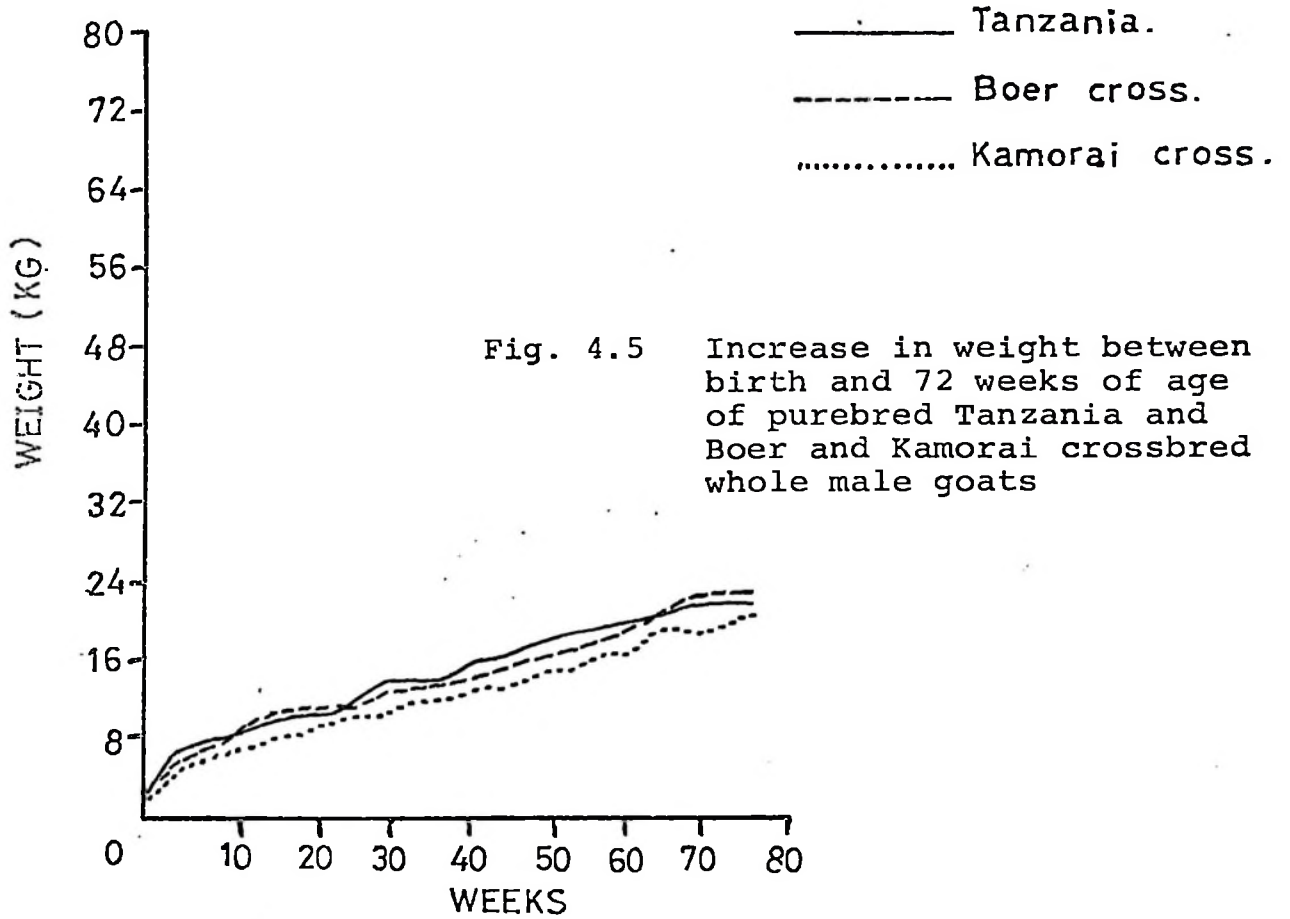
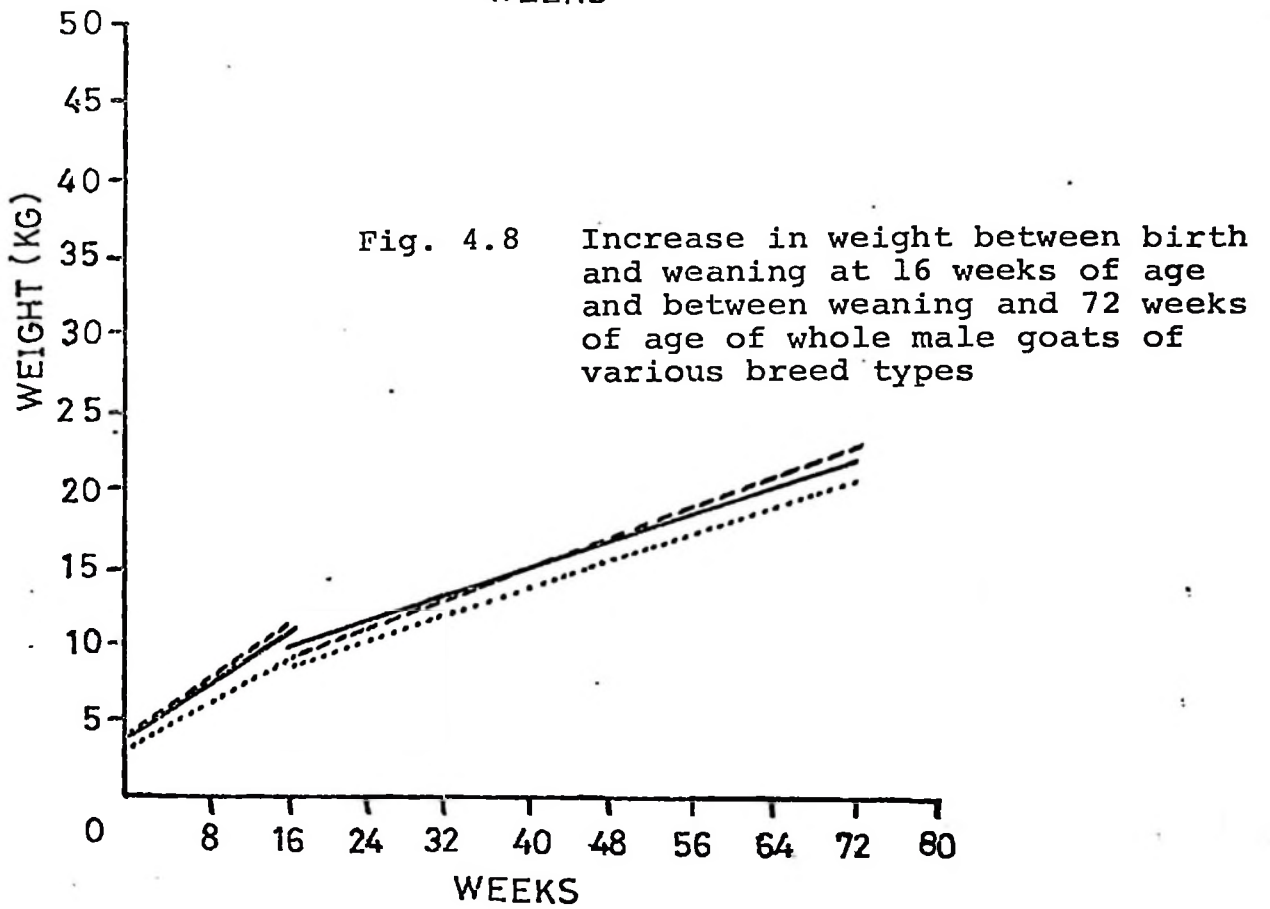
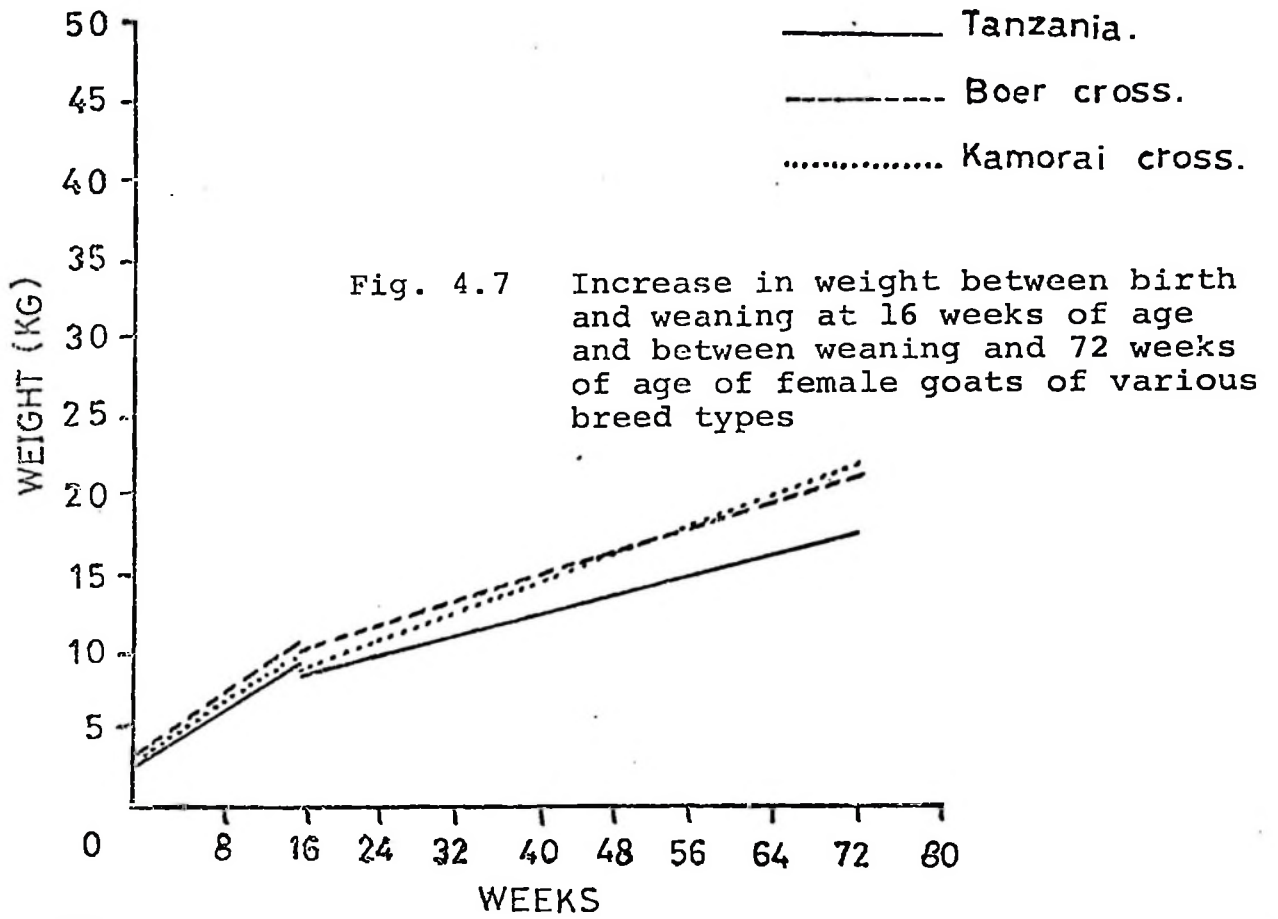


Fig. 4.4 Increase in weight between birth and 72 weeks of age of purebred Tanzania and Kamorai and Boer crossbred female goats





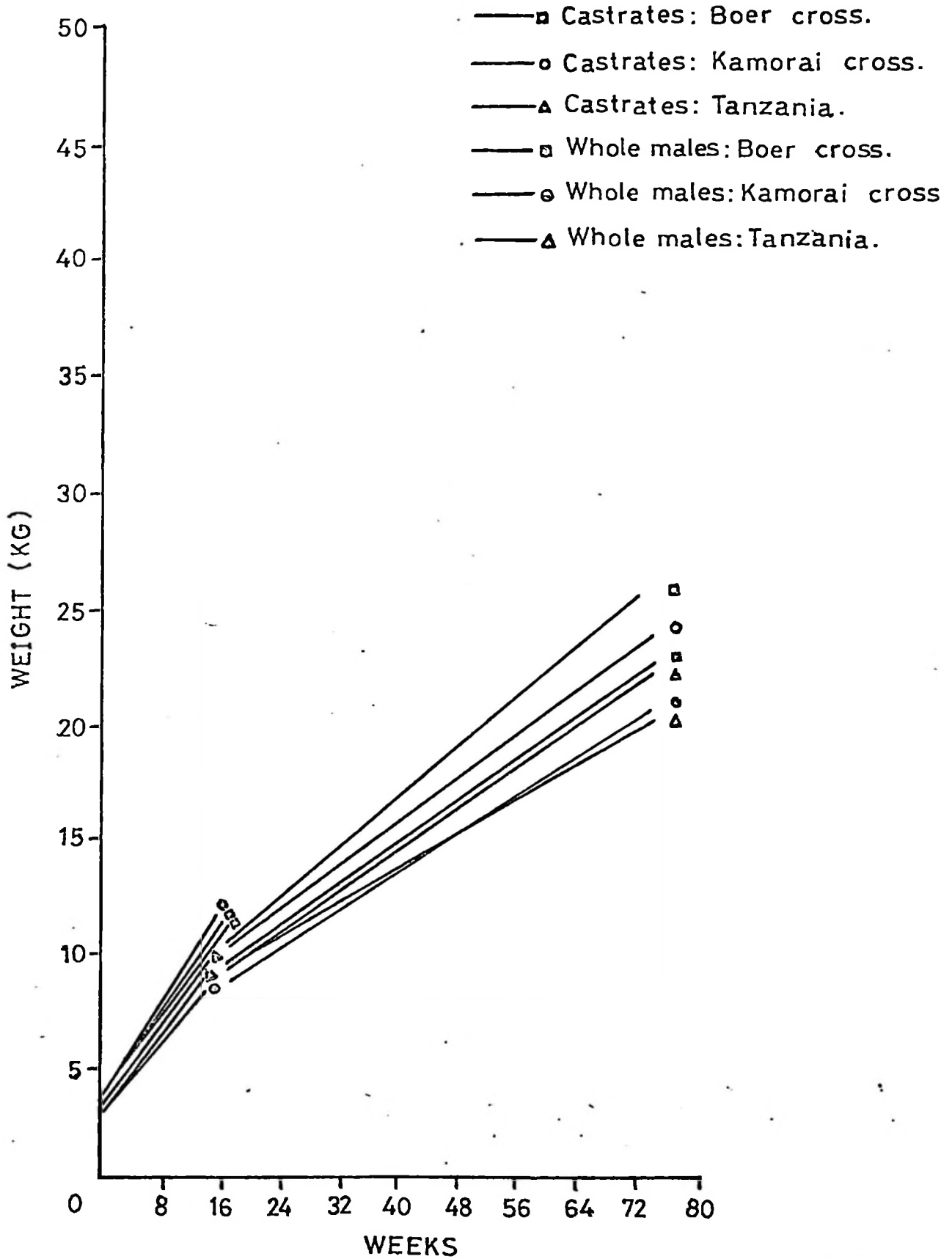


Fig. 4.9 Increase in weight between birth and weaning and between weaning and 72 weeks of age of castrate and whole male goats of various breed types

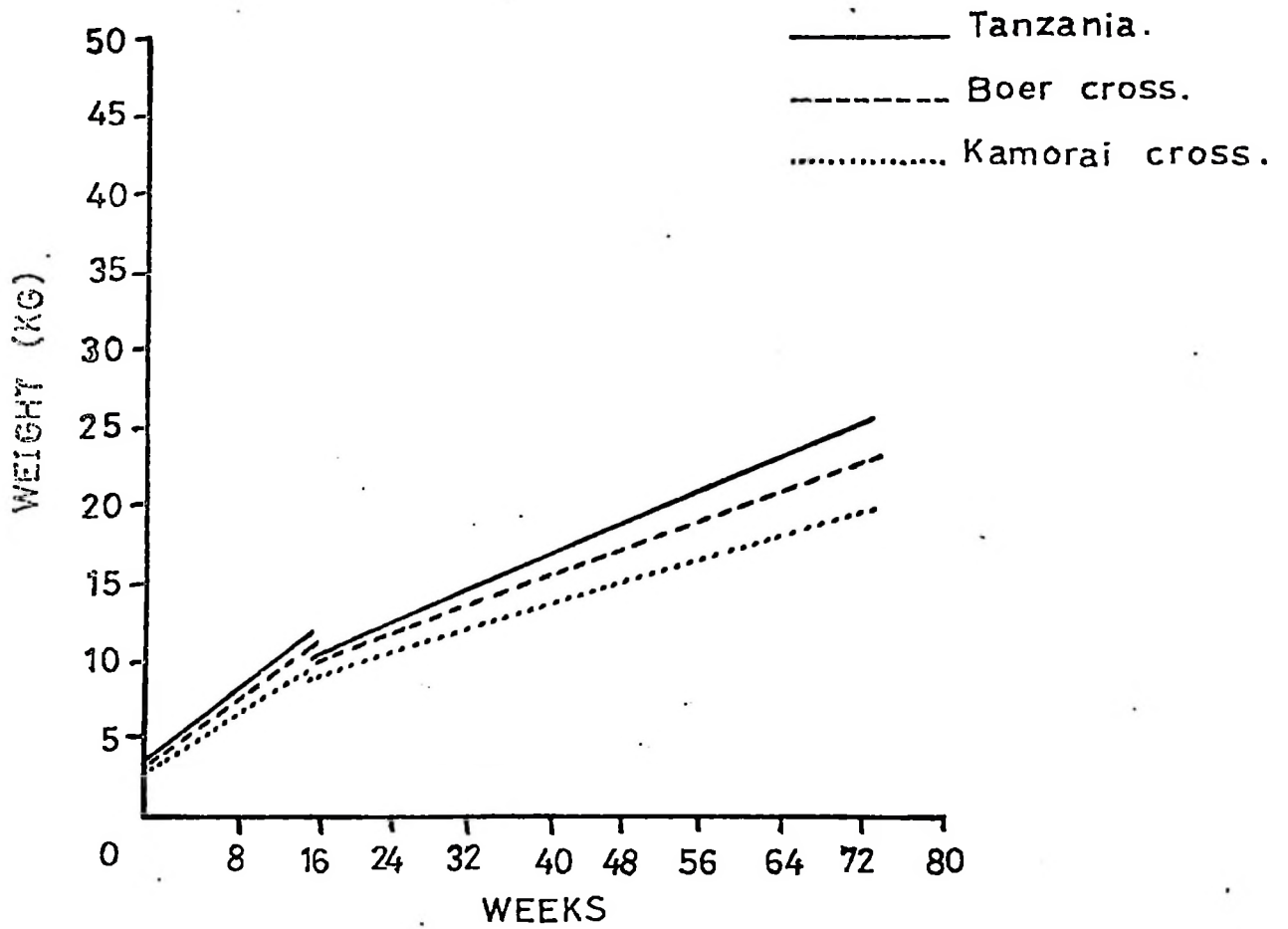
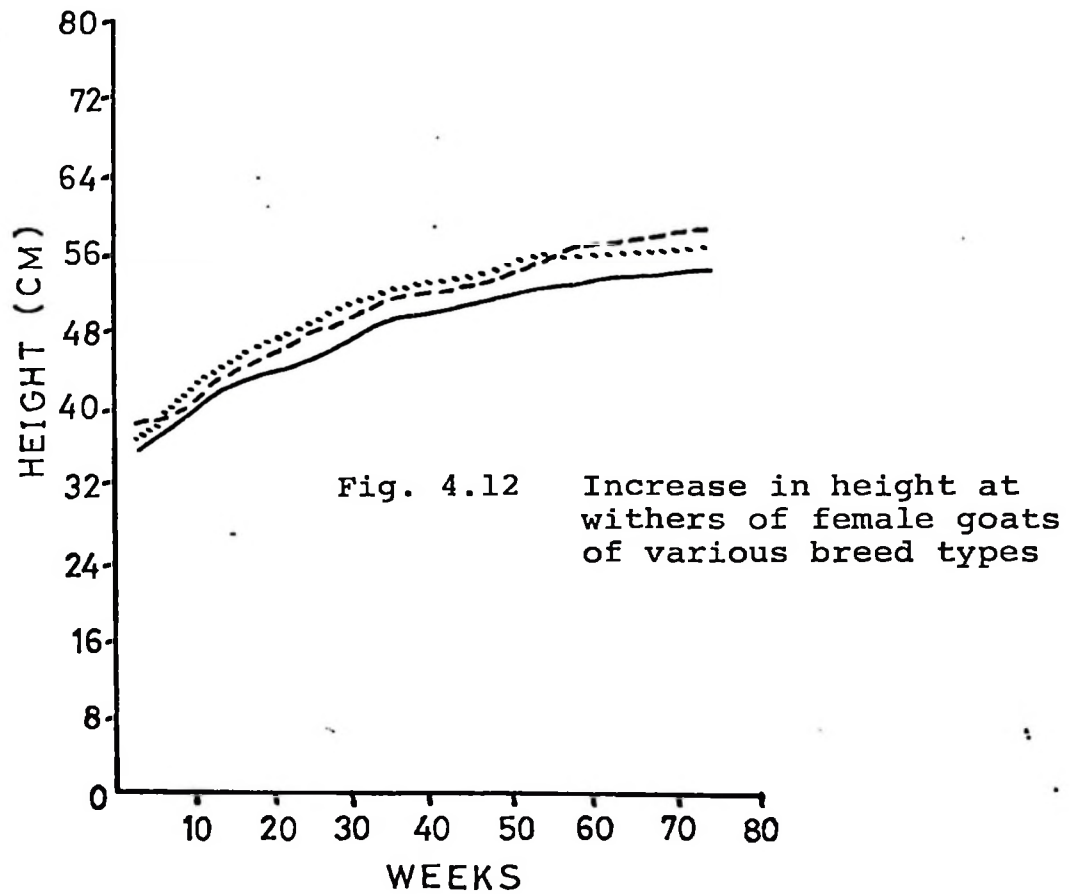
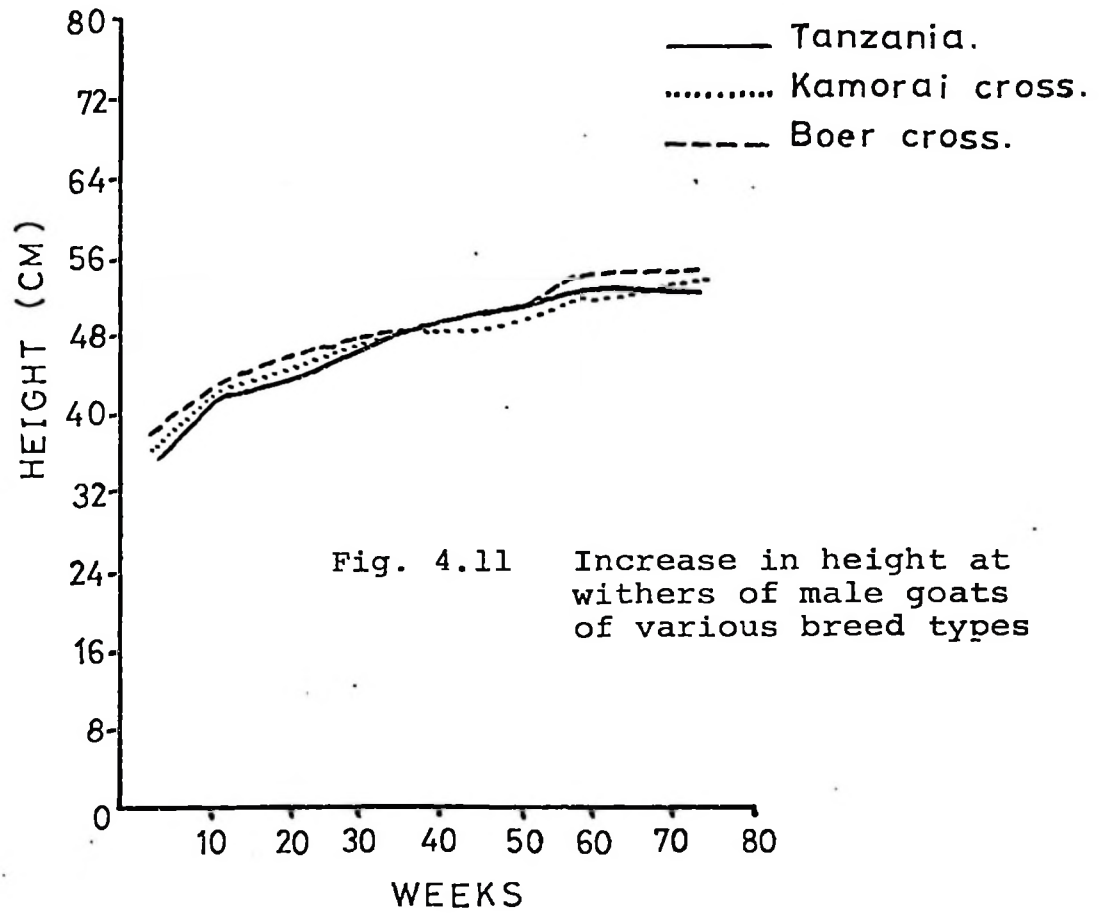
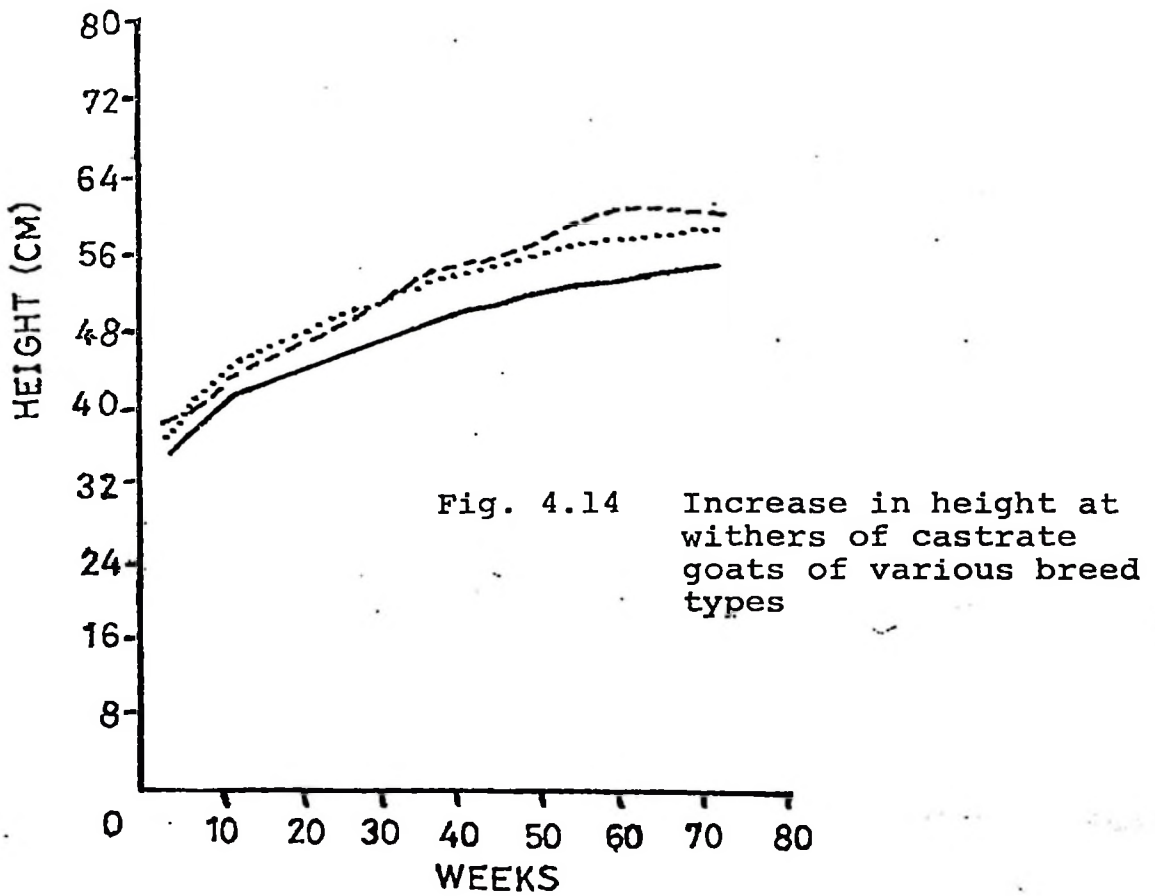
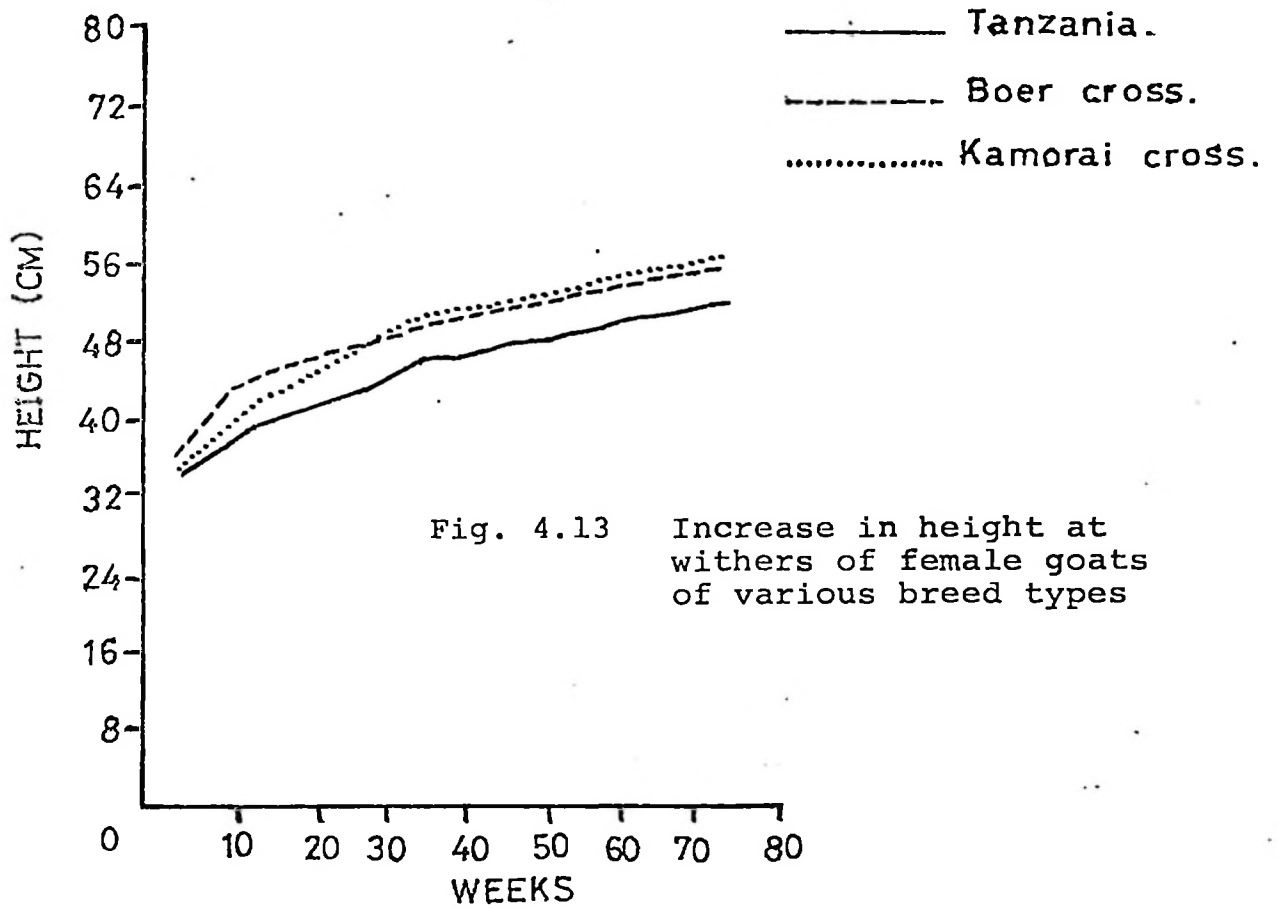


Fig. 4.10 Comparison in growth rate between birth and weaning at 16 weeks and between 16 weeks and 72 weeks of age of castrate goats of various breed types



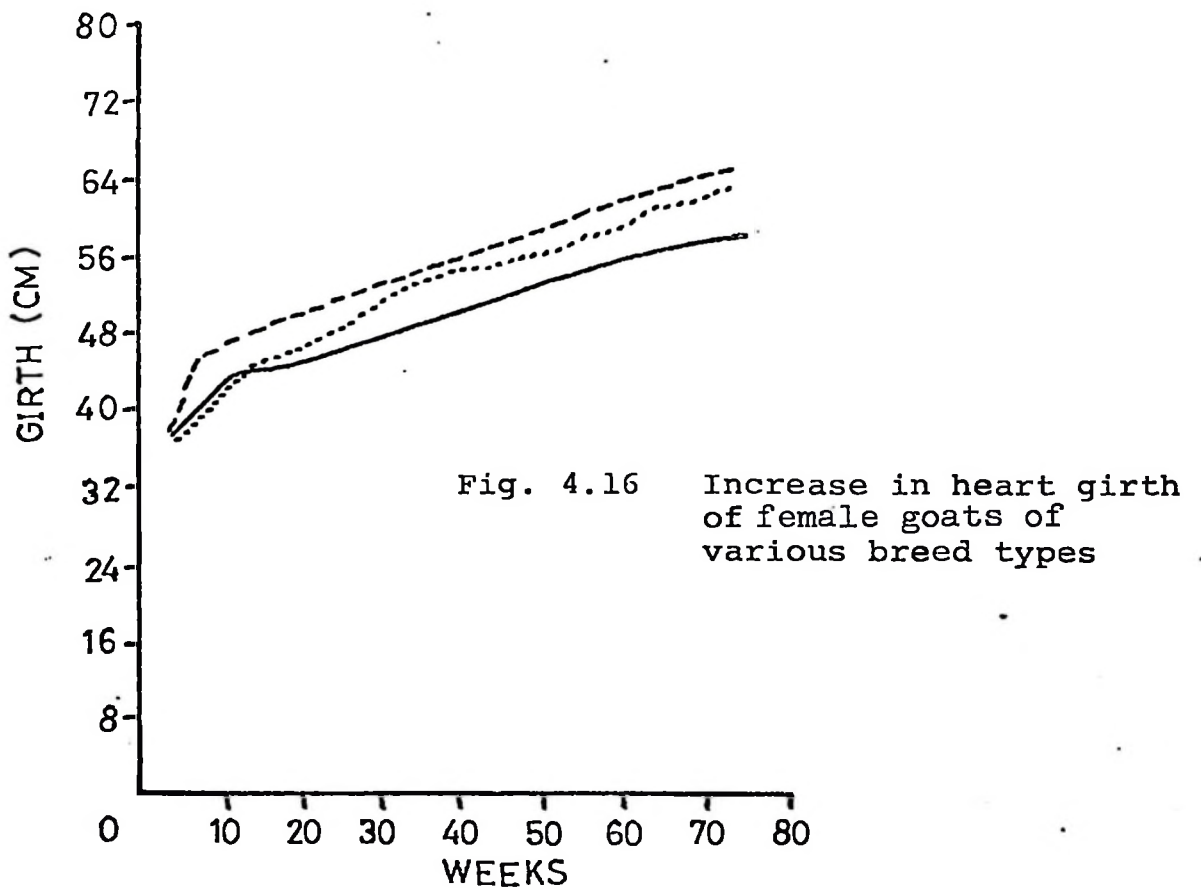
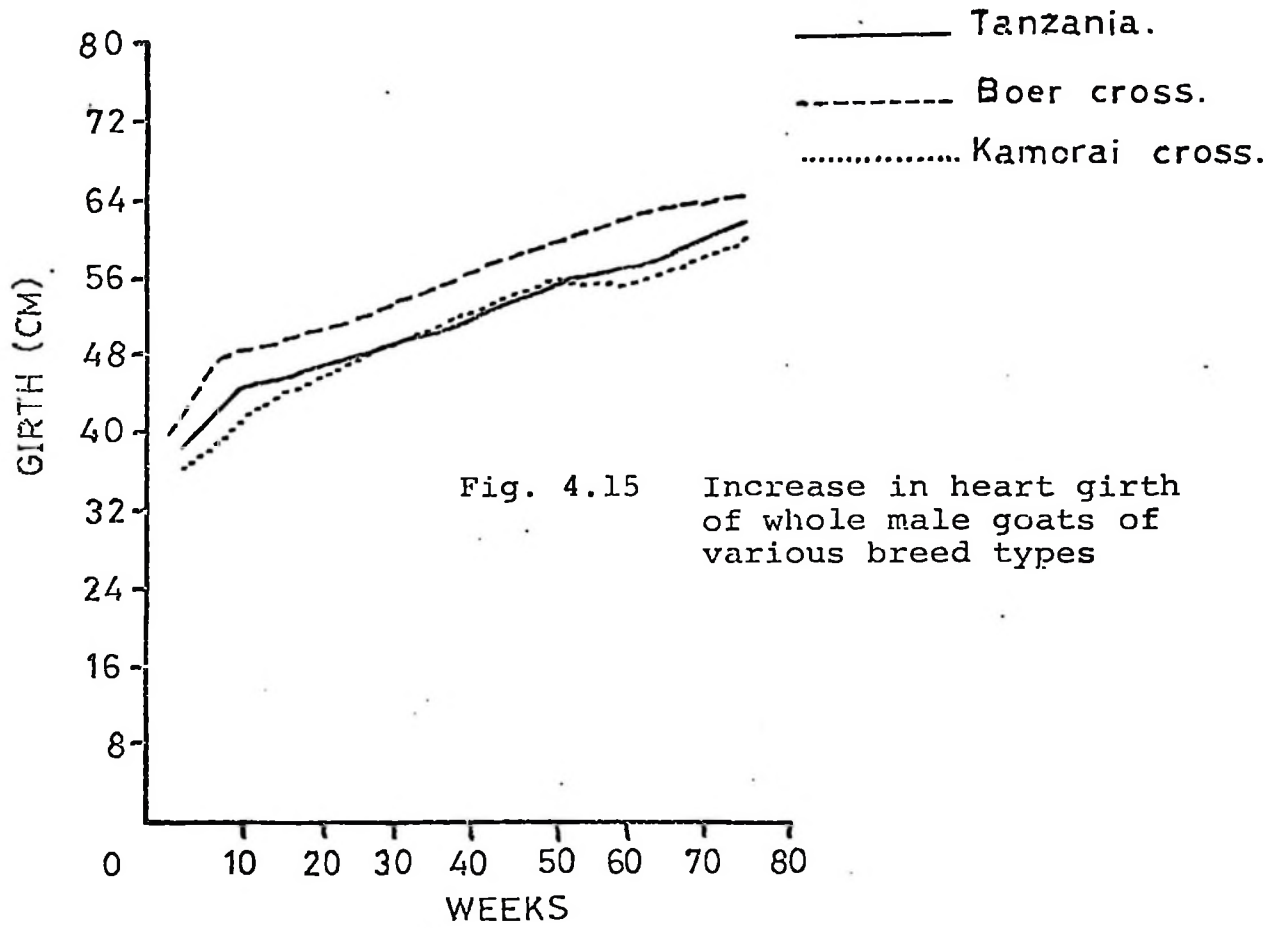


The rates of increase in heart girth (mm per day) in kids of various groups are presented in Table 4.27 and Figures 4.15 to 4.18. There was a tendency for the kids of all breed types to increase in heart girth at the same rate before and after weaning. The analysis of variance to test the differences between the various groups of kids in the increase in heart girth are presented in Table 4.26. The differences between breed types and between birth types in this measurement were significant at $P < 0.05$. There was no significant difference in heart girth between the male and the female kids. The mean heart girth measurements at various ages are shown in Table 4.28.

The rates of increase (mm per day) in width of the hind quarters at the widest point are shown in Table 29 and Figures 4.19 to 4.22. The data in this table do not show any big difference between the various groups of kids in the increase in width except for kids belonging to different age groups. The mean width of hind quarters at various ages is shown in Table 4.30. The analysis of variance (Table 4.26) to test the differences between the various groups of kids in this measurement showed that there were no significant differences between them. There was, as expected, however, a highly significant ($P < 0.001$) difference in the increase of width measurement between kids belonging to different age groups.

Table 4.27 Rate of increase in heart girth (mm per day) of goat kids during the various age periods

Age Periods	Grand Mean ± 0.0260	Breed ± 0.0205			Birth type ± 0.0201		Sex ± 0.0209		
		Tanzania	Kamurai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates
4 - 12 wks	1.1	1.0 (124)	1.2 (79)	1.2 (92)	1.1 (211)	1.2 (84)	1.0 (76)	1.2 (131)	1.1 (88)
12 - 24 wks	0.4	0.4 (124)	0.6 (79)	0.4 (92)	0.4 (211)	0.6 (84)	0.4 (76)	0.4 (131)	0.5 (88)
24 - 36 wks	0.4	0.4 (124)	0.4 (79)	0.4 (92)	0.4 (211)	0.4 (84)	0.4 (76)	0.4 (131)	0.4 (88)
36 - 48 wks	0.4	0.4 (124)	0.4 (79)	0.4 (92)	0.4 (211)	0.4 (84)	0.5 (76)	0.3 (131)	0.5 (88)
48 - 60 wks	0.4	0.4 (124)	0.3 (79)	0.4 (92)	0.4 (211)	0.3 (84)	0.3 (76)	0.4 (131)	0.4 (88)
60 - 72 wks	0.3	0.3 (124)	0.3 (79)	0.3 (92)	0.3 (211)	0.4 (84)	0.4 (76)	0.3 (131)	0.3 (88)



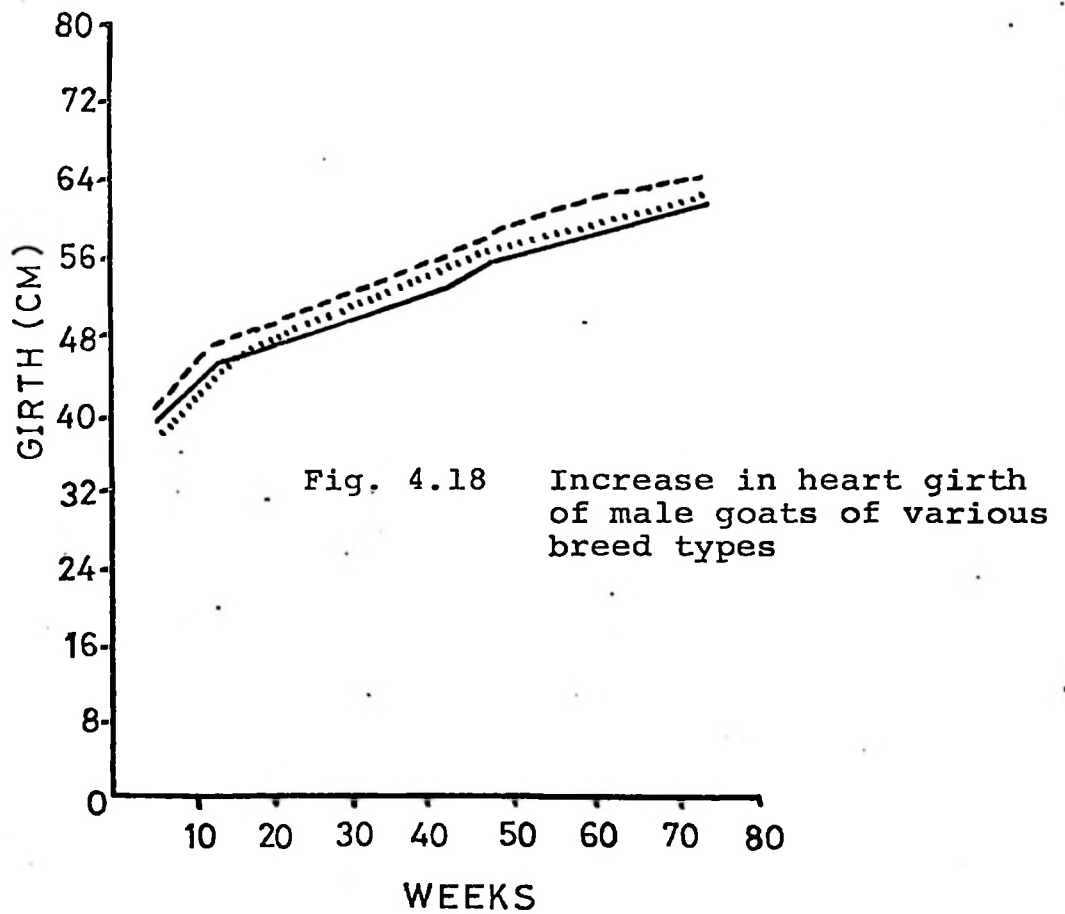
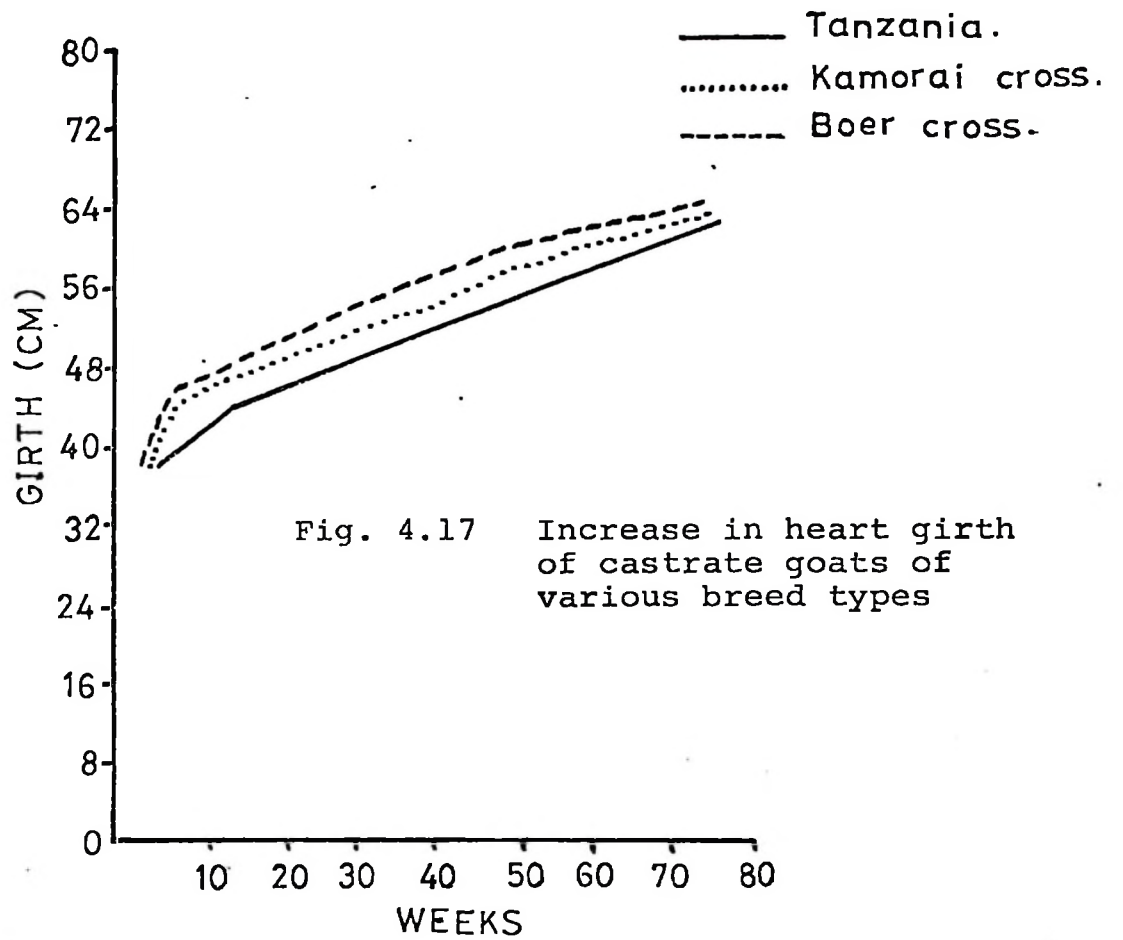
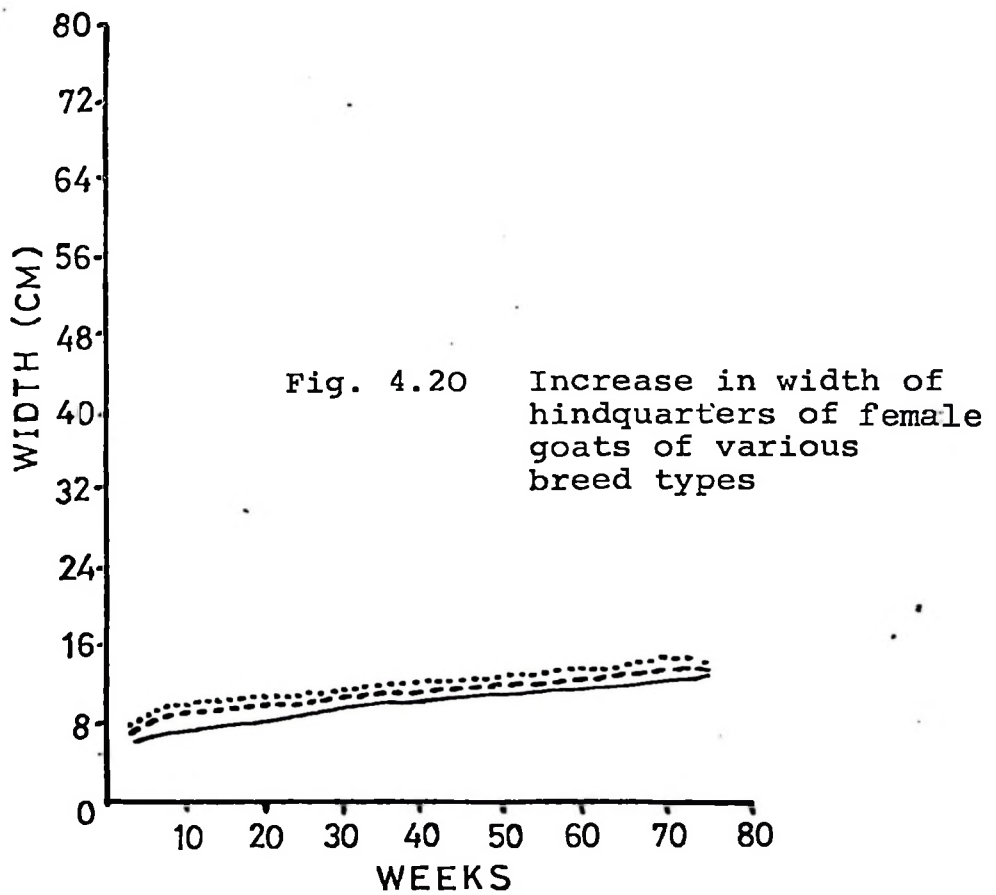
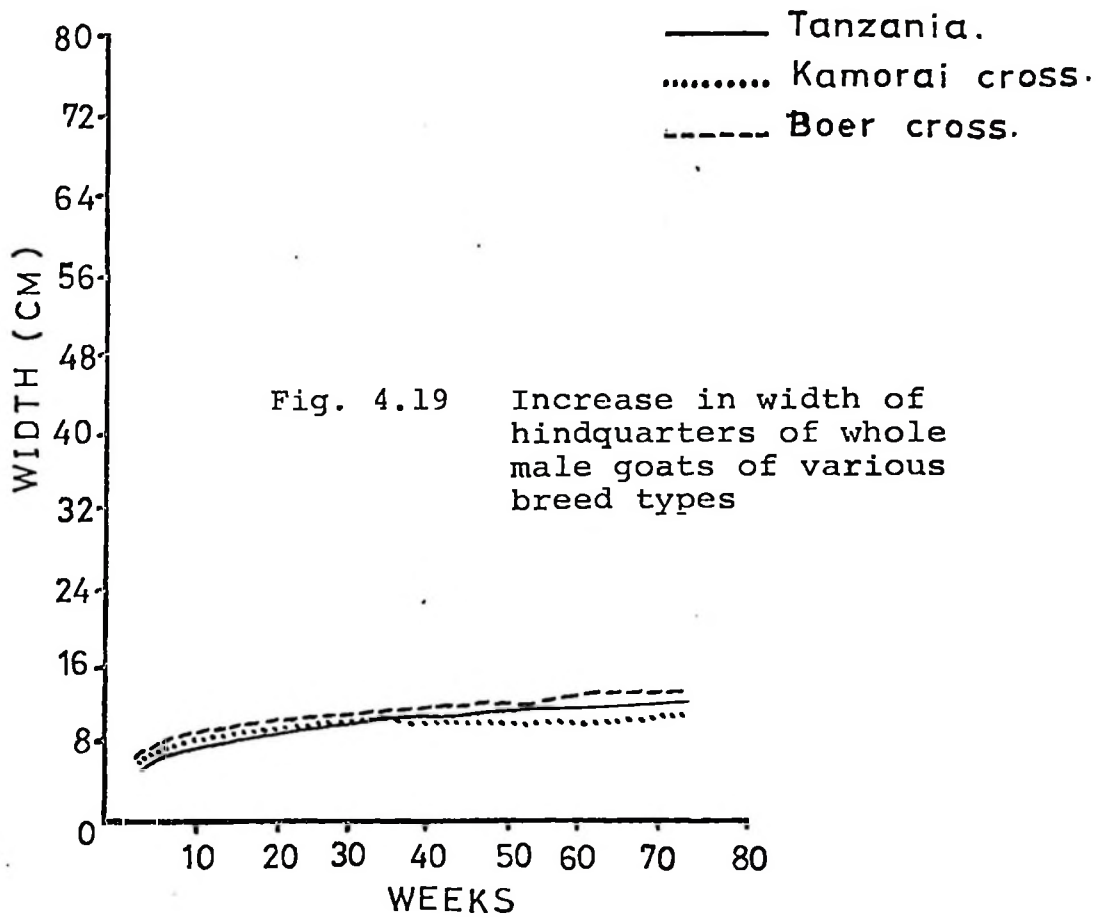


Table 4.28 Mean girth (cm) at various ages

Age in weeks	Grand Mean	Breed			Birth type		Sex		
		Tanzania	Kamorai	Boer	Singles	Twins	Male	Female	Castrate
4	38.0	37.7	36.7	39.3	38.7	36.1	38.4	37.2	38.6
	SE ± 0.28	± 0.21	± 0.21	± 0.21	± 0.20	± 0.20	± 0.21	± 0.21	± 0.21
12	44.2	43.3	43.4	46.0	44.8	42.6	43.9	43.8	45.0
24	47.9	46.4	48.4	49.6	48.1	47.5	47.6	47.5	48.9
36	51.4	49.7	52.3	52.9	51.5	51.2	51.1	50.9	52.4
48	54.7	52.8	55.6	56.6	54.8	54.7	55.1	53.4	56.4
60	57.8	55.9	58.5	59.7	58.0	57.2	57.5	56.8	59.5
72	60.4	58.6	61.1	62.1	60.3	60.5	60.3	59.5	61.8

Table 4.29 Rate of increase in width of hind quarters (mm per day) in goat kids during different age periods

Age	Grand Mean	Breed			Birth type			Sex		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates	
4 - 12 wks	0.4	0.3 (124)	0.4 (79)	0.4 (92)	0.4 (211)	0.4 (84)	0.4 (76)	0.4 (131)	0.4 (88)	
12 - 24 wks	0.1	0.1 (124)	0.1 (79)	0.1 (92)	0.1 (211)	0.1 (84)	0.1 (76)	0.1 (131)	0.1 (88)	
24 - 36 wks	0.1	0.1 (124)	0.1 (79)	0.1 (92)	0.1 (211)	0.1 (84)	0.1 (76)	0.1 (131)	0.1 (88)	
36 - 48 wks	0.1	0.1 (124)	0.1 (79)	0.1 (92)	0.1 (211)	0.1 (84)	0.1 (76)	0.1 (131)	0.1 (88)	
48 - 60 wks	0.1	0.1 (124)	0.1 (79)	0.1 (92)	0.1 (211)	0.1 (84)	0.1 (76)	0.1 (131)	0.1 (88)	
60 - 70 wks	0.1	0.1 (124)	0.1 (79)	0.1 (92)	0.1 (211)	0.1 (84)	0.1 (76)	0.1 (131)	0.1 (88)	



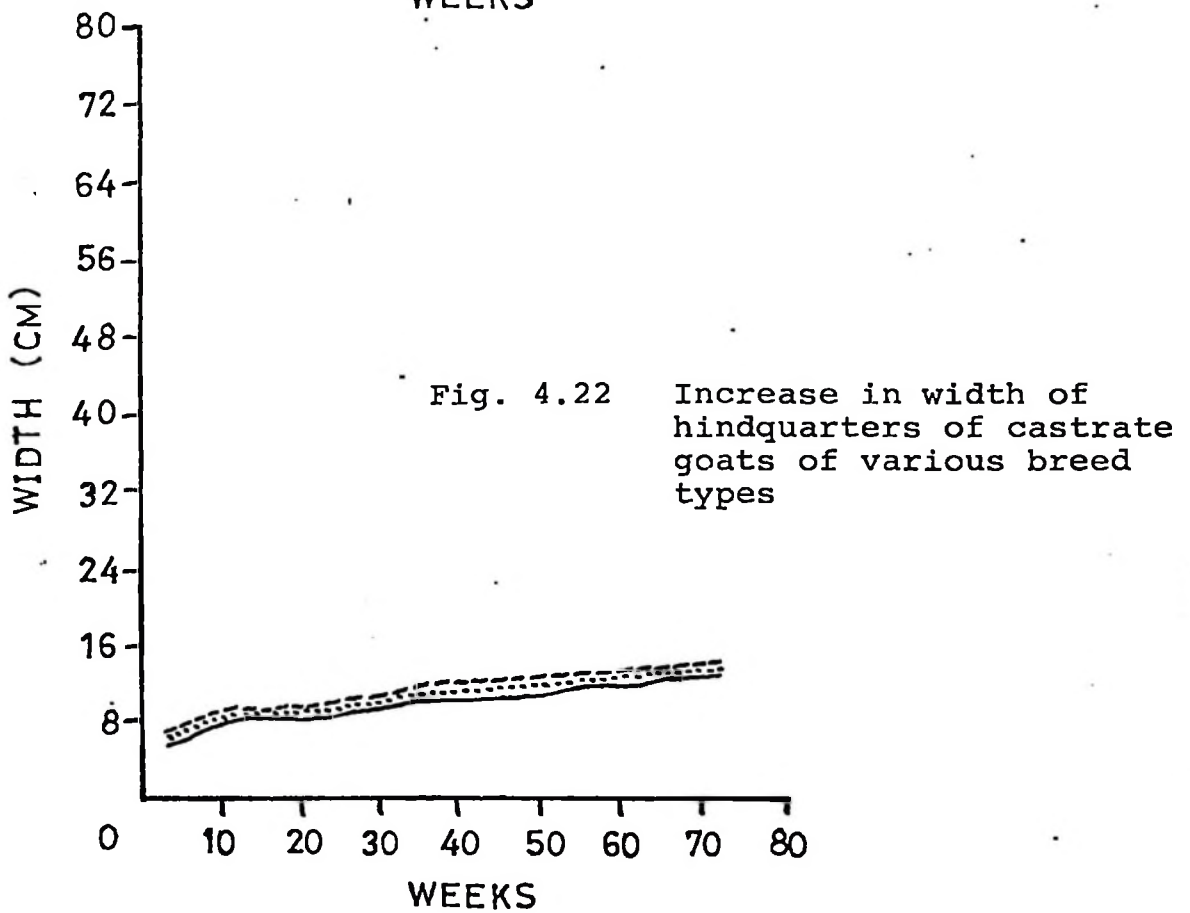
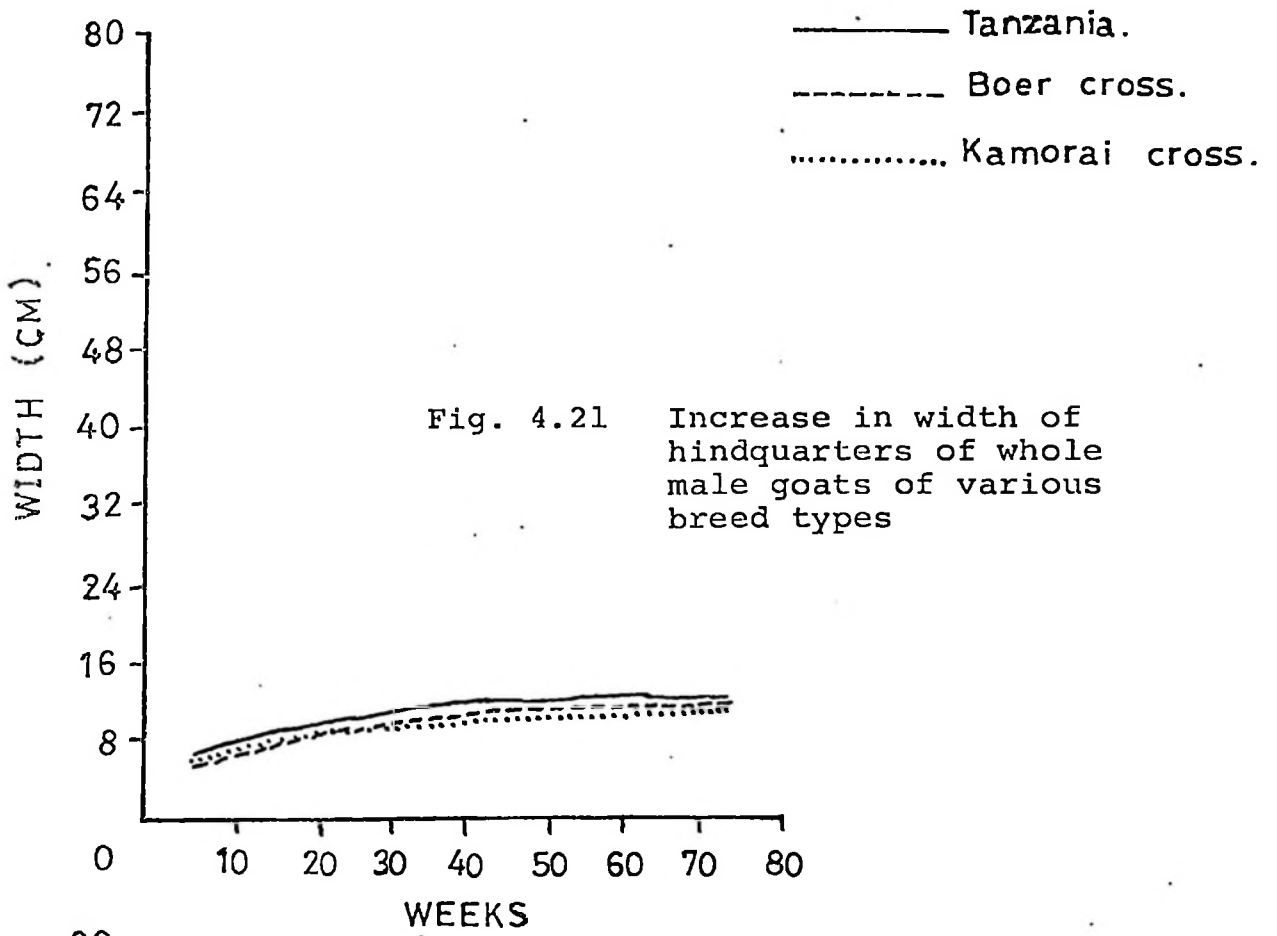


Table 4.30 Mean width (cm) at various ages

Age in weeks	Grand Mean	Breed			Birth type		Sex		
		Tanzania	Kamorai	Boer	Singles	Twins	Male	Female	Castrate
4	SE ± 0.11 6.4	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08	± 0.08
		6.3	6.3	6.6	6.6	6.1	6.2	6.3	6.8
12	8.4	8.1	8.6	8.8	8.6	8.1	8.2	8.3	8.9
24	9.3	8.9	9.4	9.6	9.3	9.2	9.2	9.1	9.6
36	10.4	10.1	10.7	10.5	10.4	10.4	10.1	10.3	10.8
48	11.1	10.7	11.4	11.4	11.1	11.0	11.1	10.8	11.6
60	11.8	11.4	12.0	12.3	11.9	11.6	11.6	11.6	12.5
72	12.7	12.5	12.8	12.8	12.7	12.6	12.1	12.5	13.4

The rates of increase (mm per day) in body lengths of kids are shown in Table 4.31 and Figures 4.23 to 4.26, while the mean body lengths are shown in Table 4.32. The Kamorai crossbred kids increased in length faster than either the Boer crossbred or the Tanzania kids. The Boer crossbred kids in turn increased in length faster than the Tanzania kids. This difference in the rate of increase of body length between breed types was significant at $P < 0.05$ (Table 4.26).

The rates of increase in this measurement between the male and the female kids, single and twin kids, and kids from different parities were not significant.

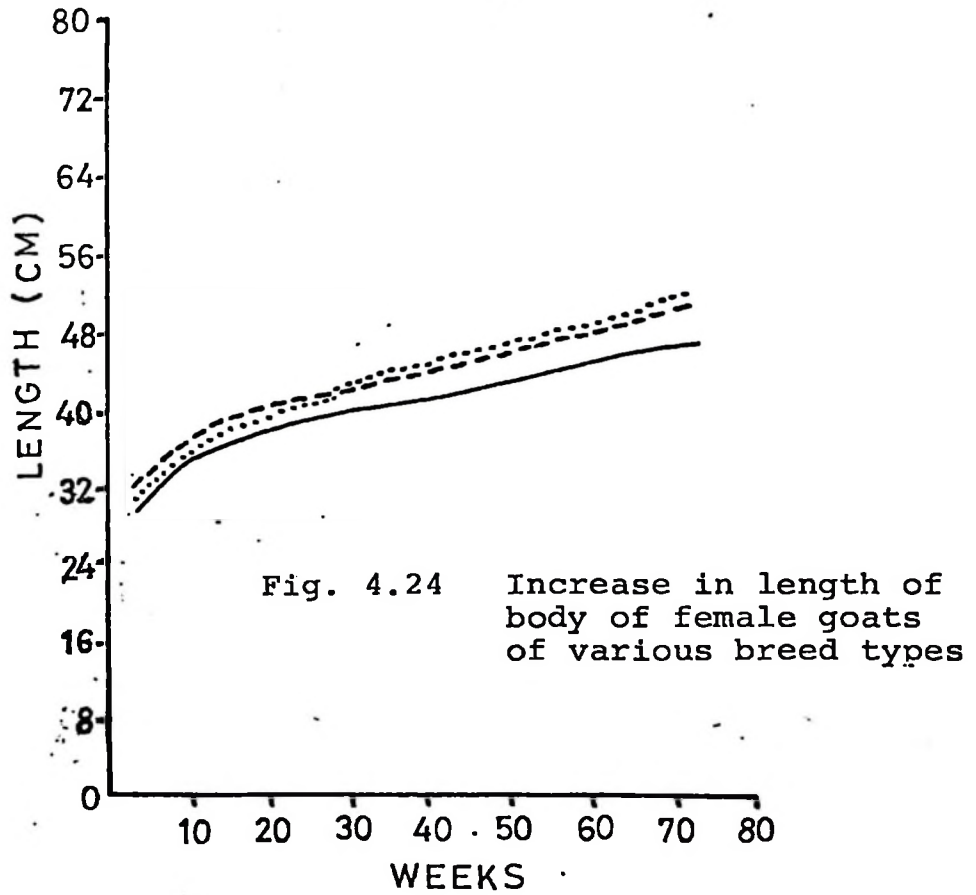
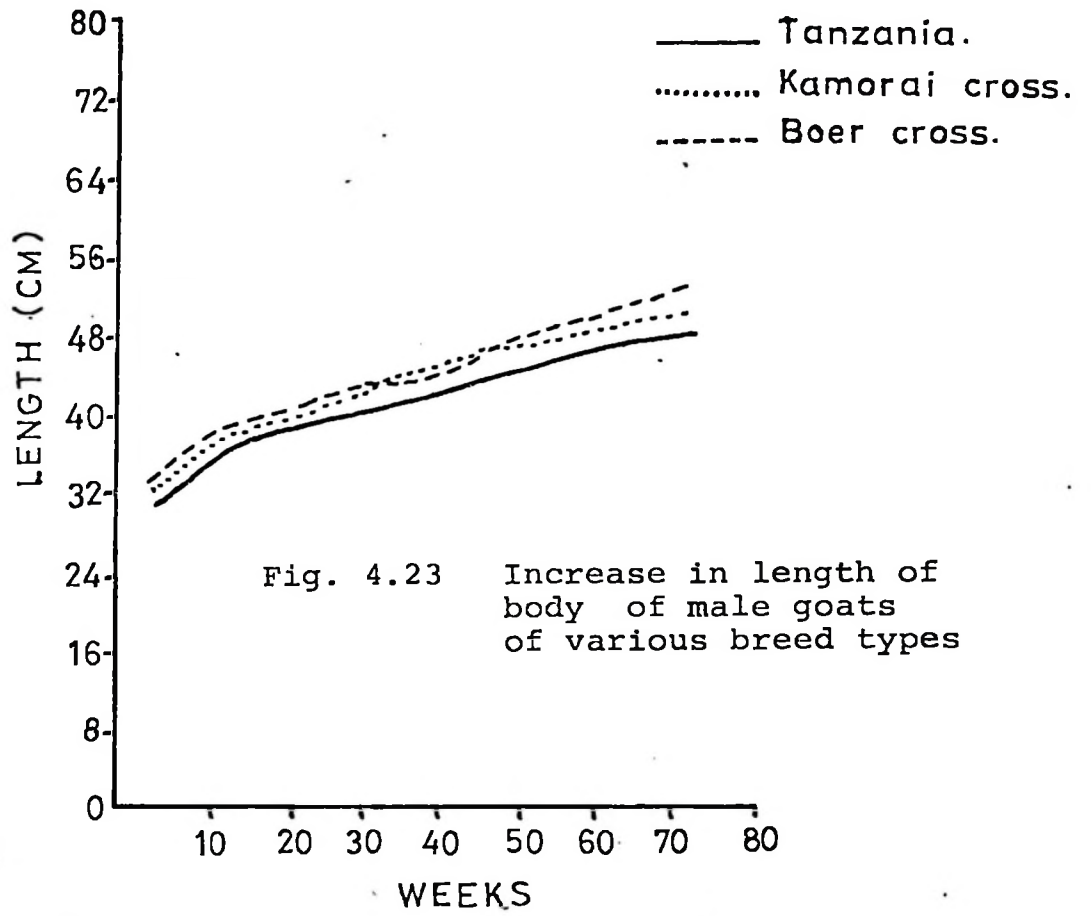
Table 4.33 shows the rate of increase in external body measurements when the increase was expressed as a percentage of measurement at 4 weeks of age. For each breed type the width of the hind quarter had the greatest increase between 4 and 72 weeks of age than other external body measurements. The heart girth was next, followed by length, and lastly height.

4.3.1.3 Correlations between weight and external body measurements

The relationships between liveweight in kg and body measurements in cm were estimated by undertaking regression and correlation analyses. The simplest equations thus obtained were :

Table 4.31 Rate of increase in body length (mm per day) in goat kids at various age groups

Age Periods	Grand Mean	Breed \pm 0.02			Birth type \pm 0.02			Sex \pm 0.02		
		Tanzania	Kamorai Crosses	Boer Crosses	Singles	Twins	Males	Females	Castrates	
4 - 12 wks	0.9	0.8 (124)	1.0 (79)	0.9 (92)	0.9 (211)	0.8 (84)	0.9 (76)	0.9 (131)	0.9 (88)	
12 - 24 wks	0.4	0.3 (124)	0.4 (79)	0.4 (92)	0.3 (211)	0.5 (84)	0.3 (76)	0.4 (131)	0.4 (88)	
24 - 36 wks	0.3	0.2 (124)	0.3 (79)	0.3 (92)	0.3 (211)	0.3 (84)	0.3 (76)	0.3 (131)	0.3 (88)	
36 - 48 wks	0.3	0.3 (124)	0.3 (79)	0.4 (92)	0.3 (211)	0.3 (84)	0.3 (76)	0.3 (131)	0.3 (88)	
48 - 60 wks	0.3	0.3 (124)	0.4 (79)	0.3 (92)	0.3 (211)	0.3 (84)	0.4 (76)	0.3 (131)	0.3 (88)	
60 - 72 wks	0.3	0.2 (124)	0.3 (79)	0.3 (92)	0.3 (211)	0.3 (84)	0.3 (76)	0.3 (131)	0.2 (88)	



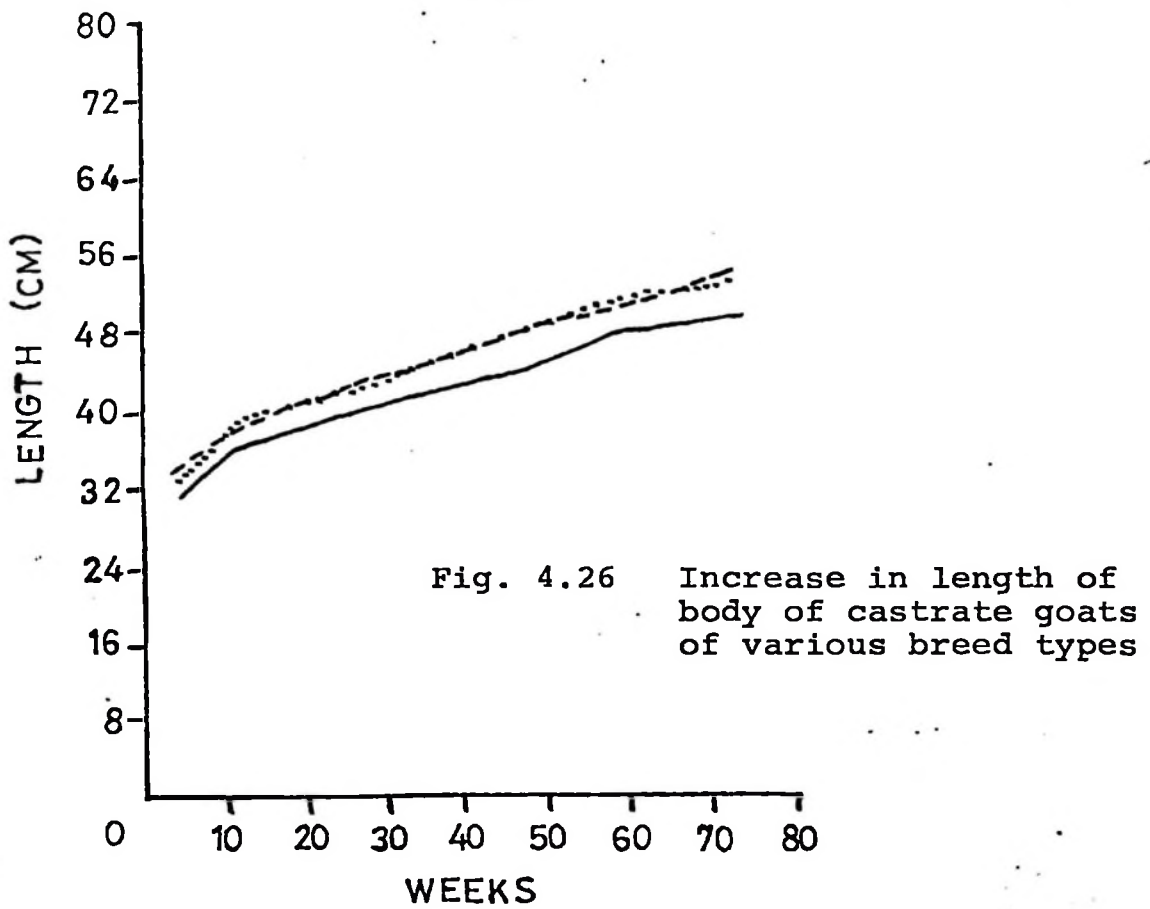
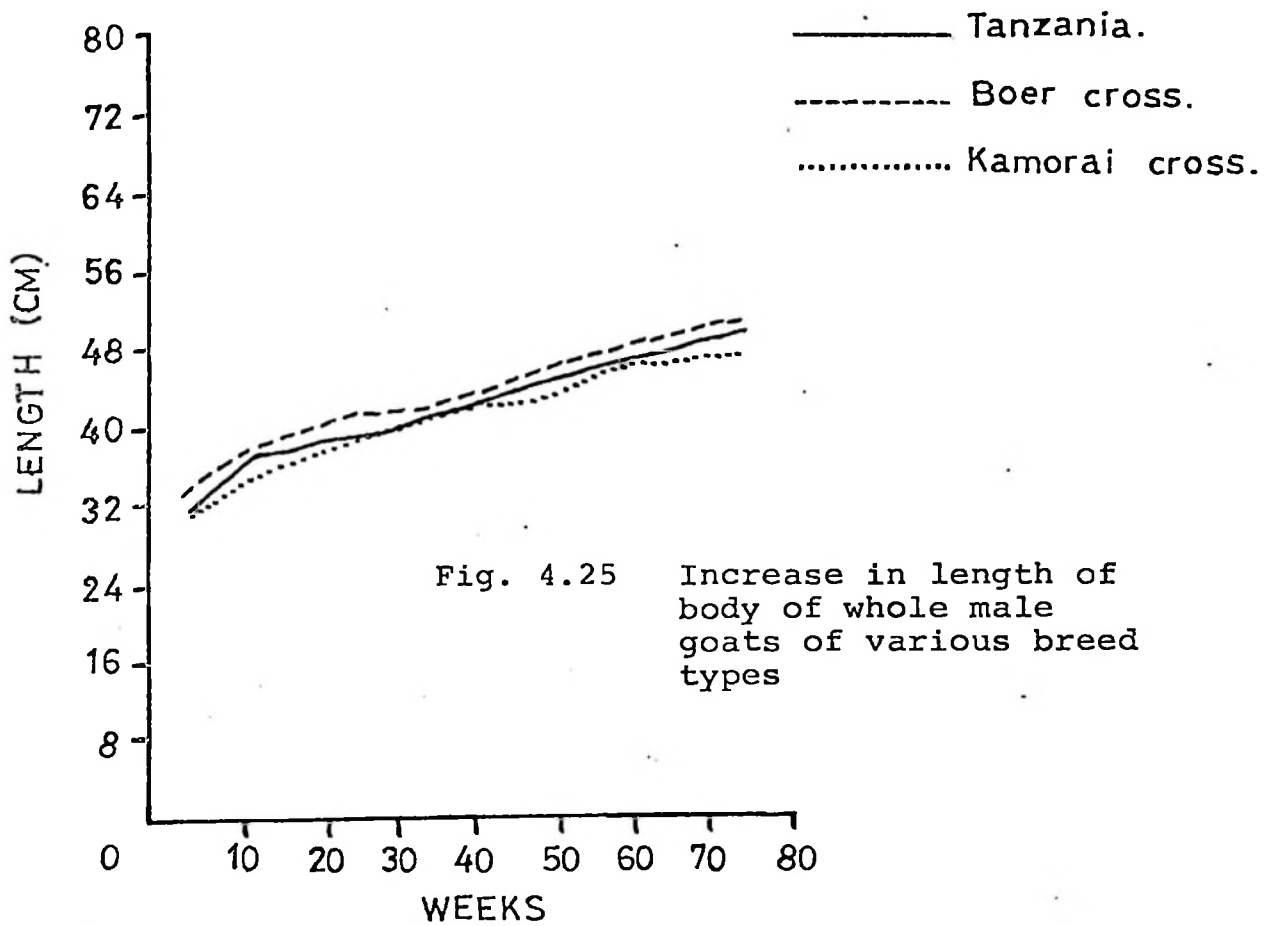


Table 4.32 Mean body length (cm) at various ages

Age in weeks	Grand Mean	Breed				Sex			
		Tanzania	Karorai	Boer	Birth type	Male	Female	Castrate	
4	± 0.25 31.4	± 0.18	± 0.18	± 0.18	± 0.18	± 0.18	± 0.18	± 0.18	
		30.7	31.2	32.4	31.7	30.6	31.8	30.5	32.3
12	36.4	35.5	36.5	37.4	36.8	35.2	36.6	35.7	37.2
		38.2	40.0	40.6	39.6	39.1	39.1	38.9	40.4
24	39.4	40.5	43.0	42.8	42.0	41.7	41.7	41.1	43.2
		43.0	45.3	45.7	44.5	44.2	44.2	43.5	46.0
36	41.9	45.3	48.3	48.1	47.0	47.1	47.2	45.7	48.6
		47.0	49.5	49.5	49.1	49.3	49.5	47.9	50.7
48	44.4	47.0	50.6	50.8	49.1	49.3	49.5	47.9	50.7
		49.5	50.6	50.8	49.1	49.3	49.5	47.9	50.7
60	47.0	49.5	50.6	50.8	49.1	49.3	49.5	47.9	50.7
		49.5	50.6	50.8	49.1	49.3	49.5	47.9	50.7
72	49.5	49.5	50.6	50.8	49.1	49.3	49.5	47.9	50.7
		49.5	50.6	50.8	49.1	49.3	49.5	47.9	50.7

Table 4.33 The rate of increase in external body measurement. Increase in measurements as a percentage of measurement at 4 weeks of age

Measurement	Breed type	Age in weeks						
		4	12	24	36	48	60	72
Height at withers	Tanzania	100	115	124	135	141	146	149
	Kamorai	100	118	129	140	147	152	157
	Boer	100	115	126	136	142	148	152
Heart girth	Tanzania	100	117	123	132	140	148	155
	Kamorai	100	118	132	142	152	159	166
	Boer	100	117	126	134	144	152	158
Width of hind quarters	Tanzania	100	129	142	161	170	182	198
	Kamorai	100	134	148	167	178	187	200
	Boer	100	130	146	160	172	186	194
Length shoulder to pin bones	Tanzania	100	115	124	132	140	151	153
	Kamorai	100	117	129	138	145	155	162
	Boer	100	115	125	132	141	149	157

Boer crossbred kids

$$\text{Wt} = - 4.65 \pm 0.31 + (0.00823 \pm 0.0013 \times \text{Girth} \times \text{Length})$$

$$(R^2 = 86.8\%)$$

Kamorai crossbred kids

$$\text{Wt} = 4.33 \pm 0.24 + (0.00806 \pm 0.00011 \times \text{Girth} \times \text{Length})$$

$$(R^2 = 92.0\%)$$

Tanzania purebred kids

$$\text{Wt} = - 3.87 \pm 0.25 + (0.00796 \pm 0.00012 \times \text{Girth} \times \text{Length})$$

$$(R^2 = 85.8\%)$$

Breeds pooled

$$\text{Wt} = - 4.22 \pm 0.15 + (0.00806 \pm 0.00007 \times \text{Girth} \times \text{Length})$$

$$(R^2 = 88.2\%)$$

The analysis of variance (Table 4.34) indicated that the differences between the pooled and individual breed regressions were not significant.

The more complicated equations for predicting weight from body measurements and the age of an animal were as follows :

Table 4.34 The Analysis of Variance to test the differences between the pooled and individual Regressions

Source of variation	d.f.	SS	MS	F
Pooled Regression	1	62694	62694	
Individual Regression	4	36	9.00	1.94 NS
Residual	1804	8370	4.62	
Total	1809	71100		

NS = Not significant at $P < 0.05$

Boer crossbred kids

$$\begin{aligned} \text{Wt} = & 0.56 \pm 0.52 + (0.00293 \pm 0.00046 + 0.0000186 \\ & \pm 0.0000027 \times \text{Age}) (\text{Girth} \times \text{Length}) + (0.00216 \\ & \pm 0.000022 \times \text{Height} \times \text{Length} \times \text{Width}) \\ & (R^2 = 89.4\%) \end{aligned}$$

Kamorai crossbred kids

$$\begin{aligned} \text{Wt} = & - 0.58 \pm 0.43 \pm (0.00429 \pm 0.0040 + 0.0000199 \\ & \pm 0.0000024 \times \text{Age}) (\text{Girth} \times \text{Length}) + (0.000116 \\ & \pm 0.000018 \times \text{Height} \times \text{Length} \times \text{Width}) \\ & (R^2 = 93.3\%) \end{aligned}$$

Tanzania purebred kids

$$\begin{aligned} \text{Wt} = & 0.68 \pm 0.43 + (0.00286 \pm 0.00041 + 0.0000165 \\ & \pm 0.00000025 \times \text{Age}) (\text{Girth} \times \text{Length}) + (0.000224 \\ & \pm 0.000020 \times \text{Height} \times \text{Length} \times \text{Width}) \\ & (R^2 = 88.5\%) \end{aligned}$$

Breeds pooled

$$\begin{aligned} \text{Wt} = & 0.25 \pm 0.27 + (0.00333 \pm 0.00024 + 0.0000184 \\ & \pm 0.0000015 \times \text{Age}) (\text{Girth} \times \text{Length}) + (0.000187 \\ & + 0.000012 \times \text{Height} \times \text{Length} \times \text{Width}) \\ & (R^2 = 90.3\%) \end{aligned}$$

The analysis of variance (Table 4.35) to test the differences between the simple pooled, the more complicated pooled and the more complicated individual breed regressions showed that all these differences between equations were highly significant ($P < 0.001$). The other phenotypic correlations between weights of the kids and individual body measurements are shown in Tables 4.36 to 4.39.

Table 4.35 The Analysis of Variance to test the differences between simple pooled regression equation and more complicated pooled regression equation

Source of Variation	d.f.	SS	MS	F
Simple Equation pooled Regression	1	62694	62694	
Complicated Equation pooled Regression	2	1528	764	201 ***
Complicated Equation by Breed Regression	8	137	17.1	4.5 ***
Residual	1792	6783	3.79	
Total	1803	71142		

*** = Significant at $P < 0.001$

Table 4.36 Phenotypic correlations between weight of animal, and various external body measurements, namely, height, girth, width, and length of growing goat kids (Tanzania goats)

(a)	1	2	3	4	5
Weight (1)	1.00				
Height (2)	0.36	1.00			
Girth (3)	0.47	0.42	1.00		
Width (4)	0.32	0.28	0.41	1.00	
Length 5	0.39	0.35	0.52	0.42	1.00

(b)	1	2	3
Weight (1)	1.00		
Girth x Length (2)	0.93	1.00	
Height x Width x Length (3)	0.92	0.95	1.00

Weight = - 1.07 ± 0.34 + 0.0044 ± 0.00 (Girth x Length)
+ 0.0023 ± 0.00 (Height x Width x Length)

Table 4.37 Phenotypic correlations between weight of animal, and various external body measurements, namely, height, heart girth, width of hind quarter, and length of body of growing goat kids (Kamorai crossbred goats)

(a)	1	2	3	4	5
Weight (1)	1.00				
Height (2)	0.34	1.00			
Girth (3)	0.47	0.51	1.00		
Width (4)	0.38	0.36	0.52	1.00	
Length (5)	0.46	0.45	0.53	0.53	1.00

(b)	1	2	3
Weight (1)	1.00		
Girth x Length (2)	0.96	1.00	
Height x Width x Length (3)	0.93	0.95	1.00
$\text{Weight} = - 2.94 \pm 0.34 + 0.0063 \pm 0.00 (\text{Girth} \times \text{Length})$ $+ 0.00011 \pm 0.00 (\text{Height} \times \text{Width} \times \text{Length})$			

Table 4.38 Phenotypic correlations between weight of the animal, and various external body measurements, namely, height, girth, width and length of growing goat kids (Boer. crossbred goats)

(a)	1	2	3	4	5
Weight (1)	1.00				
Height (2)	0.41	1.00			
Girth (3)	0.50	0.51	1.00		
Width (4)	0.43	0.46	0.50	1.00	
Length (5)	0.41	0.49	0.54	0.46	1.00

(b)	1	2	3
Weight	(1)	1.00	
Girth x Length	(2)	0.93	1.00
Height x Width x Length	(3)	0.93	0.95
Weight = - 1.61 ± 0.43 + 0.0047 ± 0.00 (Girth x Length) + 0.00022 ± 0.00 (Height x Width x Length)			

Table 4.39 Phenotypic correlations between the weight and rate of change of the animal, and various external body measurements, namely, height, girth, width and length of growing goat kids (all breeds pooled)

(a)	1	2	3	4	5
Weight (1)	1.00				
Height (2)	0.37	1.00			
Girth (3)	0.48	0.47	1.00		
Width (4)	0.38	0.35	0.47	1.00	
Length (5)	0.42	0.42	0.53	0.46	1.00

(b)	1	2	3
Weight (1)	1.00		
Girth x Length (2)	0.94	1.00	
Height x Width x Length (3)	0.93	0.95	1.00

Weight = - 1.78 ± 0.22 + 0.0050 ± 0.00 (Girth x Length)
+ 0.00019 ± 0.00 (Height x Width x Length)

4.4 Weight at Birth, Weaning, One Year and 72 Weeks of Age.

4.4.1 Discussion.

4.4.1.1 Birth weight.

Because of the large differences in mature size between the breed types used in this study (Table 4.18), the kids belonging to them were also expected to differ in birth weights (Devendra and Burns, 1970). Although the Boer crossbred kids were slightly heavier than either the Kamorai crossbred or the Tanzania kids, this difference was not significant. The possible reason for the lack of differences between breeds in this trait could be attributed to the adverse climatic conditions which might have affected the larger breed types more than the smaller ones. The total rainfall per year during the period of the study was declining each year from 1973. Because of the low total annual rainfall during the years of 1974 and 1975, the period covering these years was regarded as a drought period. Since grazing and browse formed the bulk of the dams' feed supply, low rainfall must have adversely affected forage growth and hence led to reduced availability of feed. The quality of forage must also have been affected by prolonged dry periods. The genetic superiority of the larger breed, the Boer, must therefore have failed to express itself in a poor environment. The superiority in this trait of the male over the female kids ($P < 0.01$) and of the single as against the twins ($P < 0.001$) is in

agreement with the observations made on goats of similar breed types in other parts of Tanzania by Hutchinson (1964) and those observed in the East African goat types by Wilson (1958) and Sacker and Trail (1966a). The lack of influence of season in which the animal was born on this trait was remarkable. Since some kids were born during the hot and dry season, while others were born during either the hot and humid, the cool and rainy, or the cool and dry seasons, it was expected that the kids' birth weights would have been affected by seasons. It would seem therefore that foetal weight in these breed types of goats is not affected very much by the variations of short duration in the climatic factors. The review on the studies conducted on pregnancy in sheep by Robinson (1957), however, showed that, although the nutrition of the dam had no influence on the weight of the foetus during the first three months of pregnancy, later on the foetus was affected irrespective of the condition of the dam. He observed that the loss in weight of the foetus was independent of the dam's condition during the restricted maternal food intake and that this phenomenon could have been due to the fact that the dam's reserves were not sufficiently labile to permit maximum growth of the former. Moulick and Syrstad (1970), working with Black Bengal goats in India, reported similar findings to those reported in this study. These authors observed that years had a highly significant effect on birth weight, while the effect of season was negligible. The lack of influence of parity of dam on

birth weight in the present study was contrary to the findings on the Mubende goats in Uganda reported by Sacker and Trail (1966). These authors' findings would be in agreement with those observed in the Black Bengal goat kids by Moulick and Syrstad (1970). The latter obtained a highly significant effect of parity of dam on birth weight of kids.

4.4.1.2 Weight at weaning

The variation in weight of kids belonging to different breed types at weaning would partly be due to the differences in mature sizes of their parent breeds and partly due to the maternal influence. In the present study, in which most of the dams belonged to one breed type, namely, the Tanzania goat breed, most of the variation in the weaning weight of kids would be expected to be due to the genetic influences of their breeds of sires. The Boer crossbred kids were heavier at weaning than either the Kamorai crossbred or the Tanzania kids, thus reflecting a genetic superiority of the former over other breed types in growth. This difference was, however, not significant. The differences in weight which existed between kids born as singles and those born as twins had disappeared at weaning. However, the differences in weaning weights of kids belonging to different sexes continued to exist as in other species of livestock like cattle or sheep. The highly significant effects of years and seasons on this trait were probably due to their effects on the feed supply of dams, and

therefore indirectly on the milk yield of the latter on which the kids depended for food supply up to weaning. Although the differences in weight between the castrates and the entire male kids were not significant, the slightly heavier weights of the former were not expected. There will be more discussion on these differences when the growth rate of kids is being considered in Section 4.5 of this thesis.

4.4.1.3 Weights at one year and 72 weeks of age.

The differences in weights of kids at these post-weaning ages would mainly be due to the differences in their genetic potential for growth. This would especially be the case in the studies such as the present one, in which the kids had similar management and their dams belonged to one breed type. The Boer crossbred kids continued to have heavier weights than either the Kamorai crossbred or the Tanzania goat kids at these ages, indicating that the former had a larger mature size than the others. The significant influence of years and seasons on weight at these ages would probably be mainly due to their indirect effects on feed supply. The significant effect of parity of dam on weight at these two ages of kids was, however, not expected. Owen (1976) has cited a study in sheep which tends to indicate that prenatal influences continue to show even at the age of 100 days after birth. Lambs born in litters of various sizes and subsequently suckled as singles or twins or artificially reared had different liveweights. The lambs born in larger litters had lighter

weights than the others. Whether such differences would continue to exist up to maturity was not stated. In goats too, the prolonged pre-natal influence on weight of kids similar to that observed in the present study does not seem to have been reported.

4.4.1.4 Correlations between birth weight and weight at various ages

For selection purposes, we would be more interested in the genetic correlation, since this is the correlation of breeding values (average effects of genes an animal is carrying). Furthermore, the correlations between kid body weights at different ages are actually part-whole correlations. Weight at a young age contributes to weight at the later ages. Studies to find genetic correlations between kid body weights at different ages with which to compare those reported in the present study were not found in the literature. In sheep, however, Vort et al. (1967) have reported a high and positive genetic correlation (0.73 ± 0.26) between birth weight and weaning weight when estimated on half-sib analyses, and even higher but negative genetic correlation (-3.20) between the same traits when estimated on full-sib analyses. It was pointed out that sampling errors probably accounted for some of the difference between the two correlations. The genetic correlation of 1.43 between birth weight and weaning weight reported in the present study, using half-sib analyses, was similar to that reported by Ragab et al. (1953) in sheep.

The latter was based on a dam-daughter regression analysis.

The environmental correlations cover environmental deviations and non-additive genetic deviations. The genetic and environmental correlations combine in a form of covariances to give a phenotypic covariance or phenotypic correlation as discussed by Falconer (1964). Sacker and Trail (1966) reported on phenotypic correlations between kid body weights at different ages. The correlations between birth weight and weaning weight, birth weight and weight at one year of age, and between weaning weight and weight at one year of age were similar to those reported in the present study. Devendra and Burns (1970), however, cited a study in Sri Lanka on the nondescript South Indian meat goats, in which a higher phenotypic correlation between birth weight and live weight at one year of age than that found in the present study were obtained. It is worth noting that, where two characters have low heritability estimates, the phenotypic correlation is determined chiefly by the environmental correlation, and that, if they have high heritabilities, the genetic correlation is the more important.

4.4.1.5 Heritability estimates for weight at birth, weaning, one year and 72 weeks of age

The heritability estimate of 0.07 ± 0.10 for birth weight was higher than that reported by Moulick and Syrstad (1970) of 0.01 for birth weight in the Black

Bengal goat in India, but smaller than the estimate of 0.19 reported by Amble et al. (1964) who had studied the heritability estimates in the Beetal goats in India. The latter workers had used the daughter-dam regression method, while Moulick and Syrstad had calculated the heritability as four times the sire component of variance divided by the total variance obtained from the analysis of variance method. Falconer (1960) has stated that the half-sib correlation and the regression of offspring on father are the most reliable methods of estimating heritability. The regression of offspring on mother is liable to give too high an estimate on account of maternal effects, and the full-sib correlation has a high environmental component of covariance and variance due to dominance. The low heritability estimates for birth weight would tend to indicate that within breeds the improvement of the dam's environment would lead to heavier birth weights than direct selection for it.

The heritability estimates for weights at weaning and at 72 weeks of age of 0.14 ± 0.14 and 0.17 ± 0.16 , respectively, would tend to indicate that these traits are moderately heritable. Progeny testing would be the method to use in improving them.

4.5 Growth of Kids

4.5.1 Discussion

4.5.1.1 Increase in weight

The average increase in weight of 60.2 g per day between birth and weaning by the Tanzania goat kids was very similar to those of other East African goats reported by Sacker and Trail (1966a). It was, however, higher than that of the East African goat kids which were on a low plane of nutrition, reported by Wilson (1958). The kids on a higher plane of nutrition in Wilson's study had a higher growth rate of 101.2 g per day than those found in the present study. The higher growth rates of the Boer and Kamorai crossbred kids, compared with the Tanzania kids, indicates that crossbreeding would improve the growth rate of kids of the Tanzania breed type. The average growth rate between weaning and one year of age of about 25.0 g per day for the Tanzania kids was lower than that of other East African breed type as reported by Sacker and Trail (1966a). They reported an average growth rate of 36.3 g per day for the kids from the Mubende goats at Mbarara in Uganda. The major difference in environmental factors between Morogoro and Mbarara is that Morogoro can have a continuous dry period of up to six months, whereas Mbarara gets a three month dry period only. This difference could account for the differences in growth rate of kids from parents which belong to the same breed

type. Forage growth and therefore food supply for the kids after weaning in an environment with a longer dry season must be more adversely affected than the forage growth in an environment with almost continuous rainfall.

4.5.1.2 Increase in external body measurements

The relatively larger increases in width and heart girth than in length and height are in agreement with the findings of Wilson (1958). He found that length measurements in the East African goat had smaller post-natal increases than depth measurements. He measured the lower and the upper parts of the hind and fore limbs, body length, width of the pubes and pelvis, depth of thorax, head length, and ear span. He demonstrated centripetal growth, in which the wave of growth started at the body extremities, such as the lower parts of the limbs, and from the head during the pre-natal life, and progressed through the body during the post-natal life and converged in the loin area. The latter was the last part of the body to develop. The data in the present study would tend to support this theory of growth. The width of the hind quarters could be looked at as an indirect measure of depth of the pelvic region. Since there was a greater increase in this measurement than for the heart girth, it would seem that the former was late maturing and that it had in post-natal life a greater growth potential.

4.5.1.3 Correlations between live weight and external body measurements

In Tanzania, the marketing of slaughter livestock is changing from that of bidding on visual assessment to that of basing payment on live weight. It is planned that weighing scales will be introduced in large livestock markets throughout the country. It will, however, take some time before they are introduced in all parts of the country. In the meantime, individual or combined body measurements which yield high correlations with weight would be of much practical value. The weight prediction equations shown in section 4.3.1.3 show that simple equations which combine girth with length are nearly as precise in predicting weight as the more complicated ones which combine age, height, girth, width and length. Although the differences between the two sets of equations are highly significant, the complicated equation does not remove very much of the remaining variation ($R^2 = 90.3\%$ for the latter, as compared with $R^2 = 88.2\%$ for the simple one). In comparing various linear body measurements with weight of growing cattle, Brody (1964) found chest girth to be the only measurement which was closely correlated with weight. The equation $y = ax^b$ in logarithmic form, where y = body weight in kg or lb, a is a constant, and X is chest girth in cm or feet, and b is the power to which chest girth is related to body weight, was developed to express this relationship. In this study Brody found that weight varied nearly with the cube of chest girth.

Height at withers was not as accurate in predicting weight as the chest girth, and the inclusion of age of cattle in the weight to chest girth relationship did not improve the precision. In the present data (Tables 4.36 to 4.39), it is shown that weight is more highly correlated with a combination of body measurements, such as girth and length or height, width and length, than with any of these measurements taken singly.

4.6 Carcass Characteristics

4.6.1 Results

The number of castrated and entire male kids belonging to various breeds and birth types, and sex, are shown in Table 4.40. The least squares means and their standard errors and the factors for adjusting the means of the various traits to a sample mean are shown in Table A4.4.

4.6.1.1 Final weight at slaughter and dressing percentage

The weights taken before slaughter and after the kids had been starved for 24 hours show that the Boer crossbred kids were heavier than either the Kamorai crossbred or the Tanzania purebred kids (Table A4.4). The average live weights for the three breed types were 21.5 ± 1.29 , 20.1 ± 1.40 , and 18.4 ± 1.28 kg respectively. The castrated kids were heavier than the entire male kids and their live weights were 21.9 ± 1.02 and 18.1 ± 1.25 kg, respectively. The differences between the three breed

Table 4.40 Number of kids in each breed type, sex (entire males and castrates), and birth type (singles or twins) contributing to the study in carcass characteristics

Group of kid	Number
Boer crossbred ^a	24
Kamorai crossbred ^b	24
Tanzania ^c	44
Castrates	52
Entire males	40
Singles	73
Twins	19
Castrated singles	39
Castrated twins	13
Entire male singles	34
Entire male twins	6
Total a + b + c	92

Table 4.41 The analysis of variance to test the differences between factors which might influence carcass characteristic in goat kids slaughtered at 72 weeks of age

Carcass characteristic	Source of variation				
	Breed	Sire	Sex	Type of birth	Sex x type birth
Live weight of slaughter	NS	NS	**	NS	NS
Live weight starved	NS	NS	**	NS	NS
Warm dressed weight	NS	NS	**	NS	NS
Cold dressed weight	NS	NS	**	NS	NS
Dressing %	NS	***	NS	NS	NS
Length of hind leg	NS	NS	NS	NS	NS
Circumference of hind leg	NS	NS	***	NS	NS
Length of fore leg	NS	NS	**	NS	NS
Length of chuck	*	NS	**	NS	NS
Circumference of fore leg	NS	*	NS	NS	NS
Length of loin	NS	NS	*	NS	NS
Depth of chest	NS	NS	*	NS	NS
Length of external measurements	NS	NS	**	NS	NS
Length of side	NS	NS	NS	NS	NS
Weight of hind leg	NS	*	**	NS	NS
Weight of loin	NS	NS	**	NS	NS
Weight of hind quarter	NS	*	**	NS	NS
Weight of fore quarter	NS	*	**	NS	NS
Weight of right half	NS	*	**	NS	NS
Weight of fore leg	NS	NS	**	NS	NS
Weight of chuck	NS	*	**	NS	NS
Weight of left half	NS	*	**	NS	NS
Total lean in half carcass	NS	NS	NS	NS	NS
Total fat in half carcass	NS	NS	**	NS	NS
Weight of kidney	NS	NS	***	NS	NS
Weight of stomach	NS	NS	NS	*	NS
Weight of small intestine	NS	NS	NS	NS	NS
Weight of head	NS	NS	NS	NS	NS

* = Significant at $P < 0.05$

NS = Not significant at $P < 0.05$

** = Significant at $P < 0.01$

*** = Significant at $P < 0.001$

types in both the weight before slaughter and starved weight, however, were not significant. The differences between the entire and castrated male kids in weight at these two periods, however, were significant ($P < 0.01$). The warm dressing percentages for the three breed types were very similar, namely, 45.6 ± 1.72 for the Boer crossbred kids, 45.3 ± 1.86 for the Kamorai crossbred kids and 45.3 ± 1.97 for the Tanzania kids. The castrated kids had a higher dressing percentage than the entire male kids and these were 46.2 ± 1.35 and 44.7 ± 1.44 , respectively. These differences were, however, not significant. There were similarly no significant differences in dressing percentage between kids born as singles and those born as twins.

4.6.1.2 Composition of the carcass

Table 4.42 shows the weights of various constituents of the kid carcasses. The Boer crossbred kids produced slightly more lean in the half carcass than either the Kamorai crossbred or the Tanzania kids and their weights were 3.2 ± 0.27 , 2.9 ± 0.29 and 3.1 ± 0.30 kg, respectively. The castrates in turn produced more lean meat in the half carcass than the entire males and these weights were 3.3 ± 0.22 and 2.8 ± 0.25 kg, respectively. Both these differences, one for the breed type and the other for sex of kids, were not significant, however. The Boer crossbred kids had also more fat in the half carcass than either the Kamorai crossbred or the Tanzania kids, namely, 0.4 ± 0.07 and 0.36 ± 0.01 kg, respectively. The

Table 4.42 The least squares means and standard errors for total lean, fat and bone in the whole carcass and proportions of these tissues as percentage of cold dressed carcass

Independent	Breed type	No. of animals	Least Squares means (kg)	SE	Tissue Component as % of the Carcass
Total lean	Overall mean	92	6.09	0.20	68.04
	Boer	24	6.29	0.27	65.38
	Kamorai	24	6.25	0.30	68.76
	Tanzania	44	5.73	0.29	70.31
	Castrates	52	6.54	0.22	65.93
	Males	40	5.63	0.25	70.55
	Singles	73	5.95	0.19	69.11
	Twins	19	6.23	0.27	66.99
Total fat	Overall mean	92	0.88	0.04	9.83
	Boer	24	1.04	0.06	10.81
	Kamorai	24	0.86	0.07	9.46
	Tanzania	44	0.72	0.06	8.83
	Castrates	52	1.04	0.05	10.48
	Males	40	0.62	0.12	7.77
	Singles	72	0.88	0.07	10.22
	Twins	19	0.87	0.13	9.35
Total bone	Overall mean	92	1.64	0.05	18.32
	Boer	24	1.72	0.07	17.88
	Kamorai	24	1.74	0.08	19.14
	Tanzania	44	1.46	0.08	17.91
	Castrates	52	1.84	0.06	18.55
	Males	40	1.44	0.06	18.05
	Singles	72	1.54	0.05	18.23
	Twins	19	1.71	0.07	18.39
Dressed cold Carcass weight (kg)	Overall mean	92	8.95	0.65	
	Boer	24	9.62	0.87	
	Kamorai	24	9.09	0.95	
	Tanzania	44	8.15	0.97	
	Castrates	52	9.93	0.69	

castrates contained more fat than the entire male kids, i.e. 0.6 ± 0.05 as against 0.3 ± 0.06 kg. The differences in the weight of fat between the breed types were not significant, while the differences between sexes were significant ($P < 0.01$). The crossbred Boer and Kamorai kids were very similar in the weight of bones in their half carcasses, while the Tanzania kids had less weight of this carcass constituent. The weights of bone in the half carcass for the three breed types were 0.9 ± 0.07 , 0.9 ± 0.08 and 0.7 ± 0.08 kg, respectively. The castrates had a higher weight of bone than the entire male kids and the difference was significant ($P < 0.01$).

4.6.1.3 Area of the eye muscle taken from the 10th and 11th ribs of the goat carcasses

The area of the eye muscle (Longissimus dorsi) taken from the 10th and 11th ribs of the goat carcasses have been shown in Table 4.43. The Boer crossbred kids had relatively larger eye muscle areas than the other breed types. However, these differences were not significant. The castrates in the crossbred animals had relatively larger eye muscle areas than the entire males. These differences, however, were not significant. The opposite was the case in the Tanzania goat kids - the entire male kids had slightly larger eye muscle areas than the castrates. The correlation between the area of the eye muscle of the 10th rib and the total amount of lean in the carcass ($r = 0.84$) was highly significant ($P < 0.001$). Similarly the area of the eye muscle of the 11th rib and

Table 4.43 Area of the eye muscle taken from the 10th and 11th ribs of goat carcasses

Breed	Sex	Area (cm ²)		Correlation Coefficient
		10th rib	11th rib	
Boer crosses	Males	14.15 ± 0.99 (14) ^a	13.25 ± 0.85 (12) ^a	
	Castrates	14.54 ± 1.02 (15)	14.29 ± 0.81 (18)	
	Overall	14.27 ± 0.70 (29)	13.88 ± 0.59 (30)	
Kamorai crosses	Males	12.27 ± 1.26 (14)	11.01 ± 1.51 (10)	
	Castrates	13.87 ± 1.53 (7)	12.87 ± 1.51 (7)	
	Overall	12.80 ± 0.97 (21)	11.77 ± 1.08 (17)	
Tanzania	Males	12.74 ± 0.96 (13)	12.68 ± 0.59 (14)	
	Castrates	11.81 ± 0.64 (20)	12.57 ± 0.58 (21)	
	Overall	12.18 ± 0.54 (33)	12.61 ± 0.42 (35)	
All breed types		13.10 ± 0.42 (83)	12.90 ± 0.36 (82)	

0.84***

0.97***

Correlation eye muscle area: wt. of lean in carcass of 10th rib
Correlation eye muscle area: wt. of lean in carcass of 11th rib

^a = number of animals in parentheses

*** = significant at P < 0.001

the total amount of lean in the carcass ($r = 0.97$) was also highly significant.

4.6.1.4 The heritability estimates and the phenotypic, genetic and environmental correlations between live weight and some carcass characteristics

The heritability estimates based on paternal half-sib analyses, and the phenotypic, genetic and environmental correlations between live weight and some carcass characteristics have been shown in Table 4.44. The heritability estimates for dressing percentage, total lean and total bone in the carcass were high, namely, 69, 31 and 42 per cent respectively. The heritability estimate for total fat in the carcass was, however, low, i.e. 4 per cent only.

4.7 Carcass Characteristics

4.7.1 Discussion

4.7.1.1 Final weight at slaughter and dressing percentage

The average live weights before slaughter at 72 weeks of age were 23.1, 21.8 and 19.9 kg for the combined male and castrates of each of the breed types of Boer, Kamorai and Tanzania, respectively. These weights were lower than the mature weights of the parents shown in Table 4.18. The male animals in the latter table had mature sizes of 40.8, 44.0 and 37.0 kg, respectively. It was demonstrated in Figures 4.3 to 4.10 that the animals used for the carcass study were still growing at 72 weeks of age.

Table 4.44 Heritability estimates (on), phenotypic (below), environmental (below in parentheses) and genotypic (above diagonal) correlations between final and starved weights before slaughter, dressing percentage yield of lean, fat and bone in goat carcasses when slaughtered at 72 weeks of age

	LWWTBS	LMTSTA	DRPERC	TOWTLE	TOWTEA	TOWTBO
Liveweight before slaughter (LWWTBS)	0.14 ± 0.27	#	#	#	0.87 ± 1.05	#
Liveweight starved (LMTSTA)	0.99 (0.99)	0.14 ± 0.27	#	#	0.92 ± 1.02	#
Warm dressing % (DRPERC)	0.51 (0.02)	0.49 (-0.01)	0.69 ± 0.63	#	#	#
Total weight of lean in half carcass (TOWTLE)	0.93 (0.91)	0.93 (0.91)	0.65 (0.17)	0.31 ± 0.38	#	0.93 ± 0.16
Total weight of fat in half carcass (TOWTEA)	0.78 (0.78)	0.79 (0.79)	0.41 (-0.01)	0.77 (0.72)	0.04 ± 0.21	0.95 ± 1.61
Total weight of bone in half carcass (TOWTBO)	0.87 (0.83)	0.86 (0.84)	0.63 (0.05)	0.84 (0.80)	0.67 (0.73)	0.42 ± 0.46

Correlation values were greater than + 1 and could have been caused by nearly zero estimates of genetic variance

Further studies will be needed to establish the weight at maturity and the management regimen needed to make the kids grow to higher weights per given age than were achieved in this study. The average dressing percentage for goat kids of about 45 per cent obtained in this study is comparable to those of lambs reported by Spedding (1970) and Owen (1976). The slightly higher dressing percentage of castrated kids as against entire male kids is similar to the observation reported by Devendra and Burns (1970).

4.7.1.2 Composition of the carcass

The slightly higher yield of total lean in the carcass by crossbred kids as against purebred Tanzania kids showed the advantage of crossbreeding in meat goat production in Tanzania. Similarly, castration seemed to alter the composition of the carcass in that the castrates had slightly more lean, bone and fat than the entire male kids. The proportions of individual tissues expressed as percentages of the total carcass weight were similar to those reported by Wilson (1960). Although comparison between animals raised in different environments would not be valid, Table 4.45, however, could serve as a rough indication of the carcass composition in various species of livestock. The data in Table 4.45 seem to indicate that the goat has less separable fat but more lean in the carcass than other livestock. The ruminant livestock seem to have comparable bone content in the carcass.

Table 4.45 Carcass composition of various livestock species

Species of livestock	Proportion of separable tissues in the carcass (as %)					Total
	Fat	Lean	Bone	Skin	Others	
Goat ^a	9.8	68.0	18.3	-	3.9	100.0
Pork ^b (70 kg live wt)	39.5 (68 - 70) ^c	39.3	14.6	6.6	-	100.0
Lamb ^b (Choice Grade)	29.6	50.4	20.0			100.0
Beef ^b (Good Grade)	25 (52 - 58) ^c	57	18			100.0

a = data from the present study

b = data by Ziegler (1962)

c = dressing percentage

4.7.1.3 Area of the eye muscle taken from the 10th and 11th ribs of the goat carcasses

The high correlation ($r = 0.97$) between the eye muscle area taken on the 11th rib and weight of separable muscle or lean meat in the goat kid carcasses was very similar to the observations made on lamb carcasses by Timon and Bichard (1965). These workers found a high correlation ($r = 0.9$) between the eye muscle area obtained by splitting the 12th and the 13th ribs of the lamb carcasses and weight of lean in the carcass. In their study the mean area of the eye muscle taken on the above ribs from 83 lamb carcasses was 10.9 ± 0.16 square centimetres. This was smaller than the area ranging between 11.8 and 14.5 square centimetres observed in the goat carcasses in the present study. The fact that the average weight of the lamb carcasses in the study by Timon and Bichard was 16.1 as against 7.0 kg for goat carcasses indicates that there is a difference in relative mature sizes of the two groups of animals.

4.7.1.4 Heritability estimates and phenotypic, genetic and environmental correlations between live weight and some carcass characteristics

The heritability estimates obtained from paternal half-sib analyses of 0.14, 0.69, 0.31, 0.04 and 0.42 for live weight before slaughter, warm dressing percentage, total weight of lean, total weight of separable fat and total weight of bone, respectively, were within the ranges of heritability estimates observed on similar traits in sheep (M.L.C., 1972). They show that, apart from weight

of separable fat in the carcass, most of the traits connected with carcass composition and weight have large amounts of additive genetic variation, and selection for any of these traits except fat content would lead to increased yields. The phenotypic and genetic correlations between the various carcass traits observed in the present study were high and these findings were similar to those observed in lamb carcasses by Timon and Richard (1965) and Bowman et al. (1968).

CHAPTER 5CONCLUSIONS

The study has proved that Tanzanian goats breed throughout the year. Conception rate, however, is highest after the does have had access to better grazing which comes after short and long rains. Age at first kidding is late, even after withholding the young female kids from joining the mating groups until they reach 72 weeks of age. Crossbreeding with "improver" breed types reduces the age at first kidding substantially. The kidding interval in the goats, however, was not, under conventional management systems, reduced by crossbreeding. Twinning rate was improved by crossbreeding, but only if an "improver" breed type proved to have higher twinning rate. A kid mortality of 35.6 per cent was obtained under conventional management and pneumonia tended to cause a higher percentage of deaths than other causes. It is suggested, therefore, that an attempt be made to design better goat houses when plans to raise meat goats for commercial purposes are envisaged. Incidences of does failing to conceive are rare in Tanzania (<1 per cent). However, death rate in does was rather high; 4 per cent among the does aborting or producing still births. It is suggested that good management, especially feeding, might reduce this loss of does.

Crossbreeding did not seem to influence birth weight to a large extent. As found in other ruminant livestock, the male kids were significantly heavier than female kids at birth, and kids born singly were heavier than those born as twins or triplets. Crossbreeding had, however, a slight effect on weight of kids at weaning. It is suggested that the lack of milk in Tanzanian does made the crossbred kids fail to express their potential for higher weight-for-age compared with purebred kids. Sire, sex, years and seasons had an influence on weaning weight. Weights of kids at one year and 72 weeks of age are expected to be less influenced by maternal factors than weights at younger ages. Crossbreeding tended to improve the weight-for-age of kids at these ages. Castration tended to improve weight-for-age of kids. This trend existed in all the years and it is suggested that more experiments be undertaken to prove this fact. The generally low heritability estimates of birth weight, weaning weight, weight at one year and at 72 weeks of age were obtained with data adjusted for type of birth, sex, breed and parity of dam, suggest that selection of individual bucks on the basis of their own pre-weaning growth under conventional management may be rather ineffective. The difficulty here might lie in the inability to adequately remove the environmental differences through adjustments. If the adjustments reduced the influence due to those factors, then more accurate estimates of genetic differences would enable the selection of bucks

on their weaning weight. This would allow the bucks to be used for breeding at an early age and attain a higher genetic gain through reduction of generation interval. At present, however, preliminary selection of young bucks on individual performance, based on weight at weaning and later at 72 weeks, followed by progeny testing, seems to be the most promising procedure.

The study has also shown that crossbreeding leads to improvement in growth rate of kids. The width of hind quarter shows a greater increase between 4 and 72 weeks of age than other external body measurements. The heart girth was next, followed by length, and lastly height above the withers. Various formulae to estimate weight from external body measurements, by combining body measurements in various ways, were worked out, using simple and multiple regression analyses. However, before advocating the use of any one formula, there will be a need to test them in the field using large samples of kids of various ages.

Crossbreeding does not seem to improve dressing percentage in goats. However, there is a tendency for the crossbred kids to have higher lean, bone and fat content than the purebred Tanzania kids. This is mainly a reflection of larger size or weight-for-age of crossbred kids than purebred Tanzania kids. The castration seems to improve all the carcass characteristics in goat kids. The high heritability estimates for the major carcass characteristics, such as dressing percentage, total lean

and total bone in the carcass suggests that selection based on performance testing of full or half-sibs or progeny would lead to improvement in carcass traits. The high correlation between the area of the rib eye muscle (Longissimus dorsi) of either the 10th or the 11th rib suggests that area of this muscle can be an indicator of the amount of lean in the carcass. The study has shown that the 72 week old entire male and castrated kids have relatively less fat but more lean than carcasses of beef and lamb at a similar stage of maturity. However, the proportion of bone in the carcass seems to be the same in the three species of livestock.

CHAPTER 6THE RELEVANCE OF THE FINDINGS
TO THE PRESENT AND FUTURE GOAT MEAT
PRODUCTION SYSTEMS IN TANZANIA

The transformation of agriculture and improvements in the quality of life of the people in developing countries will depend in large measure on how much research and development is undertaken in the rural areas where the majority of the people live. To meet the calorific requirements of the people, some effort is being made to produce high yielding varieties of crops, such as cassava, maize, sorghum, rice, wheat, sugar cane, etc. at various national and international research centres. To meet their protein requirements, the Food and Agriculture Organisation of the United Nations (F.A.O.) advocates the exploitation, through increased off-take, numbers and weight per animal, of small ruminant livestock such as the goat. In a country such as Tanzania where there are about 5 million goats, and where goat meat is very popular, increased off-take by at least double the present figure of 26 per cent will raise the number of carcasses from the present 1,250,000 to 2,500,000 per year. This number of carcasses will go a long way towards providing meat to the country's human population of about 16 million, and some surplus for export. Suggestions based on the observations made in the present study on how to improve practically the productivity of goats for meat will be discussed in this chapter.

It has been observed in the present study that cross-breeding between the relatively small sized Tanzania goat and some larger tropical breeds, such as the Boer from the Southern part of Africa and the Kamorai from Pakistan, can lead to improvement in most of the major economic meat traits. In such a crossbreeding programme, the aim will be to exploit the good adaptation to the local environment of the Tanzania goat and to maximise the genetic gain through sire-son, sire-daughter, dam-son, and dam-daughter selection methods. The expected genetic gain (ΔG) depends on the factors shown in the equation :

$$\Delta G = \frac{ih^2\sigma_P}{L}$$

where i represents the intensity of selection, h^2 represents heritability of a trait, and σ_P represents the standard deviation of the trait, and L represents generation interval. When the values of i , h^2 and σ_P increase, the genetic gain becomes larger. However, when L increases, the genetic gain decreases. The improvement through the sire-son pathway represents about 50 per cent of the total genetic gain if selection is based on performance testing and is superior to the other pathways described above. The selection of sires and their sons should therefore receive special consideration in the goat breeding programme.

The selection of sires can be done through performance testing, progeny testing or through pedigree selection. Usually a combination of these three methods are used in meat production from ruminants. For meat goat production, weaning weight can be improved by selecting animals based

on their own performance at an early age and thereby reduce the generation interval. Traits with low heritabilities such as fertility and growth rate could be improved through progeny testing. A similar method would be appropriate for sex limited traits such as mothering ability and milking capacity, and for carcass traits which can be measured only in slaughtered animals. The generation interval will be reduced and the inconvenience of collecting data from small flocks will be avoided if selection of individual animals within flocks and centres is on the basis of their own performance.

One of the ways of improving meat goats in Tanzania will be to set up élite breeding flocks at some government and semi-government farms. Already some goats are being bred at Malya in the north-west, West Kilimanjaro in the north, Kongwa and Mpwapwa in the central part of the country, the University Farm at Morogoro in the east, and Mtwara in the southern part of Tanzania. It is being recommended that two separate flocks of pure indigenous goats and pure exotic tropical breeds be maintained for data collection to study further their performance and for producing purebred animals, respectively. Cross-breeding by mating exotic male goats with pure indigenous females should be undertaken at the Centres and the cross-bred males be used for mating to indigenous female goats in the villages. It is expected that the villagers will in the meantime castrate all their purebred indigenous male goats. Already, the extension staff perform the castrations of unwanted males of all livestock and therefore

the farmers in the villages will not object to this system. The ideal will be to obtain progeny from reciprocal crossbreeding systems at the Breeding Centres so as to get the best crossbred animals which are adapted to the Tanzanian environment. Space at these Centres, however, might not allow for the maintenance of too many animals. The alternative will be for some Breeding Centres to specialise in carrying a flock of pure indigenous goats, while others specialise in keeping animals belonging to one of the exotic breed types. The tropical breed types which could possibly be used in such a breeding programme are, in addition to the Boer and the Kamorai used in the present study, the Nubian from the Sudan, the Jamnapari from India and the Ma'Tou from China. All these breed types are renowned for good reproductive performance, high growth rates, large size and good mothering ability.

In the initial stages of the goat improvement programme, only a few villages would be allowed to participate. Extension workers, specialists in rural sociology and animal breeders would be involved in studying the effect of these breed improvement programmes and the reaction of the villagers to such schemes. The experience gained from similar schemes, which involve the introduction of improved poultry, goats, pigs and cattle in a few co-operating villages by staff from the Faculty of Agriculture, Forestry and Veterinary Science of the University of Dar es Salaam at Morogoro, indicate that

the villagers would be willing to participate in such goat improvement schemes. It would, however, be advisable to study not only the performance of crossbred goats in the villages, after initiating a good recording system, but also the acceptance of improved management of these goats. The construction of cheap but well designed goat houses, the adoption of strict disease control programmes, the provision of adequate feed and water, the implementation of regular breeding programmes and the sale or slaughter for meat of surplus animals, are some of the management practices which need to be introduced. Change in the national flock will come about when farmers in the villages see the advantages of improved breeding.

Breeding goals will be, to aim at weaning two kids per year, getting high kid growth rates, getting better carcass and meat quality, and having does with good mothering ability and high milking capacity. The bucks will be ranked according to their daughters' fertility, milking capacity, mothering ability and growth rates of their daughters' kids, as measured by the kid growth rates and viability up to weaning. The bucks will, in addition, be ranked according to their expected breeding value and a score or index, which will include weaning weight at about 112 days, carcass weight of at least 10 contemporary progeny, weight of hind quarter, and area of the eye muscle measured on the 12th rib, weighted according to their relative economic values, will be

constructed. Weaning weight will be adjusted for age, type of birth (single, twin, triplet etc.), sex, rearing intensity and age of dam. The adjusted weaning weight could be taken as a deviation from the adjusted flock average. The other traits will be corrected for type of birth and rearing. To reduce the generation interval a preliminary selection index of bucks will be calculated from the weight of their daughters' kid weights at 28 and 42 days of age. From the overall ranking, the top 3 to 5 per cent of bucks could be used in mating to élite dams, and male kids resulting from such matings be used for the next generation in the same flock. From the remaining group of bucks the best one-third would be used in breeding in the villages, while the remaining two-thirds would be slaughtered for meat production (Fig. 6.1).

At present meat goats are slaughtered at different ages. One of the aims in the above meat goat improvement programmes will be to determine an optimum weight and age at which to slaughter the kids. At present carcass weight is more important economically than quality. This is probably true in most of the developing countries. Crossbreeding involving males from breeds with large mature sizes will provide progeny with faster growth rates and heavier weight for age than the progeny from the pure Tanzania goats. Reduced mortality will increase the number of animals being marketed at any one time and therefore increase the cash return to the villagers. Such returns act as incentives which

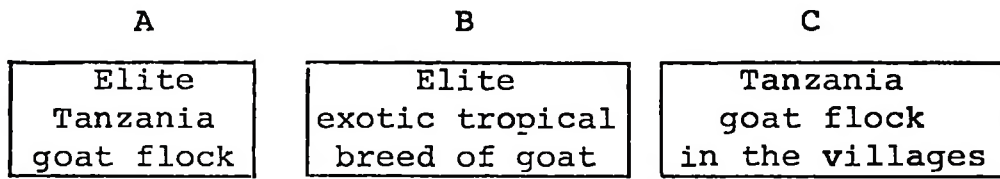
stimulate farmers to look for improved breeding stock and to accept improved management systems. Since monetary returns from slaughtered goats come from the sale of skins also, it will be important to ensure that improved slaughter techniques which produce clean carcasses and undamaged skins are introduced in the villages.

The dissemination of information by means of which the efficiency of meat goat production can be improved will take several forms. One way of doing this is by running short courses on goat husbandry at the Breeding Centres for Government Extension Officers working in co-operating villages. The other ways will be to undertake demonstration on good goat husbandry in the villages, using mobile cinema vans and illustrations. Introducing improved meat goat in primary and secondary schools and expecting that the pupils would pass the information to their parents would be yet another way of disseminating information on good goat husbandry to farmers. There are several aspects of goat production, such as outbreaks of pneumonia when several goats are reared together, concentrate feed requirements by goats reared indoors, feed conversion efficiency of meat goats being fed on locally available feedstuffs, such as sugarcane tops, cassava leaf or flour, ground maize cob mixed with molasses, treated rice straw, maize stover, sisal waste or dry grass, etc., which need to be studied. Introducing courses on goat management

and breeding in agricultural colleges and universities will attract future specialists in various fields of goat production.

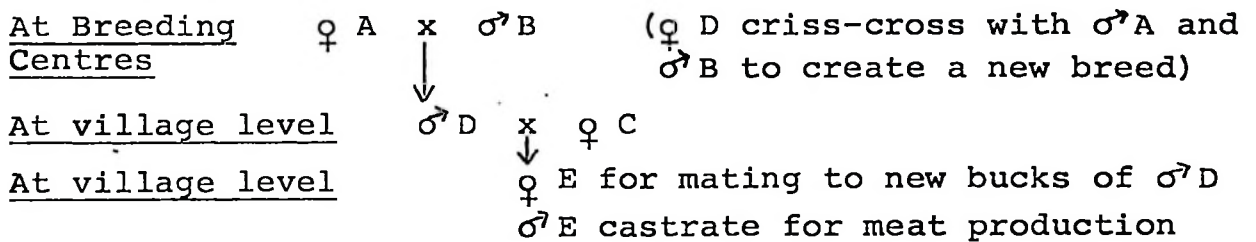
Lastly, it must be emphasised that goat improvement will come about when accurate records are taken regularly at the Breeding Centres and in the villages, and when these are analysed periodically and the results are used in selection of future breeding animals. The training of livestock recorders should therefore precede or go hand in hand with the introduction of improved goat breeds in the villages.

Fig. 6.1 Proposed meat goat improvement scheme in Tanzania

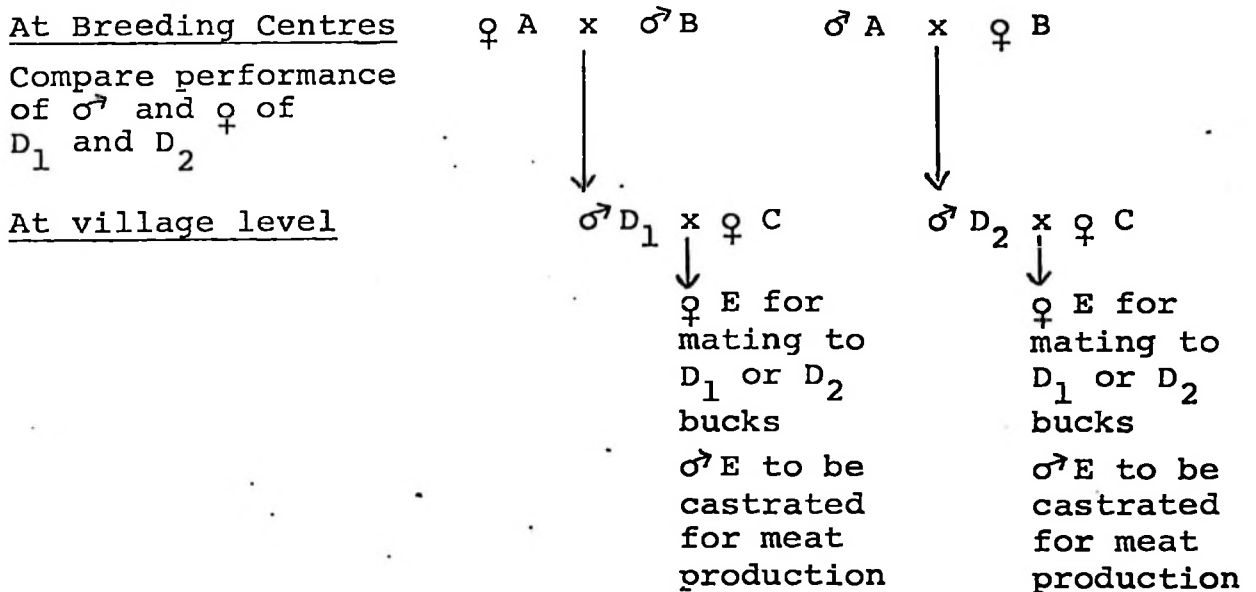


Collect performance data of animals in each of these flocks

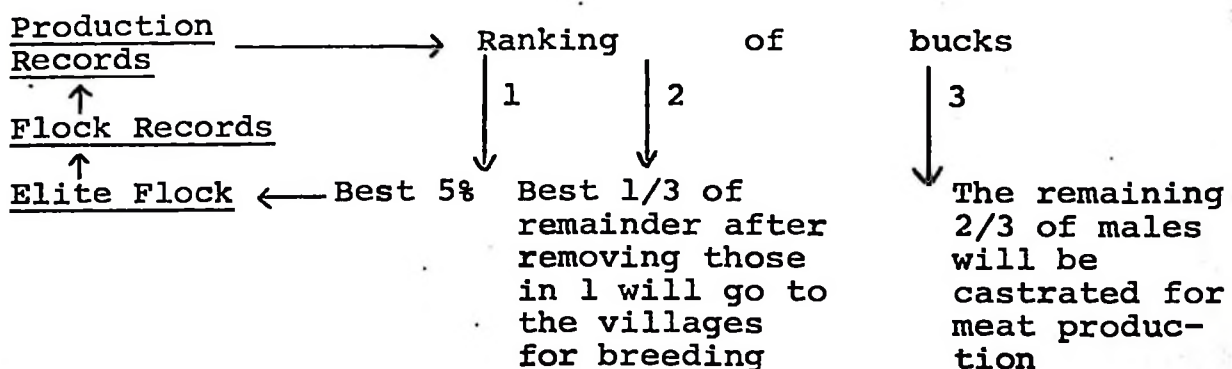
Alternative I



Alternative II



In each of the elite flocks of purebred or crossbred animals at Breeding Centres the following scheme will be followed :



CHAPTER 7SUMMARY

A comparison was made of reproductive performance, growth rate and carcass yield between the indigenous Tanzania goats, and the Tanzania x Boer and Tanzania x Kamorai goats from the data collected on them at the Dar es Salaam University's Farm between 1972 and 1976, inclusive. The total number of animals included in the study comprised 7 sires, 177 dams and 559 progeny.

The study confirmed earlier untested theories that the Tanzania goat, which belongs to the East African breed type of goat, produces kids throughout the year. There were, however, peak periods in which more dams kidded than in others. The total amount of rain falling during any given period was the only climatic factor which affected the time of conception of the dams ($P < 0.001$). The Tanzania, the Tanzania x Boer and the Tanzania x Kamorai female kids took 268.6 ± 25.8 , 237.8 ± 9.4 and 240.3 ± 16.9 days, respectively, before kidding for the first time, after being drafted into mating groups at 72 weeks of age. The age at first kidding was therefore approximately 773, 742 and 744 days, respectively. The mean overall kidding intervals were 302.0, 299.2 and 304.5 days, respectively. The corresponding rates of twinning for these three breed types were 16.4, 31.5 and 3.9 per cent, respectively,

and during the five year study, only one birth from a Tanzania x Boer dam resulted in a set of triplets. The overall kid mortalities were 22.7 per cent before weaning, and 12.9 per cent after weaning. Of all the diagnosed causes of death of kids, pneumonia was responsible for the highest mortality rate of 19 per cent between birth and one year of age of kids. Other causes of death were enteritis, septicaemia, snake bite, plant poisoning, being trampled by adult goats, and an undiagnosed skin disease suspected to be either Goat Pox (Variola caprina) or Contagious Pustular Dermatitis. The percentages of does failing to conceive during the whole of the five year period of the study were 0.2 for Tanzania, and zero for both the Tanzania x Boer and Tanzania x Kamorai breed types.

The birth weights of the kids for the three breed types were 2.0 ± 0.08 , 2.3 ± 0.09 and 2.1 ± 0.09 kg, respectively. There was a significant difference between birth weights of kids from different sexes ($P < 0.01$), birth types ($P < 0.001$) and the year in which they were born ($P < 0.001$). The differences in this trait between the three breed types and parities of dams were not significant. The weights of kids at weaning were affected by sex of kids ($P < 0.05$), birth type ($P < 0.05$), year ($P < 0.001$) and seasons in which they were weaned ($P < 0.001$). There were no significant effects due to breed and parity of dam on this trait. Sex of kids, years and seasons had significant effects

on weights at one year and at 72 weeks of age of kids, $P < 0.01$, $P < 0.001$ and $P < 0.001$, respectively. The highly significant effect of parity ($P < 0.001$) on the weights at these two ages was not expected. There were no significant effects on weight at these two ages due to breed types and birth types. The interaction between parity and sex, and between sex and birth type did not reach significance at any of the above ages. The castrated kids had heavier weights than the entire male kids at weaning, one year and 72 weeks of age. However, these differences in weight between the two groups of kids were not significant. The heritability estimates calculated on paternal half-sib method were 0.07, 0.14, 0.07 and 0.17 for weight at birth, weaning, one year and 72 weeks of age, respectively.

The average growth rate of kids between birth and weaning, and between weaning and 72 weeks of age, were 64.3 and 24.3 g per day, respectively. The single kids grew faster than twin kids between birth and weaning, at 65.8 and 60.4 g per day, respectively. After weaning, however, the kids in the two groups grew at the same rate. The difference in growth rate between the entire male and castrated kids existed after weaning. This difference was, however, not significant. The changes in body measurements, namely, height at withers, heart girth, width of hind quarters and length of body from point of shoulder to pin bones, were not affected

by sex of the animals. However, breed and birth type affected height and heart girth ($P < 0.05$ in each case). The width of the hind quarters increased at a faster rate than the other body measurements between 4 and 72 weeks of age, followed by heart girth, then length, and lastly height. Weight at any age could, under farm conditions, be predicted by the relationship :

$$\text{Weight} = 4.22 \pm 0.15 + (0.00806 \pm 0.00007 \times \text{Girth} \times \text{Length})$$

$$R^2 = 88.2\%$$

The average cold dressed carcass percentages for the Tanzania, Tanzania x Boer and Tanzania x Kamorai kids were 45.3, 45.6 and 45.3, respectively. The area of the eye muscle (Longissimus dorsi) measured on the 10th and 11th ribs of the male and castrated kids ranged between 11.8 and 14.3 square centimetres. The mean percentages of separable fat, lean and bone in the carcass were 11.5, 68.0 and 18.0 per cent, respectively. The castrated kids had more total lean, fat and bone than the entire male kids when slaughtered at the same age. The heritability estimates for cold dressing percentage, total weight of lean, fat and bone within the carcass, were 0.69, 0.31, 0.04 and 0.42, respectively.

The study has contributed to the present meagre knowledge on meat goat production characteristics in the tropics. The findings from it can be used in formulating commercial meat goat production systems in Tanzania and elsewhere.

BIBLIOGRAPHY

- ALI, S.Z., HOQUE, M.M. and HASNATH, M.A. (1973). A study on the growth and reproductive performance of Black Bengal goats under farm conditions. Indian vet. J. 50 (5) : 438-440. (A.B.A., 41, No. 5337).
- AMBLE, V.N., KHANDEKAR, N.C. and GARG, J.N. (1964). Statistical studies on breeding data of Beetal goats. I.C.A.R. Res. Ser., No. 38. New Delhi : Indian Council of Agricultural Research. 70 pp. (A.B.A., 36, No. 522).
- ASDELL, S.A. (1950). Low temperature as a factor in developing capacity for bulk. Br. Goat Soc. Year Book 1950, p. 28.
- ASDELL, S.A. (1964). Patterns of Mammalian Reproduction. 2nd ed. Ithaca, N.Y. Comstock.
- ASDELL, S.A. and BRODY, S. (1935). Maintenance ration - resting metabolism of the goat. Br. Goat Soc. Year Book, p. 21.
- ASDELL, S.A. and TURNER, C.W. (1938). Energetic conversion efficiency of goats. Missouri Agric. Exp. Stat. Res. Bullet. No. 291.
- AYRE-SMITH, R.A., SKERMAN, P.J. and BEALE, C.I.A. (1968). Increased livestock production and improved grassland use in Tanzania. UNDP/FAO, Rome.
- BAKER, R.D., LARGE, R.V. and SPEDDING, C.R.W. (1973). Size of animal in relation to productivity with special reference to the ruminant-economic aspects. Symp. Size and Productivity. Proc. Br. Soc. Anim. Prod. 1973. (2) : 35-42.
- BERG, R.T. and BUTTERFIELD, R.M. (1976). New concepts of cattle growth. Sydney University Press. 240 pp.
- BLACKWELL, R.L. and HENDERSON, C.R. (1955). Variation in fleece weight, weaning weight and birth weight of sheep under farm conditions. J. Anim. Sci. 14 : 831-843.
- BOHMAN, V.R. (1955). Compensatory growth of beef cattle. The effect of hay maturity. J. Anim. Sci. 14 : 249-255.

- BOWMAN, J.C. (1966). Meat from sheep. Anim. Breed. Abstr. 34 : 293-319.
- BOWMAN, J.C. (1973). Photoperiodicity in mammals. J. Reprod. Fert., Suppl. 19, 85-88.
- BOWMAN, J.C. and HENDY, C.R.C. (1972). A study of retail requirements and genetic parameters of carcass quality in polled Dorset Horn Sheep. Anim. Prod. 14 : 189-198.
- BOWMAN, J.C. and BROADBENT, J.S. (1966). Genetic parameters of growth between birth and 16 weeks in Down cross sheep. Anim. Prod. 8 : 129-135.
- BOWMAN, J.C., MARSHALL, J.E. and BROADBENT, J.S. (1968). Genetic parameters of carcass quality in Down cross sheep. Anim. Prod. 10 : 183-191.
- BRINKS, J.S., CLARK, R.T., RICE, F.J. and KIEFFER, N.M. (1961). Adjusting birth weight, weaning weight, and pre-weaning gain for sex of calf in range Hereford cattle. J. Anim. Sci. 20 : 363-367.
- BRITISH VETERINARY ASSOCIATION (1968). Handbook on animal diseases in the tropics. Br. Vet. Ass. London. 232 pp.
- BRODY, S. (1927). Growth and development, with special reference to domestic animals. Res. Bull. Mo. agric. Exp. Sta. No. 103. 40 pp.
- BRODY, S. (1945). Bioenergetics and growth. New York: Reinhold.
- BRODY, S. (1964). Bioenergetics and growth with special reference to the efficiency complex in domestic animals. Hafner Publ. Company Inc., New York.
- BROOKS, and ASDELL, S.A., quoted by Mackenzie, D. (1967). Goat husbandry. Faber & Faber Ltd., London.
- BROWN, G.H. and TURNER, H.N. (1968). Response to selection in Australian Merino Sheep. II. Estimates of phenotypic and genetic parameters for some production traits in Merino ewes and an analysis of the possible effects of selection on them. Aust. J. Agric. Res. 19 : 79-112.
- BUTTERFIELD, R.M. and BERG, R.T. (1972). Anatomical aspects of growth. Proc. Br. Soc. Anim. Prod., 1972, 109-112.

- BUVANENDRAN, V. and JALATGE, E.F.A. (1974). A note on comparative growth rates of Jamnapari, South Indian goats and their crosses. Ceylon vet. J. 22 (1-2) : 14-15. (A.B.A., 43, No. 4073).
- CANNON, W.B. (1929). Organisation for physiological homeostasis. *Physiol. Rev.* 9 : 399-431.
- CARRERA, M.C. and SEVILLA, A. (1971). A study of some production characters in Criollo goats on pasture. XII Infme. Invest. Agric. Ganad. Inst. tecno. Estad. Sup. Monterrey 1969-1970 : 152-155.
- CARRERA, M.C. and DIEGO, V.R. (1971). Effect of flushing prior to mating in goats. XII Infme. Invest. Esc. Agric. Ganad. Inst. tecnol. Estud. Sup. Monterrey 1969-1970 : 156-157.
- CARRÒLL, M.A. (1976). The impact of carcass and meat aspects on experimental design, particularly in relation to feeding levels and time of slaughter. In: Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments. Ed. A.V. Fisher, J.C. Tayler, H. de Boer and D.H. van Andrichem Boogaert. pp. 17-24. Commission of European Communities, Luxembourg.
- CASTILLO, M.J. and GARCIA, B.O. (1971). The Nubian x Criollo cross. I. Growth of kids. III. Reun. lat.-am. Prod. anim., Bogota, 1971 : 111. (Estacion Exp. Zonas Aridas, Venezuela).
- CASTILLO, J., GARCIA, B.O. and OSAL, N. (1972). (The Criollo x Nubian crossbred. I. Kid growth). El mestizo Criollo x Nubian. I. Crecimiento de cabritos. *Agronomia Trop.* 22 (3) : 251-259. (Es en). (A.B.A. 41, No. 3508).
- CHAMBERLAIN, G.T. (1959). Trace elements in some East African soils and plants. I. Cobalt, Beryllium, Lead, Nickel and Zinc. *E. Afr. agric. J.* 25 : 121-125.
- CHAMBERLAIN, G.T. and SEARLE, A.J. (1963). Trace elements in some East African soils and plants. II. Manganese. *E. Afr. agric. J.* 19 : 114-119.
- CHENOST, M. and GEOFFROY, F. (1973). (Observation on the performance of a herd of Alpine dairy goats in a humid tropical climate). Observations sur le comportement d'un troupeau de caprins laitiers de race Alpine en zone tropicale humide. In IIC Conference Internat. de Elevage Caprin, Tours, Paris. pp. 241-250.

- CHOSNIAK, I., TADMOR, A. and SHKOLNIK, A. (1976). The rumen and drinking capacity in desert goats. *Israel J. Med. Sci.* 12 (2) : 177.
- CHOSNIAK, I. and SHKOLNIK, A. (1977). Rapid rehydration in the Black Bedouin Goats: Red blood cells fragility and role of the rumen. *Comp. Biochem. Physiol.* 56A : 581-583.
- COGNIE, Y., HOUIX, Y. and LOGEAY, B. (1971). (Growth and reproductive performance of the Criollo goat in Guadeloupe). Données sur la croissance et la reproduction de la chèvre créole en Guadeloupe. In IIC Conference Internationale de Elevage Caprin, Tours, 17-19 Juillet, 1971. (A.B.A. 42, No. 1487).
- CUTHBERTSON, A. (1976). Note on the use of the scanogram on live cattle to predict carcass composition. In: *Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments*. Ed. A.V. Fisher, J.C. Tayler, H. de Boer and D.V. van Andrichem Boogaert. pp. 65-69. Commission of European Communities, Luxembourg.
- CUTHBERTSON, A., HARRINGTON, G. and SMITH, R.J. (1972). Tissue separation to assess beef and lamb variation. *Proc. Br. Soc. Anim. Prod. Symp. "Aspects of Carcass Evaluation"*, 1972, pp. 113-122. Edinburgh. Longman. 149 pp.
- DATTA, I.C., KARKUN, J.N. and KAR, A.B. (1969). Physiological and biochemical changes in cervix of goats during oestrous cycle. *Indian vet. J.* 46 : 490-492. (A.B.A. 38, No. 2).
- DEBACA, R.C., BORGART, R., CALVIN, L.D. and NELSON, O.M. (). Factors affecting weaning weight of cross-bred spring lambs. *J. Anim. Sci.* ___ : 667-678.
- DE BOER, H., DUMONT, B.L., POMEROY, R.W. and WENIGER, J.H. (1974). Manual on E.A.A.P. reference methods for the assessment of carcass characteristics in cattle. *Livestock Production Science* 1 : 151-164.
- DEVENDRA, C. (1966). Goats improvement in Malaysia. *Malays. vet. J.* 4 : 18-22.
- DEVENDRA, C. and BURNS, M. (1970). Goat production in the Tropics. *Techn. Commun. No. 19 of the C.A.B. Commonwealth Agric. Bureaux, Farnham Royal, Bucks, England.* 184 pp.
- DOANE, B.B. (1971). Practical Husbandry Methods for Increasing Sheep Prolificacy. In: *Lamb Production by the U.S. Feed Grains Council, 28 Mount Street, London.* 78 pp.

- DONALD, H.P. (1962). Effect of production records of sex of lamb, twinning, and dam's age in a grass-land flock. *Anim. Prod.* 4 : 369-377.
- DRUMMEL, J. and DRITSCHILO, W. (1977). Resource costs of animal protein production. *Wld. Anim. Rev.* 21 : 6-10.
- DUCKER, M.J. and BOWMAN, J.C. (1970). Photoperiodism in the ewe. 3. The effects of various patterns of increasing daylength on the onset of anoestrus in Clun Forest ewes. *Anim. Prod.* 12 : 465-471.
- DUCKER, M.J., THWAITES, C.J. and BOWMAN, J.C. (1970). Photoperiodism in the ewe. 2. The effects of various patterns of decreasing daylength on the onset of anoestrus in Clun Forest ewes. *Anim. Prod.* 12 : 115-123.
- DUCKER, M.J., BOWMAN, J.C. and TEMPLE, A. (1973). Proc. III Internat. Symp. Reprod. J. Reprod. Fert. Suppl. 19 : 143.
- DUCKER, M.J. and BOWMAN, J.C. (1974). Effect of artificial daylight changes on the reproductive rate of sheep. *Vet. Rec.* 95 : 96-98.
- DUTT, R.H. and BUSH, L.F. (1955). The effect of low environmental temperatures on initiation of breeding season and fertility in sheep. *J. Anim. Sci.* 14 : 885-896.
- DYRMUNDSSON, O.R. and LEES, J.L. (1972). Attainment of puberty and reproductive performance in Clun Forest ewe lambs. *J. agric. Sci. Camb.* 78 : 39-45.
- DYRMUNDSSON, O.R. and LEES, J.L. (1972). A note on factors affecting puberty in Clun Forest female lambs. *Anim. Prod.* 15 (3) : 311-314.
- DYRMUNDSSON, O.R. (1973). Puberty and early reproductive performance in sheep. I. Ewe lambs. *A.B.A.* 41 : 273-289.
- EAST AFRICAN RANGE CLASSIFICATION COMMITTEE (1967). Quoted by the Food and Agriculture Organisation of the United Nations (FAO) : East African Livestock Survey, Rome, 1967.
- EL HAG, G.A. (1976). A comparative study between Desert Goat and Sheep: Efficiency of feed utilisation. *Wld. Rev. Anim. Prod.* 12 (3) : 43-48.

- EL WISHY, A.B. and EL SAWAF, S.A. (1971). Development of sexual activity in male Damascus goats. *Indian J. Anim. Sci.* 41 : 350-356. (A.B.A. 40, No. 2013).
- ELDER, A.H. (1977). Personal communication (Meat and Livestock Commission of the United Kingdom).
- ELLIS, P.R. and HUGH-JONES, M.E. Disease as a limiting factor to beef production in the developing countries. In: *Beef Production in Developing Countries*, ed. A.J. Smith, pp. 105-116. Centre for Tropical Veterinary Medicine, University of Edinburgh.
- EPSTEIN, H. (1953). The dwarf goats in Africa. *E. Afr. agric. J.* 18 : 123-132. (A.B.A. 21, No. 1789).
- EPSTEIN, H. (1965). Regionalisation and stratification in livestock breeding, with special reference to the Mongolian People's Republic (Outer Mongolia). *Anim. Breed. Abstr.* 33 : 1969-1981.
- EPSTEIN, H. (1969). Domestic animals of China. With a foreword by A.H. Boerma. *Tech. Commun. Commonw. Bur. Anim. Breed. Genet.*, No. 18. Farnham Royal, Bucks : Commonwealth Agricultural Bureaux. xviii + 166 pp. + 205 illustrations.
- FALCONER, D.S. (1960). Introduction to Quantitative Genetics. 365 pp. Oliver & Boyd. Edinburgh.
- FEHR, P.M. and SAUVANT, D. (1976). Production of heavy kids. I. Influence of the age and mode of weaning on the performance of kids slaughtered at 26.5-29 kg. *Annls. Zootech.* 25 (2) : 243-257 (English summary).
- FEHR, P.M., SAUVANT, D., DELAGE, J., DUMONT, B.L. and ROY, G. (1976). Effect of feeding methods and age at slaughter on growth performances and carcass characteristics of entire young male goats. *Livestock Prod. Sci.* 3 : 183-194.
- FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1967). East African Livestock Survey. Regional: Kenya, Tanzania, Uganda. Vols. I-III. United Nations Development Program, FAO, Rome, Italy.
- FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1970). Commodity Bulletin Series No. 48. The World Hides, Skins, Leather and Footwear. FAO, Rome, Italy.
- FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1972). The State of Food and Agriculture --- 1972. FAO, Rome, Italy.

- FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS
(FAO) (1975). FAO Production Year Book, 1975.
Vol. 29. Rome, Italy.
- FOUGNER, J.A. (1976). Uterine insemination with frozen semen in goats. VIIth International Congress on Animal Reproduction and Artificial Insemination. Cracow. pp. 987-999.
- FRENCH, M.H. (1944). The feeding of goats. E. Afr. agric. J. 10 : 66-71.
- FRENCH, M.H. (1952). Mineral deficiencies in farm livestock. E. Afr. agric. J. 18 : 1-5.
- FRENCH, M.H. (1970). Observations on the goat. FAO Agricultural Studies No. 80. FAO, Rome, Italy, 204 pp.
- GAILI, E.S.E., GHANEM, Y.S. and MUKHTAR, A.M.S. (1972). A comparative study of some carcass characteristics of Sudan Desert Sheep and Goats. Anim. Prod. 14 : 351-357.
- GAILI, E.S.E. (1976). Body composition of male Sudan Desert Goats. Wld. Rev. Anim. Prod. 12 (4) : 83-87.
- GARCIA, B.O. (1971). (Heritabilities of milk and butter-fat production in goats). III. Reun. lat-am. Prod. anim., Bogota. (Sp.) (A.B.A. 40, No. 2008).
- GARCIA, B.O., CASTILLO, J. and GADO, C. (1972). (Present position of goat breeding in Venezuela). Situacion actual de la ganaderia caprina en Venezuela. Agron. Trop. 22 (3) : 239-250. (Es en). (A.B.A. 41, No. 3509).
- GIHAD, E.A. (1976). Intake, digestibility and nitrogen utilisation of tropical natural grass hay by goats and sheep. J. Anim. Sci. 43 (4) : 879-883.
- GJEDREM, T. (1971). Practical Breeding Methods for Improving Sheep Prolificacy. Weight Gains and Meat Yield. In: Lamb Production. U.S. Feed Grains Council. London, 1971. pp. 63-68.
- GONZALEZ, S.C. and CASTILLO, M.J. (1971). Sexual periodicity in goats in a tropical zone in Venezuela. III. Reun. lat-am. Prod. anim., Bogota, 1971 : 106 (Univ. Zulia, Maracaibo, Venezuela).
- GONZALEZ, S.C. and CASTILLO, M.J. (1971). (Sexual periodicity in goats in a tropical zone in Venezuela). III. Reun. lat-am. Prod. anim., Bogota : 106 (Sp.) (A.B.A. 40, No. 2015).

- HAFEZ, E.S.E. (1968). Adaptation of Domestic Animals. Lea and Febiger. Philadelphia. 415 pp.
- HAFEZ, E.S.E. (1969). The Behaviour of Domestic Animals. 2nd ed. Bailliere, Tindal and Cassel. 647 pp.
- HAMMOND, J. (1932). Growth and Development of Mutton Qualities in the Sheep. Oliver & Boyd. Edinburgh. 597 pp.
- HARVEY, W.R. (1960). Least Squares Analysis of data with unequal sub-class frequencies. USDA, Agricultural Research Service. ARS 20-8.
- HARVEY, W.R. (1964). Computing procedures for a generalised Least Squares Analysis Program. Mimeographed paper presented at the Analysis of Variance Workshop, Ft. Collins, Colorado, July 1964. 50 pp.
- HARVEY, D. and RIGG, J.C. (1964). Some aspects of goats as a livestock. Nutr. Abstr. Rev. 34 : 641-645.
- HAUMESSER, J.B. (1975). (Some aspects of reproduction in the Red Sokoto goat). Revue d'Elevage et de Medicine Veterinaire des pays Tropicaux, 28 (2) : 225-233. (A.B.A. 44 (1), No. 203).
- HAZEL, L.N. (1943). The genetic basis for constructing selection indexes. Genet. 28 : 476-490.
- HENDERSON, W.M. (1974). Discussion of productivity and health of animals. Proc. Br. Soc. Anim. Prod. 3 : 3.
- HOFMEYR, H.S., JOUBERT, D.M., BADENHORST, F.J.G. and STEYN, G.J. van d. (1965). Adaptability of Sheep and Goats to a South African tropical environment. Proc. S. Afr. Soc. Anim. Prod., 1965, 4 : 191-195. (A.B.A. 36, No. 1458).
- HOFMEYR, H.S., JOUBERT, D.M., BADENHORST, F.J.G. and STEYN, G.J. van d. (1966). On the sex activity of female Boer goats. Proc. S. Afr. Soc. Anim. Prod., 1966, 5 : 134-136. (A.B.A. 36, No. 3756).
- HOMB, T. and JOSHI, D.C. (1972). The Biological Efficiency of Protein Production by stall-fed ruminants. In: J.G.W. Jones (ed.) Biological Efficiency of Protein Production. Camb. Univ. Press. 385 pp.
- HORNBY, H.E. (1936). Overstocking in Tanganyika Territory. E. Afr. agric. J. 1 (5) : 353.

- HORNBY, H.E. and VAN RENSBURG, H.J. (1948). The place of goats in Tanganyika farming systems. I. In deciduous bushland formation. E. Afr. agric. J. 14 : 94-98.
- HUNTER, G.L. (1956). The maternal influence on size of sheep. J. agric. Sci. Camb. 48 : 36.
- HUNTER, G.L. (1968). Increasing the frequency of pregnancy in sheep. I. Some factors affecting rebreeding during post-partum period. Anim. Breed. Abstr. 36 (3) : 347-378.
- HUTCHISON, G.H. (1962). 1st annual report, 1961. (Mpwapwa): Livestock Research Section, Veterinary Division, Ministry of Agriculture, Tanganyika. (Mimeograph).
- HUTCHISON, G.H. (1963). 2nd annual report, 1962. (Mpwapwa): Livestock Research Section, Veterinary Division, Ministry of Agriculture, Tanganyika. (Mimemograph).
- HUTCHISON, G.H. (1964). 34d annual report, 1963. (Dar es Salaam): Livestock Research Section, Research Division, Ministry of Agriculture, Tanganyiak. (Mimeograph). (A.B.A. 33, No. 932).
- IGBOELI, G. (1974). Semen quality in Boer and Zambia goat. E. Afr. agric. J. 40 (2) : 132-137. (A.B.A. 44 (3), No. 1237).
- JAMES, A.T. and WILKINSON, G.N. (1971). Factorisation of the residual operator and canonical decomposition of non-orthogonal factors in the analysis of variance. Biometrika 58 : 279-294.
- JASIOROWSKI, H.A. (1972). FAO activities in livestock development. Wld. Anim. Rev. 1 : 2-9.
- JASIOROWSKI, H.A. (1973). Twenty years with no progress? Wld. Anim. Rev. 5 : 1-5.
- JOHRI, C.B. and TALAPATRA, S.K. (1971). Growth studies with Jamnapari goats. III. Goat as a meat producing animal. Indian vet. J. 48 : 602-604. (U.P. Coll. Vet. Sci. Anim. Husb., Mathuray Uttar Pradesh).
- JONES, G.M., JAVED, A.H., DONEFER, E. and GAUDREAU, J.M. (1972). Voluntary intake and nutrient digestibility of forages by goats and sheep. J. Anim. Sci. 34 : 830-838.

- JOUBERT, D.M. (1959). Effect of age at which lambs are castrated on carcass weight and quality. Anim. Prod. 1 (2) : 163-165. (A.B.A. 28, No. 720).
- KALLWEIT, E. (1976). Visual assessments. In: Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments. Ed. A.V. Fisher, J.C. Tayler, H. de Boer and D.H. van Andrichem Boogaert. pp. 81-89. Commission of European Communities, Luxembourg.
- KATEGILE, J.A. (1976). The effects of iodine supplement on lambing and kidding rates at Ilonga, Tanzania. Res. Bulletin. Univ. Dar es Salaam 1 (2) : 8-9.
- KIRTON, A.H. (1969). Goats cannot be written off as producers of meat. N.Z. J. Agric. 118 (4) : 50-55. (A.B.A. 37, No. 3784).
- KIRTON, A.H. (1970). Body and carcass composition and meat quality of the New Zealand feral goat (Capra hircus). N.Z. J. agric. Res. 13 : 167-181.
- KIRTON, A.H., FOURIE, P.D. and JURY, K.E. (1972). Growth and development of sheep. 3. Growth of the carcasses and non-carcass components of the South-down and Romney and their cross and some relationships with composition. N.Z. J. agric. Res. 15 : 214-227.
- LAND, R.B. (1974). Physiological studies and genetic selection for sheep fertility. Anim. Breed. Abstr. 42 (4) : 155-158.
- LANGDALE-BROWN, I., OMASTON, H.A. and WILSON, J.G. (1964). The vegetation of Uganda and its bearing on land use. Government of Uganda, 1964.
- LEDGER, H.P. (1965). The body and carcass composition of East African ruminants. I. The composition of "Improved Boran" Bos indicus steer carcasses. J. agric. Sci. 65 : 261-284.
- LEDGER, H.P. and HUTCHISON, H.G. (1962). The value of the tenth rib as a sample joint for the estimation of lean, fat and bone in carcasses of East African Zebu Cattle. J. agric. sci. 58 : 81-88.
- LEDGER, H.P., GILLIVER, B. and ROBB, J.M. (1973). An examination of sample joint dissection and specific gravity techniques for assessing carcass composition of steers slaughtered in commercial abattoirs. J. agric. Sci. Camb. 80 : 381-392.

- LEES, J.L. (1964). Variations in the time of onset of the breeding season of sheep and their effects on subsequent productivity and performance. *Anim. Prod.* 6 : 255-256 (Abstr.).
- LEES, J.L. (1966). Variations in the time of onset of the breeding seasons in Clun ewes. *J. agric. Sci. Camb.* 67 : 173-179.
- LIND, E.M., MORRISON, M.E.S. and HAMILTON, A.C. (1974). *East African Vegetation*. Longman Group Ltd. London.
- LODGE, G.A. (1970). Quantitative and qualitative control of proteins in meat animals. In: *Proteins as Human Food*. Proc. Easter Sch. agric. Sci. Univ. Nott. 16 : 141-166. Butterworths. London.
- LOHMAN, T.G., COFFMAN, W.J., TWARDOCK, A.R., BREIDENSTEIN, B.C. and NORTON, H.W. (1968). Factors affecting potassium-40 measurement in the whole body and body components. *Symp. Public. No. 1598*. Nat. Acad. Sci. Wash. D.C.
- LOHMAN, T.G. (1971). Biological variation in body composition. *J. Anim. Sci.* 32 : 647-653.
- LOFTI, A.Y. and YOUSSEF, K.E. (1968). Studies on goat meat. I. The influence of age and sex on the proximate composition of goat meat. *Vet. Medical J. (Egypt)*. XV (16) : 119-130.
- LOFTI, A.Y. and YOUSSEF, K.E. (1968). Studies on goat meat. II. Physical and chemical characteristics of goat depot fats. *Vet. Medical J. (Egypt)*. XV (16) : 131-137.
- LOUCA, A., ECONOMIDES, S. and HANCOCK, J. (1977). Effects of castration on growth rate, feed conversion efficiency and carcass quality in Damascus goats. *Anim. Prod.* 24 (3) : 387-391.
- LOWE, H.J. (1943). Goats as a source of milk in tsetse areas. *E. Afr. agric. J.* 8 : 238-240. (A.B.A. 11, No. 172).
- LUSH, J.L. and SHRODE, R.R. (1950). Changes in milk production with age and milk frequency. *J. Dairy Sci.* 33 : 338-357.
- MACKENZIE, D. (1957). *Goat Husbandry*. Faber & Faber Ltd. London. 1st ed. 1957, 2nd ed. 1967, and 3rd ed. 1970. 366 pp.

- MAHER, C. (1945). The goat: friend or foe? E. Afr. agric. J. 11 : 115-121. (A.B.A. 14; No. 29).
- MASON, I.L. and MAULE, J.P. (1960). The Indigenous Livestock of Eastern and Southern Africa. Tech. Commun. Commonw. Bur. Anim. Breed. Genet., No. 14. Farnham Royal, Bucks, England. Commonwealth Agricultural Bureaux, XV + 151 pp + 48 plates.
- MBA, A.U., OMOLE, J.O. and OYENUGA, V.A. (1976). Studies on the ruminal concentration of total volatile fatty acids (VFAs) and their molar proportions in African cattle, sheep and goats. Livestock Prod. Sci. 3 : 43-56.
- MCCLELLAND, T.H., BONAITI, B. and TAYLOR, St.C.S. (1976). Breed differences in body composition of equally mature sheep. Anim. Prod. 23 (3) : 281-293.
- MCCULLOCH, B. (1965). Overstocking in Sukumaland, Tanganyika. E. Afr. agric. J. 30 : 219-226.
- MCCULLOCH, B. and TUNGARAZA, R. (1967). Skin disease in cattle hides and goat skins in North-Western Tanzania. E. Afr. agric. J. 32 : 240-245.
- MCCULLOCH, B. and KASIMBALA, S. (1968). The incidence of gastro-intestinal nematodes of sheep and goats in Sukumaland, Tanzania. Br. Vet. J. 124 (5) : 178-193.
- MCDOWELL, R.E. (1972). Improvement of livestock production in warm climates. W.H. Freeman & Co. San Francisco.
- MILLER, J.C., JONES, J.M. and BURT, C.R. (1943). Feedlot and carcass studies of Angora wethers. Texas Agricultural Exp. Stat. Bull. No. 631. 14 pp.
- MILNE, G. (1940). Soil and vegetation. E. Afric. agric. J. 5 : 294-298.
- MILTAL, J.P. and PANDEY, M.D. (1972). Evaluation of semen quality of Barbari and Jamnapari bucks. Indian J. Anim. Prod. 2 (4) : 14-19. (A.B.A. 49. No. 744).
- MINETT, F.C. (1950). Mortality in sheep and goats in India. Indian J. vet. Sci. 20 : 69-103. (A.B.A. 20, No. 1667).
- M.L.C. (MEAT AND LIVESTOCK COMMISSION) (1972). Sheep Improvement. Scientific study group report. Bletchley. M.L.C.

- M.L.C. (MEAT AND LIVESTOCK COMMISSION) (1975).
Planned crossbreeding and lamb carcass weights.
Pamphlet. 8 pp.
- MORE O'FERRALL, G.J. and VIAL, V.E. (1963). Correction
factors for use in sheep flock recording. Irish
J. Agric. Res. 2 (1) : 13-20.
- MOULE, G.R. (1966). Ovine reproduction in Tropical
Australia. Aust. vet. J. 42 : 13-18.
- MOULICK, S.K. and SYRSTAD, O. (1970). Genetic and
environmental causes of variation in birth weight
of Black Bengal goats. J. agric. Sci. Camb. 74 :
409-414.
- MUKUNDAN, G. and RAJAPOPALAN, T.G. (1971). An evalua-
tion of the influence of age of the dam on
frequency of multiple births in Malabari goats.
Kerala J. vet. Sci. 2 (2) : 95-98. (A.B.A. 41,
No. 1691).
- NAIK, A.H. (1965). Mineral status of grasses and soils
of part of Mbulu District of Tanzania in relation
to animal health. E. Afr. agric. J. 31 : 175-185.
- NAPPER, D.M. (1965). Grasses of Tanganyika with keys
for identification. Bulletin No. 18, Min. Agric.
Forests and Wildlife, Tanzania. Govt. Printer.
Dar es Salaam, Tanzania. 146 pp.
- NARANG, M.P., YADAVA, I.S. and VERMA, S.D. (1969).
Effect of feeding chlorotetracycline (Aurofac - 2A)
and stilboestrol (Clinestrol) on growth and carcass
characteristics of Beetal kids. J. Res. Punjab
agric. Univ. G. : 400-407. (A.B.A. 98).
- OWEN, J.E. (1974). A note on the carcass evaluation
of the indigenous Malawi goat. Trop. Sci. 16 (2) :
75-83.
- OWEN, J.E. (1975). The meat-producing characteristics
of the indigenous Malawi goat. Trop. Sci. 17 (3) :
123-138.
- OWEN, J.E., NORMAN, G.A., FISHER, I.L. and FORST, R.A.
(1977). Studies on the meat production character-
istics of Botswana goats and sheep. Part I.
Sampling, methods and materials, and measurements
on the live animals. Meat Science 1 : 63-85.
- OWEN, J.B. (1976). Sheep Production. Bailliere
Tindall. London. 436 pp.

- OWEN, J.B. (1976). Sheep production - view of the future. Dev. Agric. Assoc. Lectures. Seale-Hayne Agric. Coll., Newton Abbot, Devon, England.
- PALSSON, H. (1940). Meat qualities in the sheep with special reference to Scottish breeds and crosses. 2. Part 3. Comparative development of selected individuals of different breeds and crosses as lambs and hoggets. J. agric. Sci. Camb. 30 : 1-82.
- PAYNE, J.M. (1972). Production Disease. Jl. R. Agric. Soc. 133 : 69-86.
- POMEROY, R.W., WILLIAMS, D.R., HARRIES, J.M. and RYAN, P.O. (1974). Composition of beef carcasses. I. Material, measurements, jointing and tissue separation. J. agric. Sci. Camb. 83 : 67-77.
- POMEROY, R.W. and WILLIAMS, D.R. (1975). Beef carcasses. Methods of dressing, measuring, jointing and tissue separation. Summary of Questionnaire for the European Assoc. of Anim. Prod. Meat Res. Instit., Langford, Bristol, England.
- PRASAD, S.P., ROY, A. and PANDEY, M.D. (1972). Influence of age, body weight, parity and season on the reproductive performance of Barbari goat. Agra Univ. J. Res. (Sci.) 20 (1) : 31-39. (A.B.A. 41).
- PRESTON, T.R. (1977). A strategy for cattle production in the tropics. Wld. Anim. Rev. 21 : 11-17.
- PRESTON, T.R. and WILLIS, M.B. (1970). Intensive Beef Production. Pergamon Press. Oxford. 544 pp.
- QUARTERMAIN, A.R. and BROADBENT, M.P. (1974). Some patterns of response to climate by the Zambian goat. E. Afr. agric. J. 40 (1) : 115-124.
- RAJA, C.A.R. and MUKUNDAN, G. (1974). Age at first kidding, kidding rate and kidding interval in Malabari and Jamnapari-Malabari cross goats. Kerala J. vet. Sci. 4 (2) : 165-169. (A.B.A. 43).
- RANATUNGA, P. (1971). Kid mortality on two major Government Farms in Ceylon. Trop. Anim. Hlth. Prod. 3 : 52-61. (A.B.A. 39).
- REID, J.T., BENSADOUN, A., BULL, L.S., BURTON, J.H., GLEESON, P.A., HAN, I.K., JOO, Y.D., JOHNSON, D.E., McMANUS, W.R., PALADINES, O.L., STROUD, J.W., TYRRELL, H.F., VAN NIEKERK, B.D.H. and WELLINGTON, G.W. (1968). Some peculiarities in the body composition of animals. In: Body Composition in Animals and Man. Proc. of a Symp. Public. No. 1598. National Academy of Sciences. Washington, D.C.

- RENDEL, J. (1956). Heritability of multiple birth in sheep. *J. Anim. Sc.* 15 : 193-201. (A.B.A. 24, No. 1175).
- ROBELIN, J. (1976). Prediction of chemical carcass composition from sample joints. In: *Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments*. Ed. A.V. Fisher, J.C. Tayler, H. de Boer and D.V. van Andrichem Boogaert. pp. 241-251. Commission of the European Communities, Luxembourg.
- ROBERTSON, A. and LERNER, M.I. (1949). The heritability of all-or-none traits: viability of poultry. *Genet.* 34 : 395-411.
- ROBINSON, T.J. (1957). Pregnancy. In: *Progress in Animal Physiology*. Ed. J. Hammond. Vol. III, pp. 793-903. Butterworths. London.
- ROSSOUW, A.F. (1974). Freezing of Boer goat semen. *S. Afr. J. Anim. Sci.* 4 (2) : 165-166. (A.B.A. 43).
- SACKER, G.D. and TRAIL, J.C.M. (1966). Production characteristics of a herd of East African Mubende goats. *Trop. Agric., Trin.*, 43 : 43-51. (A.B.A. 34, No. 1338).
- SACKER, G.D. and TRAIL, J.C.M. (1966). Production characteristics of a flock of East African Black Headed sheep. *E. Afr. Agric. J.* 32 : 392-398.
- SACKER, G.D. and TRAIL, J.C.M. (1966). The effect of year, suckling, dry season and type of dam (ewe or gimmer) on milk production in East African Black Headed sheep as measured by lamb growth. *J. agric. Sci. Camb.* 66 : 93-95. (A.B.A. 34, No. 2141).
- SADA, I. and VOHRADSKY, F. (1973). West African Dwarf goat in Ghana. II. Growth rate and selection criteria. *Shomik Vysoke Skoly Zemedelske V Praze. Institut Tropickeho a Subtropickeho Zemedelstvi* 6 : 173-185. (A.B.A. 43, No. 2387).
- SAHNI, K.L. and ROY, A. (1969). Influence of season on semen quality of rams and effects of dilutors and dilutions on *in vitro* preservation. *Indian J. Anim. Sci.* 39 : 1-14. (A.B.A. 38, No. 2682).
- SAHNI, K.L. and ROY, A. (1972). A note on the effect of two storage temperatures on the keeping quality of sheep and goat semen in different diluents. *Indian J. Anim. Sci.* 42 (8) : 580-583. (A.B.A. 41, No. 4258).

- SAHNI, K.L. and ROY, A. (1972). A note on seasonal variation in the occurrence of abnormal spermatozoa in different breeds of sheep and goats under tropical conditions. *Indian J. Anim. Sci.* 42 (7) : 501-503. (A.B.A. 41, No. 4035).
- SAHNI, K.L. and ROY, A. (1972). A note on the variation of cold-shock test for determining the resistance of sheep and goat spermatozoa. *Indian J. Anim. Sci.* 42 (7) : 498-501. (A.B.A. 41, No.).
- SAHNI, K.L. and ROY, A. (1972). A study on the effect of deep-freezing (-79°C) on post-thawing revival of sheep and goat spermatozoa. *Indian J. Anim. Sci.* 42 (2) : 102-105. (A.B.A. 41, No. 1467).
- SARSON, M. (1974). The goat as a meat producer in Tanzania and an investigation into its seasonality of breeding. M.Sc.Agric. Thesis, University of Reading.
- SCHOEN, A. (1968). Studies on the water-balance of the East African goat. *E. Afr. agric. J.* 34 : 256-261.
- SEEBECK, R.M. and CAMPION, E.J. (1964). The application of body weight data to performance testing of beef cattle. *Aust. J. Agric. Res.* 15 : 471-489.
- SHALASH, M., MOUSA, A., NAWITO, M., FARRAC, H.F., OOF, F., SELIM, M.K. and TAWFIK, M.A. (1970). Economic evaluation of some goat breeds in Egypt. *Vet. Medic. J. UAR* 18 : 295-312.
- SHKOLNIK, A., BORUT, A. and CHOSHNIAK, J. (1972). Water economy of the Bedouin goat. *Symp. Zool. Soc. Lond.* 31 : 229-242. Ed. Maloiy.
- SHKOLNIK, A., BORUT, A. and CHOSHNIAK, J. (1974). Water economy and drinking regime of the Bedouin goat. *Symp. Israel-France. Special Public.* 39 : 79-96.
- SHKOLNIK, A., BORUT, A., CHOSHNIAK, J. and MALTZ, E. (1975). The Black Bedouin goat - a desert ruminant that "stores" water. *Federation Proc.* 34 (3).
- SHUKLA, K.P., MEMON, G.N. and BUCH, N.C. (1971). Induction of ovulation in immature goats with pregnant donkey serum. *Indian J. exp. Biol.* 9 : 256-257. (A.B.A. 40, No. 622).
- SKINNER, J.D. (1972). Utilisation of the Boer goat for intensive animal production. *Trop. Anim. Hlth. Prod.* 4 : 120-128.

- SKINNER, J.D. (1974). Reproductive physiology of indigenous and exotic male animals in South Africa: puberty in South African goat breeds, including the Angora. Agric. Res. 1974. (A.B.A. 48, No. 4628).
- SKINNER, J.D., VAN RENSBURG, S.J. and BADENHORST, J.F.G. (1971). The occurrence of foetal dwarfism in the Angora goat. S. Afr. J. Anim. Sci. 1 : 69-71. (A.B.A. 40, No. 607).
- SKINNER, J.D., VON LA CHEVALLERIE, M. and VAN ZYL, J.H.M. (1971). An appraisal of the Springbok for diversifying animal production in Africa. Anim. Breed. Abstr. 39 (2) : 215-224.
- SKINNER, J.D. (1975). Reproductive physiology of indigenous and exotic male animals in South Africa: puberty in South African goat breeds, including the Angora. 1970-1974. Final Report. In: Agric. Res. 1974. Pretoria. (A.B.A. 43, No. 4628).
- SIMMS, D.D. (1974). Genetic and physiological relationships of growth hormones and growth in goats. Dissert. Abstr. Internat. B (1974) 34 (8) : 3577. (A.B.A. 44 (2), No. 707).
- SINGH, B.B. (1975). Relative growth and development of Angora cross Gaddi kids. Indian J. Anim. Hlth. 141-145.
- SINGH, B.B. and SINGH, B.P. (1974). Performance of Jamnapari goats. Indian Vet. J. 51 (5) : 326-322. (A.B.A. 43, No. 2388).
- SNEDECOR, G.W. (1956). Statistical Methods. Ames, Iowa. Iowa State College Press (5th ed.) 534 pp.
- SNEDECOR, G.W. and COCHRAN, W.G. Statistical Methods. Iowa State Univ. Press, Ames, Iowa (6th ed.) 593 pp.
- SPEEDING, C.R.W. (1970). Sheep production and grazing management. London. Bailliere, Tindall and Cassell (2nd ed.). 435 pp.
- SPEEDING, C.R.W. (1974). The future of sheep and goat production. Livestock Prod. Sci. 1 : 265-268.
- SPEEDING, C.R.W., LARGE, R.V. and WALSINGHAM, J.M. (1972). The importance of size of the female sheep. Wld. Rev. Anim. Prod. 8 : 90-96.

- SPEDDING, C.R.W., WALSHINGHAM, J.M. and LARGE, R.V. (1976). The effect of reproductive rate on the feed conversion efficiency of meat producing animals. *Wld. Rev. Anim. Prod.* 12 (4) : 43-49.
- STAPLES, R.R., HORNBY, H.E. and HORNBY, R.M. (1942). A study of the comparative effects of goats and cattle on a mixed grass-bush pasture. *E. Afr. agric. J.* 8 : 62-70.
- STEEL, R.G.D. (1962). *Elementary Mathematics for Statistical Analysis.* The Technical Press. Raleigh, N.C. 92 pp.
- STEEL, R.G.D. and TORRIE, J.H. (1960). *Principles and Procedures of Statistics.* McGraw-Hill Book Co. Inc. 481 pp.
- SYKES, A.R. and COOP, R.L. (1977). Chronic parasitism and animal efficiency. *A.R.C. Res. Rev.* 3 (2) : 41-46.
- TALLIS, G.M., TURNER, H.N. and BROWN, G.H. (1964). The relationship between live measurements and edible meat in Merino wethers. *Aust. J. Agric. Res.* 15 : 446-452.
- TANDON, H.S. (1966). Relationship of body weight with body measurement in Beetal goat. *Indian J. Dairy Sci.* 19 : 187-190. (A.B.A. 36, No. 1635).
- TANTAWY, A.O. and AHMED, I.A. (1960). Studies in Egyptian Baladi goats. I. Frequency of multiple births and sex rates. *Emp. J. exp. Agric.* 28 : 74-82. (A.B.A. 28, No. 1424).
- TEWARI, S.D., SHARMA, R.P. and ROY, A. (1968). Effects of dilution on the preservation of ram and goat spermatozoal viability. *India J. vet. Sci.* 38 : 567-573. (A.B.A. 33, No. 533).
- THIBAUT, C., COUROT, M., MARTINET, L., MAULEON, P., MENSNIL DU BUISSON, F., ORTAVANT, R., PELLETIER, J. and SIGNORET, J.P. (1966). Regulation of breeding season and oestrous cycles by light and external stimuli in some mammals. *J. Anim. Sci.* 25 (Suppl., Environmental influences on reproductive processes) : 119-142. (A.B.A. 35, No. 2188).
- TIMON, V.M. (1968). Genetic studies of growth and carcass composition in sheep. In: *Growth and Development of Mammals.* Ed. G.A. Lodge and G.E. Lamming. pp. 400-415. Butterworths. London.

- TIMON, V.M. and BICHARD, M. (1965). Quantitative estimates of lamb carcass composition. 3. Carcass measurements and a comparison of the predictive efficiency of sample joint composition, carcass specific gravity determinations and carcass measurements. *Anim. Prod.* 7 (2) : 189-199.
- TRAIL, J.C.M. and SACKER, G.D. (1966). Lamb mortality in a flock of East African Black Headed sheep. *J. agric. Sci. Camb.* 66 : 97-100.
- TRIBE, D.E. (1964). Carcass composition and appraisal of meat animals. Symp. The Commonwealth Sci. and Ind. Res. Org. Melbourne, Victoria, Aust. Ed. D.E. Tribe.
- TULLOH, N.M. (1964). The carcass composition of sheep, cattle and pigs as functions of body weight. In: Symposium on Carcass Composition and Appraisal of Meat Animals. Tech. Conference. University of Melbourne. pp. 5-1 to 5-30. CSIRO. East Melbourne.
- TURNER, H.N. (1969). Genetic improvement of reproduction rate in sheep. *Anim. Breed. Abstr.* 37 (4) : 545-563.
- TURNER, H.N. and YOUNG, S.S.Y. (1969). Quantitative genetics in sheep breeding. Melbourne. MacMillan Co. of Australia.
- TURNER, H.N. (1977). Australian sheep breeding research. *Anim. Breed. Abstr.* 45 (1) : 9-31.
- TYAGI, J.C. and LAVANIA, J.P. (1969). Breeding seasons of indigenous and crossbred ewes and role of temperature and bright sunshine hours. *Indian J. Anim. Sci.* 39 (2) : 91-94.
- UECKERMANN, L., JOUBERT, D.M. and VAN D. STEYN, G.J. (1974). The milking capacity of Boer goat does. *Wld. Rev. Anim. Prod.* 10 (4) : 73-83.
- VANDEMAELE, F.P. (1977). The role of animal production in world agriculture. *Wld. Anim. Rev.* 21 : 2-5.
- VAN RESNBURG, H.J. (1960). Ecological aspects of the major grassland types in Tanganyika. *Proc. 8th Internat. Grassland Congress.* pp. 367-370.

- VIHNA, N.A. (1975). (Seasonal variation in the production and quality of goat semen). Variacao estacional na producao e qualidade do semen de Capra hircus. Arquivos da Escola de Veterinaria da Universidade Federal de Minas Gerais 27 (1) : 23-28 (Pt. en). (A.B.A. 43, No. 5880).
- WALKER, G.W. (1954). Annual Report of Veterinary Department, Ministry of Agriculture, Tanganyika (now Tanzania). 1954, Vol. II.
- WALTON, F.J.C., TEMPLE, A. and BOWMAN, J.C. (1973). Luteinising hormone and progesterone in the plasma of anoestrous ewes. Proc. Soc. Endocrino. 22-23 November 1973. J. Endocrino. 61.
- WASSMUTH, R. and BEUING, R. (1974). Model calculations on the economic efficiency of sheep production. Livestock Prod. Sci. 1 : 67-75.
- WIENER, G. (1967). A comparison of the body size, fleece weight and maternal performance of five breeds of sheep kept in one environment. Anim. Prod. : 177-195.
- WIJERATNE, W.V.S. (1968).. The reproductive traits of a nondescript breed of South Indian meat goats. Trop. Agric., Trin. 45 (1) : 39-45. (A.B.A. 36, No. 2764).
- WILKINSON, G.N. (1970). A general recursive procedure for analysis of variance. Biometrika. 57 : 19-46.
- WILLIAMS, D.R. (1968). A comparison between a method of jointing meat carcasses based upon their anatomical structure and a method based upon standardised butchering practice. 1. Description of jointing methods. J. agric. Sci. Camb. 71 : 297-301.
- WILLIAMS, D.R. and POMEROY, R.W. (1976). Anatomical dissection and tissue separation: techniques and grouping of tissues. In: Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments. Ed. A.V. Fisher, J.C. Tayler, H. de Boer and D.V. van Andrichem Boogaert. pp. 157-159. Commission of European Communities, Luxembourg.
- WILLIAMSON, G. and PAYNE, W.J.A. (1959). An introduction to animal husbandry in the tropics. Longmans. London.

- WILSON, P.N. (1957a). Effects of contrasted planes of nutrition on the carcass composition of the East African Dwarf goat. *Nature* 180 : 145-146.
- WILSON, P.N. (1957b). Studies of the browsing and reproductive behaviour of the East African Dwarf goat. *E. Afr. agric. J.* 23 : 138-147. (A.B.A. 26, No. 879).
- WILSON, P.N. (1958a). The effect of plane of nutrition on the growth and development of the East African Dwarf goat. Pt.I. Effect of plane of nutrition on the live-weight gains and the external measurements of kids. *J. agric. Sci. Camb.* 50 : 198-210. (A.B.A. 26, No. 1448).
- WILSON, P.N. (1958b). The effect of plane of nutrition on the growth and development of the East African Dwarf goat. Pt.II. Age changes in the carcass composition of female kids. *J. agric. Sci. Camb.* 51 : 4-21. (A.B.A. 26, No. 2022).
- WILSON, P.N. (1960). The effect of plane of nutrition on the growth and development of the East African Dwarf goat. Pt.III. The effect of plane of nutrition and sex on the carcass composition of the kid at two stages of growth, 16 lb weight and 30 lb weight. *J. agric. Sci. Camb.* 54 : 105-130. (A.B.A. 29, No. 906).
- WILSON, P.N. and OSBOURN, D.F. (1960). Compensatory growth after undernutrition in mammals and birds. *Biol. Rev.* 35 : 324-363.
- WILSON, R.G. (1976). Studies on the livestock of Southern Darfur, Sudan. IV. Production traits in goats. *Trop. Hlth. Prod.* 8 : 221-232.
- WINGFIELD, R.C. (1975). List of grass and legume species which grow at Morogoro on the University of Dar es Salaam's Faculty of Agriculture, Forestry and Veterinary Science Campus. Personal communication.
- WORRALL, J. (1977). Breakthrough in battle against tsetse fly. *New African.* June 1977. p. 579.
- YOUNG, S.S.Y., TURNER, H.N. and DOLLING, C.H.S. (1963). Selection for fertility in Australian Merino Sheep. *Aust. J. Agric. Res.* 14 : 460-482. (A.B.A. 32, No. 287).

APPENDIX 1

DATA SUPPLEMENTARY TO

CHAPTER 3

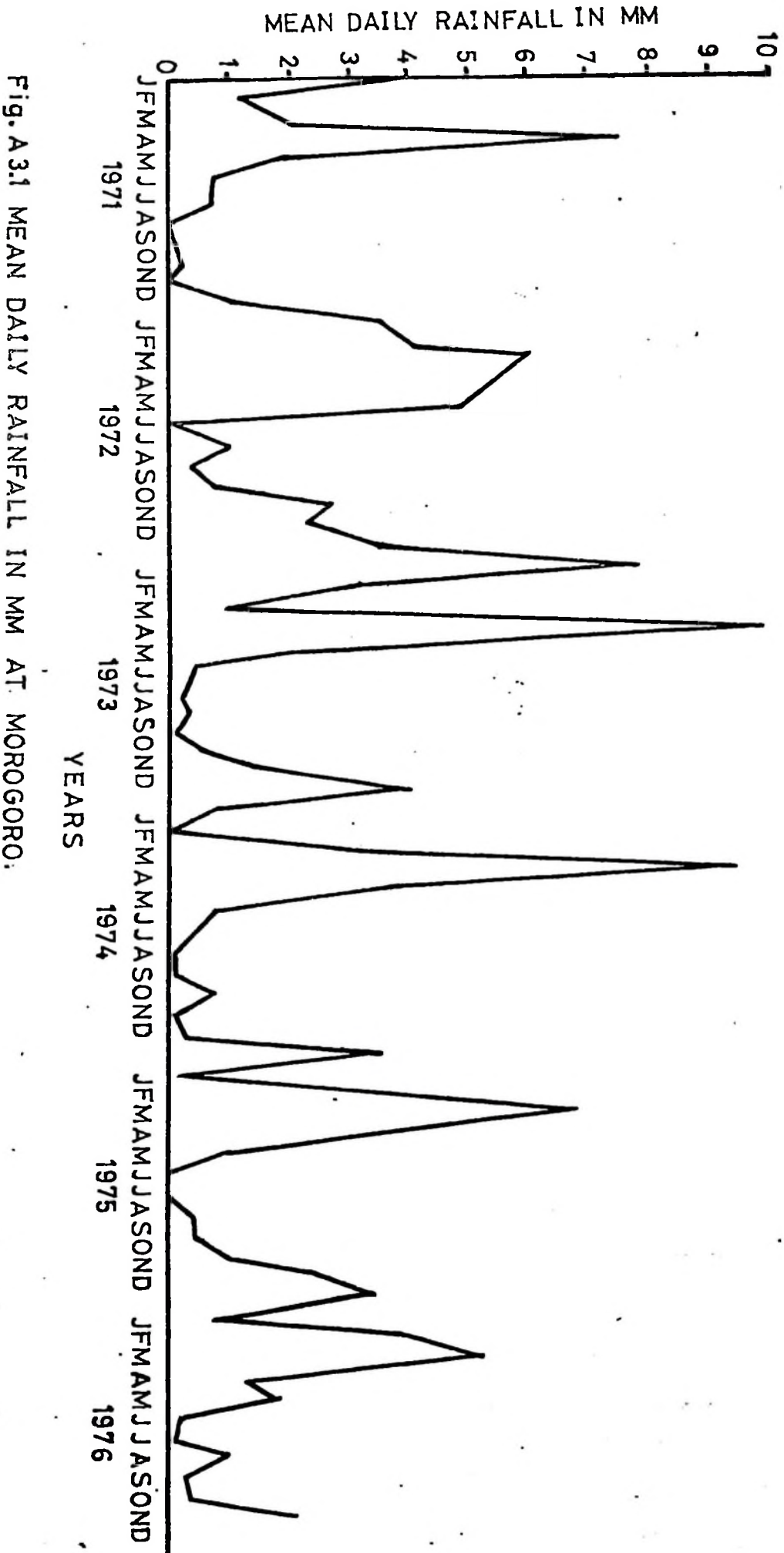


Fig. A.3.1 MEAN DAILY RAINFALL IN MM AT MOROGORO.

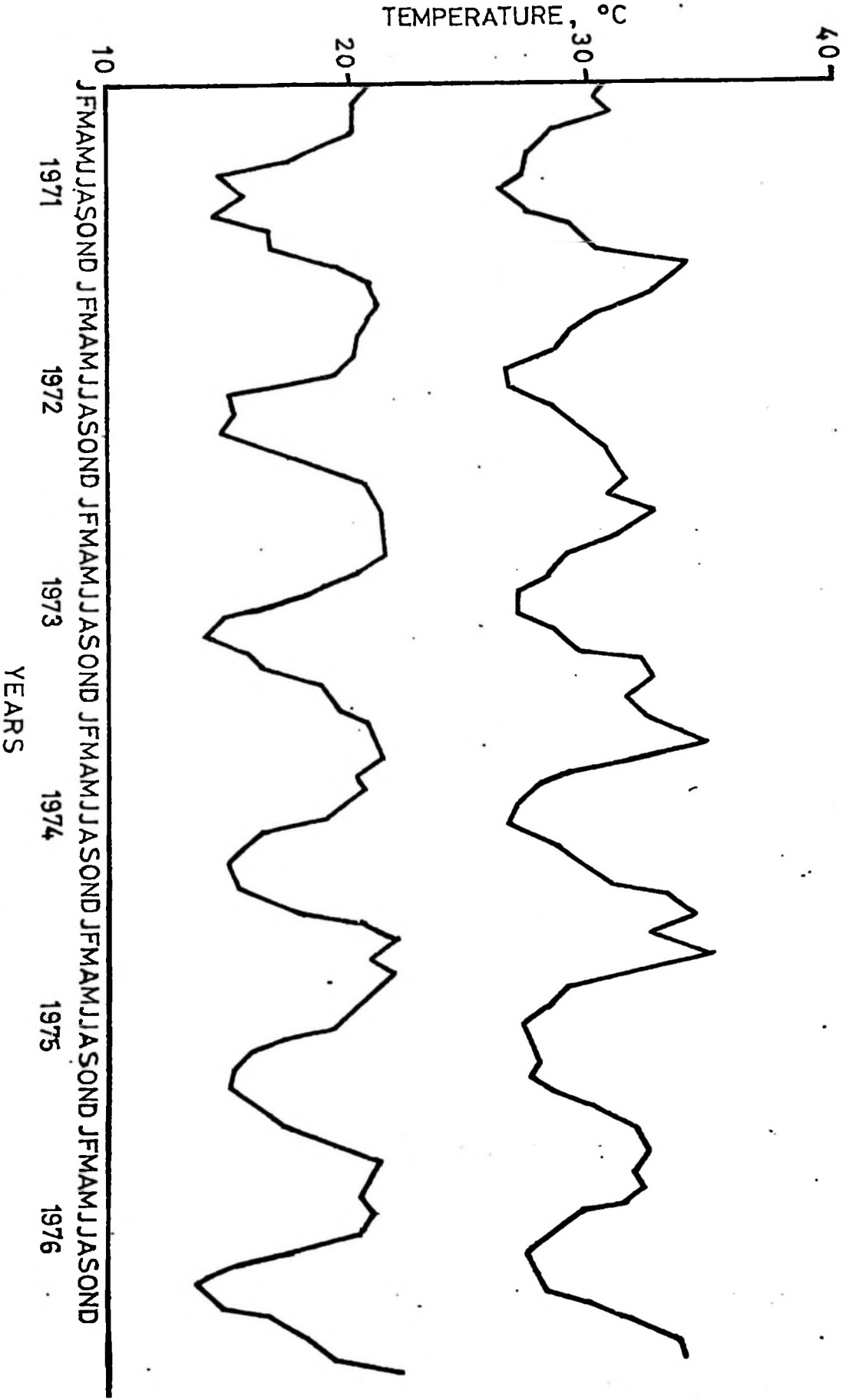


Fig. A.3.2 MEAN DAILY MAXIMUM AND MINIMUM TEMPERATURES (°C) FOR MOROGORO.

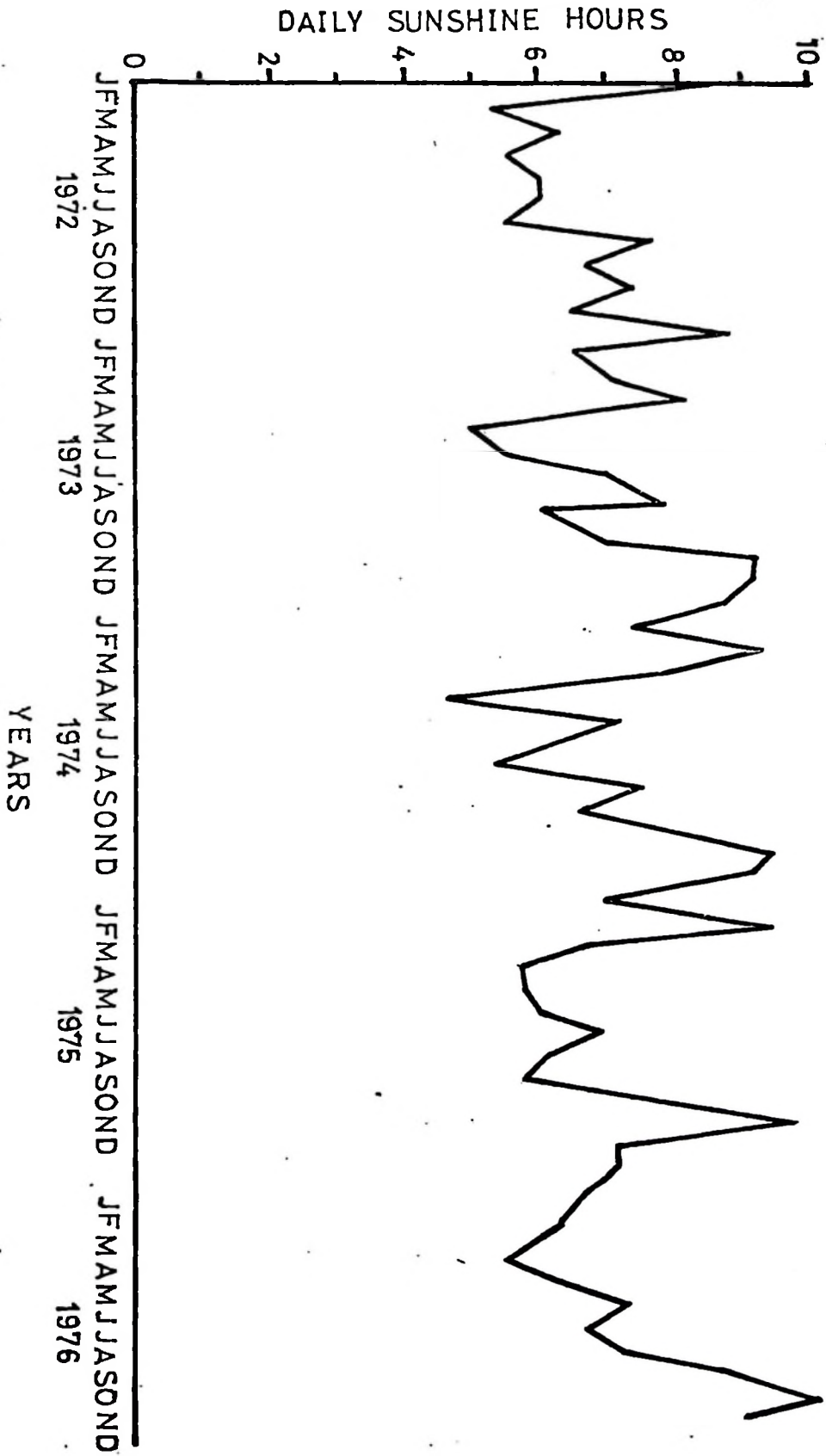


FIG. A.33 MEAN DAILY SUNSHINE HOURS AT MOROGORO.

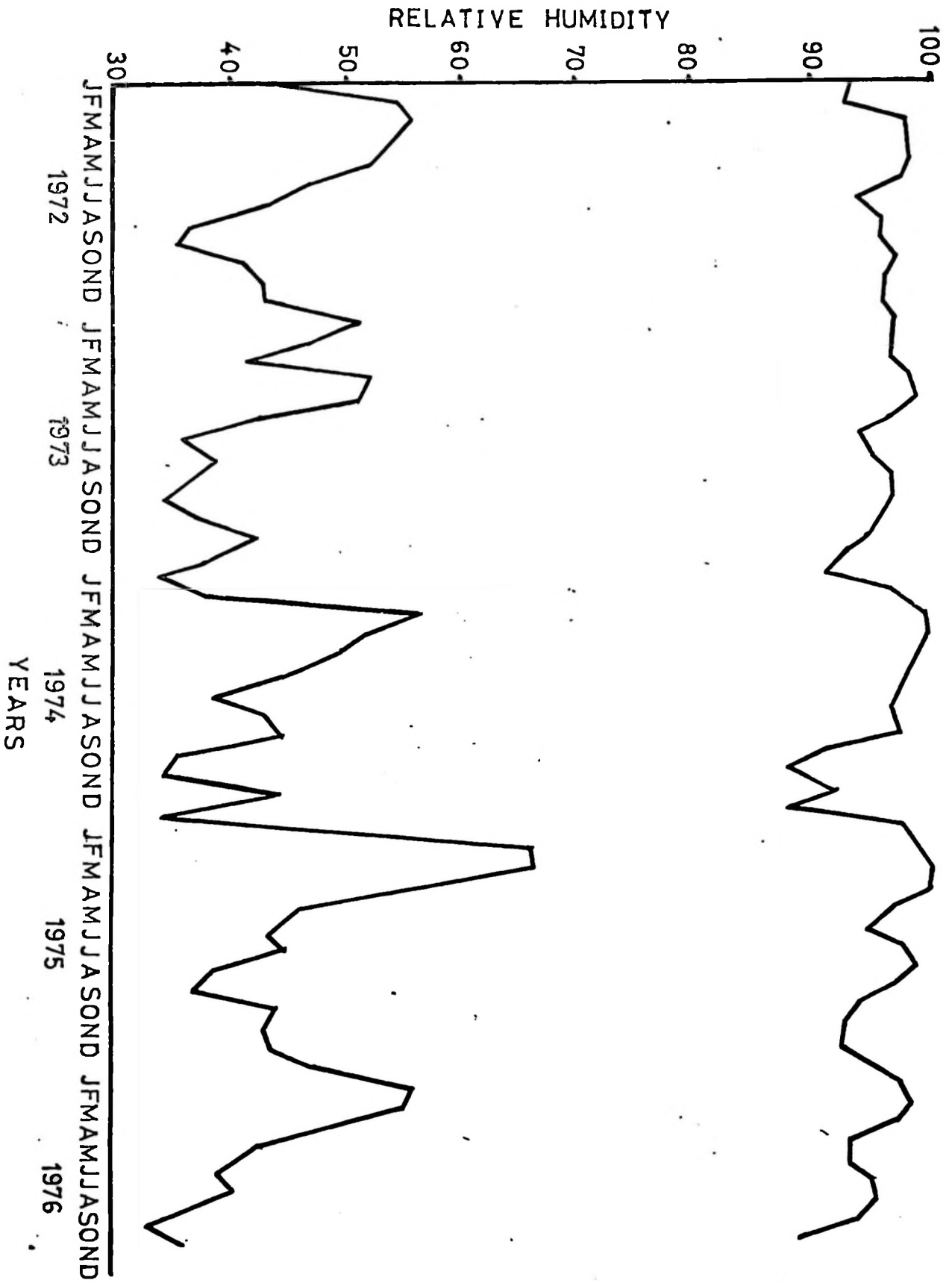


Fig. A3.4 MEAN DAILY MAXIMUM AND MINIMUM RELATIVE HUMIDITY AT MOROGORO

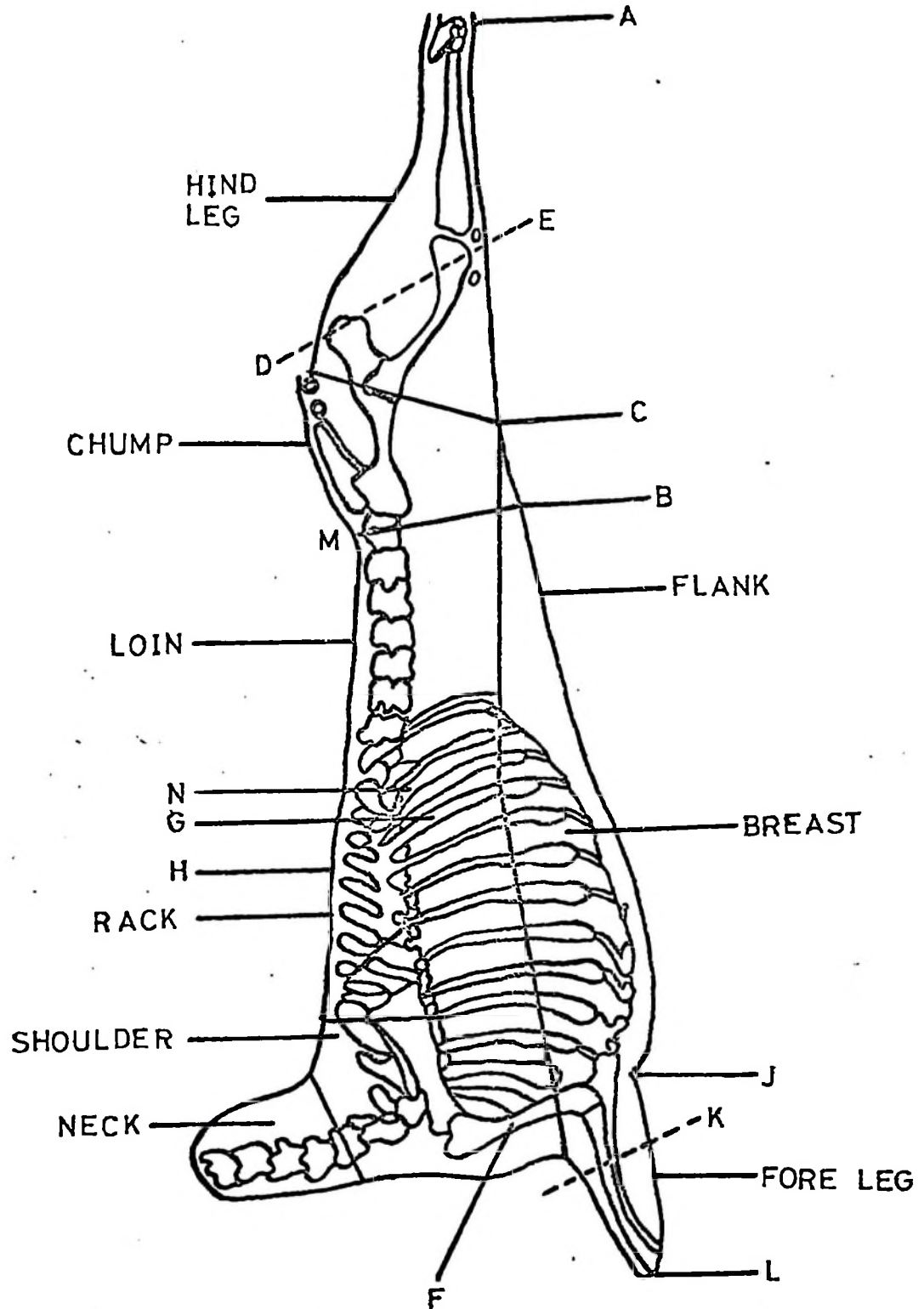


Fig.A3.5 DIAGRAM SHOWING VARIOUS PARTS OF THE GOAT CARCASS AND POINTS OF MEASURING AND IN SOME CASES POINTS OF JOINTING

Appendix A3.1

Climatic data collected one year before and during the period of the study at Morogoro

Table A3.1.1 Monthly total and mean daily rainfall in mm at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Total & Mean
1971 T	124.6	37.6	61.3	226.1	58.6	22.0	21.9	0.0	3.9	6.0	0.7	33.6	596.3
1971 M	4.0	1.3	2.0	7.5	1.9	0.7	0.7	0.0	0.1	0.2	0.0	1.1	29.7
1972 T	109.3	115.4	187.0	165.9	150.9	0.0	31.1	0.5	22.8	83.0	71.3	107.2	1048.5
1972 M	3.5	4.0	6.0	5.5	4.9	0.0	1.0	0.0	0.8	2.7	2.4	3.5	87.4
1973 T	238.6	85.1	40.8	290.7	61.3	14.7	9.6	9.8	3.5	18.1	48.3	121.0	941.5
1973 M	7.7	3.0	1.3	9.7	2.0	0.5	0.3	0.3	0.1	0.6	1.6	3.9	78.5
1974 T	25.6	2.9	94.7	278.6	103.4	22.5	14.3	2.7	4.4	25.0	1.4	9.5	585.0
1974 M	0.8	0.1	3.1	9.3	3.3	0.8	0.5	0.1	0.1	0.8	0.1	0.3	48.8
1975 T	104.2	4.3	112.0	197.6	102.5	25.5	0.7	0.0	11.3	15.7	29.5	78.0	681.3
1975 M	3.4	0.2	3.6	6.6	3.3	0.9	0.0	0.0	0.4	0.5	1.0	2.5	56.8
1976 T	106.4	22.3	118.0	156.7	41.5	54.0	7.5	3.3	28.9	7.5	9.4	59.4	615.1
1976 M	3.4	0.8	3.8	5.2	1.3	1.8	0.2	0.1	1.0	0.2	0.3	1.9	51.3
Total for six years													4467.7
Average per year													744.6

Table A3.1.2 Total number of days in which the rain fell, shown within months and within years, at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Total
1971	9	9	12	26	13	9	8	0	7	3	2	7	105
1972	11	10	14	22	22	0	8	1	7	10	14	10	129
1973	20	12	11	27	13	7	5	7	4	4	6	11	127
1974	7	3	7	26	18	6	8	3	4	3	3	2	90
1975	10	2	16	21	15	11	2	0	4	4	4	8	101
1976	6	12	19	16	13	6	3	1	7	3	3	5	94
Total	63	48	79	138	94	39	34	12	33	27	32	43	646
Average	10.5	8.0	13.2	23.0	15.7	6.5	5.7	2.0	5.5	4.5	5.3	7.2	107.7

Table A 3.1.3 Mean daily maximum temperature °C at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	30.8	30.3	31.0	28.3	27.7	27.1	26.5	27.5	29.3	30.7	33.3	32.4
1972	31.1	30.9	29.7	28.7	28.1	26.4	26.6	28.2	29.4	30.2	30.6	31.3
1973	30.5	-	-	-	-	-	-	-	-	31.8	32.1	31.2
1974	31.9	33.8	31.6	28.6	28.1	26.8	26.3	28.2	28.9	30.2	32.8	34.0
1975	31.8	34.4	31.2	28.9	28.0	27.1	27.4	27.3	28.6	30.5	32.9	32.0
1976	31.5	32.0	31.2	29.5	28.2	27.2	27.5	28.0	29.5	31.6	33.6	33.8

Table A3.1.4 Mean daily minimum temperature °C at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	21.0	20.3	20.2	20.1	17.9	14.7	15.7	14.5	16.5	16.8	19.5	20.7
1972	21.1	20.7	20.3	20.0	19.5	15.1	15.2	14.6	16.7	19.0	20.4	20.9
1973	21.2	21.1	21.4	20.4	18.6	15.4	14.1	15.8	16.5	17.8	19.4	20.6
1974	20.9	21.5	20.3	20.5	19.1	16.6	15.5	15.0	15.3	17.2	20.3	22.0
1975	21.0	21.8	21.0	20.2	18.7	16.0	15.1	15.0	16.4	17.2	18.9	21.0
1976	20.9	20.8	21.0	20.4	18.1	15.6	13.9	14.9	16.6	18.2	19.4	21.9

Table A3.1.5 Mean daily sunshine hours at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	8.3	5.4	6.3	5.5	5.9	6.0	5.5	7.7	-	7.4	6.4	-
1973	6.4	7.0	8.1	4.9	5.5	6.8	7.6	6.0	6.9	9.2	9.1	8.7
1974	7.3	9.2	7.8	4.6	7.2	6.3	5.3	7.5	6.5	7.9	9.4	9.1
1975	6.9	9.1	6.7	5.7	5.8	6.0	6.9	6.1	5.8	7.5	9.6	7.1
1976	-	6.8	6.5	6.2	5.5	6.3	7.3	6.7	7.2	8.7	9.9	9.0

Table A3.1.6 Mean daily maximum relative humidity at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	92.9	97.3	97.7	97.9	97.2	93.7	95.5	95.3	96.7	96.0	95.8
1973	96.5	96.4	96.3	97.8	98.2	96.7	93.6	94.8	96.2	96.3	95.1	94.8
1974	92.6	90.7	96.4	98.5	98.8	98.1	97.6	95.6	96.0	96.6	90.8	87.6
1975	91.0	87.6	97.2	98.5	99.7	99.4	96.1	94.2	96.8	98.1	96.3	93.3
1976	92.2	91.9	93.9	96.8	97.8	96.7	92.5	92.4	94.2	94.7	93.1	88.4

Table A3.1.7 Mean daily minimum relative humidity at Morogoro

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	54.8	55.7	54.0	52.2	47.6	44.2	37.2	35.9	40.7	42.3	42.6
1973	50.3	46.8	42.0	52.5	51.1	42.1	35.9	37.6	36.8	34.4	37.2	41.8
1974	38.3	34.4	38.2	56.2	51.4	49.1	44.8	38.4	42.9	40.4	35.4	34.3
1975	44.4	34.3	51.9	64.5	64.6	56.3	45.6	43.3	44.4	38.7	36.6	43.3
1976	42.7	43.3	46.8	54.7	53.7	48.3	42.1	39.5	39.9	36.4	32.6	35.4

Table A3.1.8 Carcass Measurements: Sheep and Goats
 (Prepared for use in carcass studies
 in Tanzania by Hutchison, 1962)
 (For lettering see Figure A3.5)

-
1. A to C This is the 'length of hind leg' from bone edge to bone edge.
 It is measured from the top end of the tibia (A), to the bottom cut edge of the pubis (C).
 2. A to B Using the same 'line' as for (1), this measurement is from the top end of the tibia (A), to the cut line of the meat edge where it crosses the measuring tape laid on points A to C, at B.
 3. D to E This is the 'circumference of the hind leg' where the tape is passed through points D and E. Point D is the top cut edge of the pubis. Point E is the bottom edge of the patella (where the flank joins the hind leg).
 4. M to N This is the 'length of loin', which is measured from the top centre of the last lumbar vertebra (M) to the mid-line drawn across the middle of the 10th rib vertebra at the point of quartering (N).
 5. C to F This is the 'length of carcass' as measured from the bottom cut edge of the pubis (C) to the bottom edge of the first rib at the point F, which is at half the rib length.
 6. G to I This is the 'internal chest depth' at the 9th rib as measured from the centre point on the inside edge of the 9th rib vertebra (G) to the centre of the cartilaginous triangle on the top end of the sternum (I).
 7. H to I This is the 'external chest measurement' at the 9th rib and is measured from a point H which is the exterior point on the line of the spine, immediately opposite to G, to the point I, mentioned above.

Table A3.1.8 (cont'd)

-
8. J to L This is the 'length of the fore leg' and is measured from the point of the olecranon (elbow looking point) (J) to the top outside edge of the exposed radius (L).
9. K This is the 'circumference of the fore leg' measured at point K, which is half the length of J to L.
-

Table A3.1.9 Example of summary sheet for
carcass records
(For lettering see Figure A3.5)

Date of slaughter		_____
Tattoo or eartag of goat		_____
Breed		_____
Liveweight before slaughter (kg)		_____
Warm dressed carcass wt.		_____
Cold dressed carcass wt.		_____
Weight of blood		_____
Length of hind leg (cm)	A to C	_____
Length	A to B	_____
Length of chump	B to C	_____
Length of carcass	C to F	_____
Circumference of hind leg	D to E	_____
Internal chest depth	G to I	_____
Length of side	A to F	_____
External chest measurement	H to I	_____
Length of fore leg	J to L	_____
Circumference of fore leg	K	_____
Length of loin	M to N	_____
Weight of hind quarter		_____
Weight of fore quarter		_____
Weight of hind leg		_____
Weight of chump		_____
Weight of loin		_____
Weight of fore leg		_____
Weight of breast		_____
Weight of total lean in half carcass		_____
Weight of total bone in half carcass		_____
Weight of total fat in half carcass		_____

Table A3.1.9 (cont'd)

Weight of liver	_____
Weight of lungs + surrounding fat	_____
Weight of lungs - fat	_____
Weight of heart + fat	_____
Weight of heart - fat	_____
Weight of head + horns + skin + ears	_____
Weight of head - horns - skin - ears	_____
Weight of hind leg hocks	_____
Weight of fore leg hocks	_____
Weight of wet skin + fat	_____
Weight of wet skin - fat trim	_____
Weight of dry skin	_____
Weight of speen	_____
Weight of kidneys + fat	_____
Weight of kidneys - fat	_____
Weight of full four stomachs	_____
Weight of empty four stomachs	_____
Weight of full intestines	_____
Weight of empty intestines	_____
Weight of testicles	_____
Weight of udder	_____

APPENDIX 2

DATA SUPPLEMENTARY TO

CHAPTER 4

Table A4.1:

2 4 6 WTAT?? JT???

199.0745536

199.0745536

LISTING OF CONSTANTS, LEAST-SQUARES TERMS AND STANDARD ERRORS FOR MODEL NO. 2

RUN NAME	ROW CODE	INDEPENDENT VARIABLE	NO. OBS.	CONSTANT ESTIMATE	LEAST-SQUARES TERM	STANDARD ERROR
BTH WT	1	MU	294	2.15477759	2.15477759	0.15171490
BTH WT	2	PARITY 1	92	0.12996733	2.28274152	0.25995930
BTH WT	3	PARITY 2	79	-0.02172370	2.13505490	0.20925422
BTH WT	0	PARITY 3	123	-0.10733554	2.20453365	0.07346589
BTH WT	4	PARITY 1	58	-0.07374892	2.15100806	0.15547721
BTH WT	5	PARITY 2	54	0.03446411	2.22126210	0.17734760
BTH WT	6	PARITY 3	65	0.03356553	2.19364752	0.19991645
BTH WT	7	PARITY 4	39	-0.11632211	2.04743156	0.20614931
BTH WT	8	PARITY 5	27	0.00337540	2.15514359	0.11413175
BTH WT	0	PARITY 6	11	0.04537371	2.20315070	0.17979712
BTH WT	9	SEX 1	74	0.16274715	2.31552514	0.15724276
BTH WT	10	SEX 2	87	0.01200735	2.10677934	0.10294739
BTH WT	0	SEX 3	121	-0.12747311	1.93900348	0.07312233
BTH WT	11	PTHY 1	210	0.12181411	2.34859410	0.06579554
BTH WT	0	PTHY 2	84	-0.12181411	1.94496128	0.17953755
BTH WT	12	PARITY X SEX 1 1	8	-0.27461923	2.70418498	0.15721753
BTH WT	13	PARITY X SEX 1 2	18	0.13322564	2.26625806	0.13561670
BTH WT	0	PARITY X SEX 1 3	32	0.14139059	2.07767215	0.10792551
BTH WT	14	PARITY X SEX 2 1	21	-0.04511450	2.30381975	0.13751757
BTH WT	15	PARITY X SEX 2 2	32	0.05191451	2.29215697	0.10744715
BTH WT	0	PARITY X SEX 2 3	41	0.02125499	2.06774659	0.09544632
BTH WT	16	PARITY X SEX 3 1	20	0.02373041	2.32212478	0.12635142
BTH WT	17	PARITY X SEX 3 2	18	-0.07391026	2.16572291	0.12499051
BTH WT	0	PARITY X SEX 3 3	27	0.007118785	2.02407716	0.11155522
BTH WT	18	PARITY X SEX 4 1	12	0.04172486	2.24499789	0.15738781
BTH WT	19	PARITY X SEX 4 2	11	0.02077559	2.07255780	0.17053379
BTH WT	0	PARITY X SEX 4 3	16	-0.04172746	1.90183587	0.13064365
BTH WT	20	PARITY X SEX 5 1	11	0.14665558	2.51255612	0.16336201
BTH WT	21	PARITY X SEX 5 2	8	-0.01061288	2.16653054	0.12401323
BTH WT	0	PARITY X SEX 5 3	10	-0.17405289	1.81333319	0.17151913
BTH WT	0	PARITY X SEX 6 1	4	0.09959788	2.46444573	0.26979289
BTH WT	0	PARITY X SEX 6 2	2	-0.14463960	2.04941145	0.35363330
BTH WT	0	PARITY X SEX 6 3	5	0.06509177	2.09249492	0.24090998
BTH WT	12	SEX Y PTHY 1 1	54	-0.05330506	2.45603199	0.19117972
BTH WT	0	SEX Y PTHY 1 2	22	0.05330506	2.18791929	0.17206347
BTH WT	23	SEX X PTHY 2 1	66	0.07743717	2.43807343	0.09735844
BTH WT	0	SEX X PTHY 2 2	21	-0.07743717	1.89552576	0.14423541
BTH WT	0	SEX X PTHY 3 1	90	-0.02212791	2.15171548	0.08490929
BTH WT	0	SEX X PTHY 3 2	41	0.02212791	1.81034228	0.09643026
WNC WT	1	MU	294	9.24799924	9.24799924	0.35062250
WNC WT	2	PARITY 1	92	0.67957774	9.92783398	0.50215013
WNC WT	3	PARITY 2	79	-0.05678418	9.19121577	0.41949351
WNC WT	0	PARITY 3	123	-0.62374956	8.62495909	0.15193155
WNC WT	4	PARITY 1	58	0.41167606	9.64957533	0.48417588
WNC WT	5	PARITY 2	94	0.19257527	9.44057452	0.19283025
WNC WT	6	PARITY 3	65	-0.213260834	9.07457092	0.47773213
WNC WT	7	PARITY 4	39	0.54483768	9.31287492	0.49112001
WNC WT	8	PARITY 5	27	-0.47738691	8.77051233	0.54902621
WNC WT	0	PARITY 6	11	-0.46293178	8.77995046	0.44137853
WNC WT	9	SEX 1	76	0.15730004	9.43533977	0.45740345
WNC WT	10	SEX 2	87	0.47348361	9.72142286	0.52027407
WNC WT	0	SEX 3	131	-0.66034365	8.59719559	0.36557095
WNC WT	11	PTHY 1	210	0.40531977	9.63731972	0.35381476
WNC WT	0	PTHY 2	84	-0.40531977	8.4267947	0.42177718
WNC WT	12	PARITY X SEX 1 1	8	-0.33127777	9.00575760	0.24744558
WNC WT	13	PARITY X SEX 1 2	18	0.41993398	10.54307392	0.42313016
WNC WT	0	PARITY X SEX 1 3	32	1.41144279	9.40117547	0.56984063
WNC WT	14	PARITY X SEX 2 1	21	-0.47770571	9.17022755	0.65625349
WNC WT	15	PARITY X SEX 2 2	32	0.18475114	10.10579377	0.51951246
WNC WT	0	PARITY X SEX 2 3	41	0.3296057	9.76267942	0.41404777
WNC WT	16	PARITY X SEX 3 1	20	0.0319858	9.22494959	0.62225461
WNC WT	17	PARITY X SEX 3 2	18	-0.11755001	9.29174471	0.84534025
WNC WT	0	PARITY X SEX 3 3	27	0.11375143	8.49226449	0.55744439
WNC WT	18	PARITY X SEX 4 1	12	0.85793429	10.85115326	0.70264061
WNC WT	19	PARITY X SEX 4 2	11	-0.40348855	9.80867165	0.21967460
WNC WT	0	PARITY X SEX 4 3	16	-0.36746774	8.74525553	0.62552527
WNC WT	20	PARITY X SEX 5 1	11	0.32225369	9.29022767	0.74635907
WNC WT	21	PARITY X SEX 5 2	6	-0.27368418	9.00344677	1.06373547
WNC WT	0	PARITY X SEX 5 3	10	-0.06654451	8.01380417	0.82417685
WNC WT	0	PARITY X SEX 6 1	4	0.12247527	9.03930135	1.27310027
WNC WT	0	PARITY X SEX 6 2	2	0.23155572	9.47502410	1.41220547
WNC WT	0	PARITY X SEX 6 3	5	-0.34403155	7.77509076	1.14243034
WNC WT	12	SEX X PTHY 1 1	54	-0.11514271	9.77491415	0.47844210
WNC WT	0	SEX X PTHY 1 2	22	1.15742271	9.14573292	0.59447357
WNC WT	13	SEX X PTHY 2 1	66	1.15097600	10.27777355	0.44574559
WNC WT	0	SEX X PTHY 2 2	21	-0.15097600	9.15811447	0.70191145
WNC WT	0	SEX X PTHY 3 1	90	-0.16513591	8.04734135	0.44441077
WNC WT	0	SEX X PTHY 3 2	41	0.05135051	8.20985571	0.49344751

WTAT11	1	MU			294	12.5223600	12.5223600	0.15991634	
WTAT11	2	BRDITYP	1		92	1.44627190	14.17469417	1.21527469	
WTAT11	3	BRDITYP	2		79	1.35200631	12.97437451	1.25241152	
WTAT11	0	BRDITYP	3		123	-2.37473221	9.77801610	1.07513675	
WTAT11	4	PARITY	1		58	2.70494665	15.42041655	1.20026742	
WTAT11	5	PARITY	2		94	3.89312651	15.47555471	1.30140171	
WTAT11	6	PARITY	3		65	1.54177321	14.44414151	1.38105657	
WTAT11	7	PARITY	4		39	1.72751116	14.41019936	1.25562727	
WTAT11	8	PARITY	5		27	-5.48735114	9.13511107	1.57148664	
WTAT11	0	PARITY	6		11	-6.74357142	5.25578672	2.42110544	
WTAT11	9	SEX	1		74	-2.42787274	12.19449346	1.18735537	
WTAT11	10	SEX	2		87	2.59415075	15.21651855	1.39082253	
WTAT11	0	SEX	3		131	-2.16627100	11.45609022	0.99175137	
WTAT11	11	BTHTYP	1		210	-0.79228591	11.52007809	0.68757404	
WTAT11	0	BTHTYP	2		84	0.70228991	13.37465811	1.07761035	
WTAT11	12	PARITY X	SEX	1	1	8	-0.99453941	15.99701470	2.46311993
WTAT11	13	PARITY X	SEX	1	2	18	0.44402705	13.4155445	1.32817955
WTAT11	0	PARITY X	SEX	1	3	32	0.59251776	13.44465121	1.45201257
WTAT11	14	PARITY X	SEX	2	1	21	-1.64159164	14.35609032	1.30136622
WTAT11	15	PARITY X	SEX	2	2	32	-3.16045296	13.85925250	1.45159613
WTAT11	0	PARITY X	SEX	2	3	41	1.83264660	16.06132121	1.3595435
WTAT11	16	PARITY X	SEX	3	1	20	1.64598909	15.70225656	1.70433297
WTAT11	17	PARITY X	SEX	3	2	18	-1.66352533	15.41478697	1.51975071
WTAT11	0	PARITY X	SEX	3	3	27	0.01751725	12.34338774	1.57603651
WTAT11	18	PARITY X	SEX	4	1	12	1.59736762	13.56359474	2.17201055
WTAT11	19	PARITY X	SEX	4	2	11	-1.97475934	15.02495077	2.29675395
WTAT11	0	PARITY X	SEX	4	3	16	0.39349171	12.63741327	1.76875140
WTAT11	20	PARITY X	SEX	5	1	11	-0.22344783	8.42578949	2.22740610
WTAT11	21	PARITY X	SEX	5	2	7	1.64595863	13.57524944	3.01499523
WTAT11	0	PARITY X	SEX	5	3	10	-1.62254080	5.74627127	2.30993234
WTAT11	0	PARITY X	SEX	6	1	4	-0.31767684	5.06423714	3.67010146
WTAT11	0	PARITY X	SEX	6	2	2	1.54370194	10.80167941	5.19015315
WTAT11	0	PARITY X	SEX	6	3	5	-1.14102510	2.51145362	3.24200309
WTAT11	22	SEX X	BTHTYP	1	1	54	0.67544351	12.12764206	1.25963440
WTAT11	0	SEX X	BTHTYP	1	2	22	-0.63544351	12.26134166	1.72657177
WTAT11	23	SEX X	BTHTYP	2	1	66	-0.53853973	17.97563531	1.51420014
WTAT11	0	SEX X	BTHTYP	2	2	21	0.53853973	16.45734359	1.94500467
WTAT11	0	SEX X	BTHTYP	3	1	90	-0.69690378	9.65689451	1.14987463
WTAT11	0	SEX X	BTHTYP	3	2	41	0.09690378	11.25528389	1.50373760
WTAT72	1	MU			294	15.63499024	15.63499024	1.30337839	
WTAT72	2	BRDITYP	1		92	1.86644839	17.50147367	1.39509649	
WTAT72	3	BRDITYP	2		79	2.11715773	17.25214797	1.92743966	
WTAT72	0	BRDITYP	3		123	-3.98364112	11.65174911	1.68234620	
WTAT72	4	PARITY	1		58	4.14364777	19.77863170	1.74929948	
WTAT72	5	PARITY	2		94	3.37346896	19.53845910	1.45671689	
WTAT72	6	PARITY	3		65	2.56655659	16.18154635	1.57479916	
WTAT72	7	PARITY	4		39	2.70943229	13.24442323	1.75892600	
WTAT72	8	PARITY	5		27	-4.20255454	11.43243570	2.61757217	
WTAT72	0	PARITY	6		11	-9.07254476	6.56444547	3.60225692	
WTAT72	9	SEX	1		76	-0.54745589	14.98753474	1.53527690	
WTAT72	10	SEX	2		87	3.29308630	18.97807654	1.85536102	
WTAT72	0	SEX	3		131	-2.64567041	12.95955982	1.44683050	
WTAT72	11	BTHTYP	1		210	-1.00506257	14.62992757	1.32829557	
WTAT72	0	BTHTYP	2		84	1.00506257	16.64005291	1.53144209	
WTAT72	12	PARITY X	SEX	1	1	8	-1.75665257	17.35452254	3.28007775
WTAT72	13	PARITY X	SEX	1	2	18	1.14671057	24.21842758	2.33222654
WTAT72	0	PARITY X	SEX	1	3	32	0.61994200	17.75294259	1.95285480
WTAT72	14	PARITY X	SEX	2	1	21	-1.61407199	17.24695131	2.30247939
WTAT72	15	PARITY X	SEX	2	2	32	-0.91613325	21.88540724	1.91913270
WTAT72	0	PARITY X	SEX	2	3	41	2.57021025	19.24305903	1.74886729
WTAT72	16	PARITY X	SEX	3	1	20	1.73018268	19.26427361	2.19516517
WTAT72	17	PARITY X	SEX	3	2	18	-2.04107724	19.43355569	2.32222935
WTAT72	0	PARITY X	SEX	3	3	27	0.31039456	15.64681092	1.97677453
WTAT72	18	PARITY X	SEX	4	1	12	2.50913644	20.29817377	2.46756324
WTAT72	19	PARITY X	SEX	4	2	11	-2.77305469	15.44454824	2.84027303
WTAT72	0	PARITY X	SEX	4	3	16	0.12391526	15.87771107	2.37743831
WTAT72	20	PARITY X	SEX	5	1	11	-0.59565843	9.88029137	2.78134460
WTAT72	21	PARITY X	SEX	5	2	6	3.46666400	13.17210691	3.68692901
WTAT72	0	PARITY X	SEX	5	3	10	-2.51097637	6.277582891	2.37534599
WTAT72	0	PARITY X	SEX	6	1	4	-0.65290612	5.86408345	4.40353007
WTAT72	0	PARITY X	SEX	6	2	2	1.17689481	11.03442650	6.23789373
WTAT72	0	PARITY X	SEX	6	3	5	-1.12398870	2.774322636	3.95071525
WTAT72	22	SEX X	BTHTYP	1	1	54	1.31910538	15.30177005	1.71723905
WTAT72	0	SEX X	BTHTYP	1	2	22	-1.31910538	14.67528943	2.21295787
WTAT72	23	SEX X	BTHTYP	2	1	66	-1.04372493	15.27423494	1.77223014
WTAT72	0	SEX X	BTHTYP	2	2	21	1.04372493	20.9186115	2.46263977
WTAT72	0	SEX X	BTHTYP	3	1	90	-0.27038444	11.71071271	1.60627734
WTAT72	0	SEX X	BTHTYP	3	2	41	0.27038444	14.26000694	1.74335905

Table A4.2:

ESTIMATES OF HERITABILITY, GENETIC, PHENOTYPIC, ENVIRONMENTAL CORRELATIONS

JOB	ROW	COL	RM	RM	HERITABILITY OR GENETIC R	STANDARD ERRORS	PHENOTYPIC CORRELATION	ENVIRONMENTAL CORRELATION	NEG	VARIANCE COV AMONG	COMPONENTS WITHIN
2	1	1	ETM WT	STM WT	0.071	0.194	1.000	1.000	0	0.00511832	0.27410057
2	1	2	RTM WT	WMC WT	1.431	0.715	0.108	0.126	0	0.04667079	0.24023151
2	1	3	ETH WT	WTAT1Y	-0.958	1.249	0.159	0.328	0	-0.07051469	0.75486662
2	1	4	ETH WT	WTAT72	-0.414	0.875	0.151	0.224	0	-0.05479550	0.89339656
2	2	2	WNG WT	WNG WT	0.128	0.142	1.000	1.000	0	0.22877219	5.09193914
2	2	3	WNG WT	WTAT1Y	0.021	1.033	0.435	0.454	0	0.01069053	5.09123513
2	2	4	WNG WT	WTAT72	0.393	0.684	0.400	0.473	0	0.34747175	9.59487107
2	3	3	WTAT1Y	WTAT1Y	0.074	0.106	1.000	1.000	0	0.97440322	49.56071809
2	3	4	WTAT1Y	WTAT72	1.059	0.120	0.934	0.929	0	1.93142558	54.91868705
2	4	4	WTAT72	WTAT72	0.170	0.161	1.000	1.000	0	3.41615834	70.365002712

Table A4.2 (continued)

		ESTIMATES OF HERITABILITIES, GENETIC, PHENOTYPIC, ENVIRONMENTAL CORRELATIONS										
JOB	ROW	COL	RM	RM	RM	HERITABILITY OR GENETIC R	STANDARD ERRORS	PHENOTYPIC CORRELATION	ENVIRONMENTAL CORRELATION	NEG	VARIANCE AMONG	CV COMPONENTS WITHIN
2	1	1	RTM WT	STP WT	WT	0.071	0.104	1.000	1.000	0	0.00511852	0.27410057
2	1	2	RTM WT	WT	WT	1.421	0.715	0.108	0.186	0	0.04897979	0.28023151
2	1	3	RTM WT	WT	WT	-0.098	0.849	0.139	0.328	0	-0.07051449	0.75486862
2	1	4	RTM WT	WT	WT	-0.414	0.375	0.151	0.224	0	-0.05479550	0.89389856
2	2	2	WNG WT	WNG WT	WT	0.123	0.142	1.000	1.000	0	0.22877219	5.05192054
2	2	3	WNG WT	WT	WT	0.721	1.083	0.435	0.484	0	0.01000065	8.09123512
2	2	4	WNG WT	WT	WT	0.393	0.684	0.480	0.473	0	0.24727178	9.59443127
2	3	3	WTATT1	WTATT1		0.074	0.106	1.000	1.000	0	0.97440322	49.56011869
2	3	4	WTATT1	WTATT2		1.059	0.129	0.934	0.929	0	1.93142558	54.91868705
2	4	4	WTATT2	WTATT2		0.170	0.161	1.000	1.000	0	3.41613834	70.30500312

Table A4.3: COMBINED LEAST SQUARES ANALYSIS OF VARIANCE

PTH WT					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BRDTYP	2	2.794513	1.397256	3.330 NS	SIRE/E
SIRE/E	4	1.844272	0.461068	1.132 NS	REMAINDER
PARITY	5	0.989368	0.197874	0.722	REMAINDER
SEX	2	3.370830	1.685415	6.155**	REMAINDER
BTHYTP	1	7.250596	7.250596	26.452**	REMAINDER
PARITY X SEX	10	2.130195	0.213039	0.777	REMAINDER
SEX X BTHYTP	2	0.581480	0.290740	1.061	REMAINDER
REMAINDER	267	73.184852	0.274101		

WNG WT					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BRDTYP	2	82.863229	41.431615	2.205	SIRE/E
SIRE/E	4	57.235118	14.308779	2.404*	REMAINDER
PARITY	5	29.594120	5.918824	0.992	REMAINDER
SEX	2	36.237829	18.118915	3.895*	REMAINDER
BTHYTP	1	32.374203	32.374203	5.430*	REMAINDER
PARITY X SEX	10	32.234226	3.223423	0.547	REMAINDER
SEX X BTHYTP	2	2.517131	1.258565	0.211	REMAINDER
REMAINDER	267	1529.167805	5.951939		

WTAT11					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BRDTYP	2	1168.984225	584.472112	6.864	SIRE/E
SIRE/E	4	340.616606	85.154151	1.718	REMAINDER
PARITY	5	1384.995870	336.999174	6.700***	REMAINDER
SEX	2	900.714710	250.007355	5.745**	REMAINDER
BTHYTP	1	97.193309	97.193309	1.961	REMAINDER
PARITY X SEX	10	356.220526	35.622053	0.723	REMAINDER
SEX X BTHYTP	2	41.240457	20.620228	0.410	REMAINDER
REMAINDER	267	13232.551529	49.560112		

WTAT72					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BRDTYP	2	2288.464331	1144.232165	5.865	SIRE/E
SIRE/E	4	780.373300	195.093225	2.775*	REMAINDER
PARITY	5	2491.113203	498.222641	7.717***	REMAINDER
SEX	2	774.539145	387.269572	5.503**	REMAINDER
BTHYTP	1	199.262656	199.262656	2.831	REMAINDER
PARITY X SEX	10	690.252243	69.025224	0.982	REMAINDER
SEX X BTHYTP	2	171.426882	85.707441	1.219	REMAINDER
REMAINDER	267	18771.435834	70.305003		

Table A4.4:

LISTING OF CONSTANTS, LEAST-SQUARES MEANS AND STANDARD ERRORS FOR PROBLEM NO. 2

EMU NAME	FCU CODE	INDEPENDENT VARIABLE		NO. OBS.	CONSTANT ESTIMATE	LEAST-SQUARES MEAN	STANDARD ERROR
LVWYBS	1	MU		92	21.59149314	21.59149314	0.93235703
LVWYBS	2	BFFED	1	24	1.53387168	23.12436482	1.33771424
LVWYBS	3	BFFED	2	24	0.12023067	21.71972381	1.41915127
LVWYBS	4	BFFED	4	44	-1.71210175	19.87939139	1.35062765
LVWYBS	4	SEX	8	52	2.11299659	23.73246373	1.04116703
LVWYBS	4	SEX	9	40	-2.16299659	19.41639524	1.29355284
LVWYBS	5	BTHTPE	5	73	-1.06763777	20.52595666	0.87213715
LVWYBS	6	BTHTPE	6	19	1.06763777	22.59939171	1.42471706
LVWYBS	6	SEX X BTHTPE	8 5	39	-1.06763777	21.67894788	1.04524756
LVWYBS	6	SEX X BTHTPE	8 6	13	1.06763777	25.71001958	1.57563191
LVWYBS	6	SEX X BTHTPE	9 5	34	1.06763777	19.48824224	1.06191082
LVWYBS	6	SEX X BTHTPE	9 6	6	-1.06763777	19.48876285	2.21875111
LWTSTA	1	MU		92	20.06213556	20.06213556	0.89668735
LWTSTA	2	BFFED	1	24	1.47972911	21.54186467	1.29866495
LWTSTA	3	BFFED	2	24	0.09064568	20.15278125	1.32454185
LWTSTA	4	BFFED	4	44	-1.56977478	18.49261388	1.27752285
LWTSTA	4	SEX	8	52	1.97261234	21.92887590	1.02339777
LWTSTA	4	SEX	9	40	-1.97261234	18.48360123	1.25201244
LWTSTA	5	BTHTPE	5	73	0.91050334	19.07571023	0.83756576
LWTSTA	6	BTHTPE	6	19	0.91050334	20.91671690	1.37757447
LWTSTA	6	SEX X BTHTPE	8 5	39	0.95983995	20.05848241	1.02689558
LWTSTA	6	SEX X BTHTPE	8 6	13	0.95983995	23.72910919	1.56411362
LWTSTA	6	SEX X BTHTPE	9 5	34	0.95983995	19.13993704	1.04320120
LWTSTA	6	SEX X BTHTPE	9 6	6	-0.95983995	18.03626461	2.15145900
WARHDF	1	MU		92	9.16110174	9.16110174	0.64044316
WARHDF	2	BFFED	1	24	0.71427078	9.87537252	0.86969201
WARHDF	3	BFFED	2	24	0.07304715	9.23414889	0.94250086
WARHDF	4	BFFED	4	44	-0.78731793	8.37378391	0.95316292
WARHDF	4	SEX	8	52	1.01043792	10.17153946	0.68518717
WARHDF	4	SEX	9	40	-1.01043792	8.15066382	0.77221113
WARHDF	5	BTHTPE	5	73	-0.38116245	8.77993979	0.62062033
WARHDF	6	BTHTPE	6	19	0.38116245	9.54226419	0.82284880
WARHDF	6	SEX X BTHTPE	8 5	39	-0.39125777	9.39911944	0.68646384
WARHDF	6	SEX X BTHTPE	8 6	13	0.39125777	10.94395988	0.89212716
WARHDF	6	SEX X BTHTPE	9 5	34	0.39125777	8.16075914	0.67243457
WARHDF	6	SEX X BTHTPE	9 6	6	-0.39125777	8.14056850	1.15873138
COLLDF	1	MU		92	8.95495084	8.95495084	0.64662721
COLLDF	2	BFFED	1	24	0.66581701	9.62076785	0.87427310
COLLDF	3	BFFED	2	24	0.13714243	9.07209327	0.94745894
COLLDF	4	BFFED	4	44	-0.86295944	8.15199140	0.95526077
COLLDF	4	SEX	8	52	0.97067908	9.92562992	0.68834162
COLLDF	4	SEX	9	40	-0.97067908	7.98422717	0.76999418
COLLDF	5	BTHTPE	5	73	-0.34517410	8.60977673	0.62821110
COLLDF	6	BTHTPE	6	19	0.34517410	9.30012494	0.81701090
COLLDF	6	SEX X BTHTPE	8 5	39	-0.39748215	9.18973366	0.68953707
COLLDF	6	SEX X BTHTPE	8 6	13	0.39748215	10.66828618	0.88333767
COLLDF	6	SEX X BTHTPE	9 5	34	0.39748215	8.03157980	0.62511590
COLLDF	6	SEX X BTHTPE	9 6	6	-0.39748215	7.93196371	1.15739125
DRPERC	1	MU		92	45.41431750	45.41431750	1.30071417
DRPERC	2	BFFED	1	24	0.15121155	45.56552905	1.71581277
DRPERC	3	BFFED	2	24	-0.07517717	45.33014043	1.85944431
DRPERC	4	BFFED	4	44	-0.07603448	45.33828312	1.97348723
DRPERC	4	SEX	8	52	0.74289169	44.15720979	1.34572967
DRPERC	4	SEX	9	40	-0.74289169	44.67142591	1.43724901
DRPERC	5	BTHTPE	5	73	0.22613645	45.64045605	1.29127297
DRPERC	6	BTHTPE	6	19	-0.22613645	45.18817915	1.49243088
DRPERC	6	SEX X BTHTPE	8 5	39	0.26135308	46.64470081	1.36703270
DRPERC	6	SEX X BTHTPE	8 6	13	-0.26135308	45.66971777	1.57050768
DRPERC	6	SEX X BTHTPE	9 5	34	0.26135308	44.63621178	1.35315597
DRPERC	6	SEX X BTHTPE	9 6	6	-0.26135308	44.70664054	1.88800605
LENGHL	1	MU		92	32.74468874	32.74468874	0.44445728
LENGHL	2	BFFED	1	24	0.94679095	33.69147970	0.68036305
LENGHL	3	BFFED	2	24	-0.26772868	32.53376006	0.73731661
LENGHL	4	BFFED	4	44	-0.73906229	32.00762645	0.59545822
LENGHL	4	SEX	8	52	0.61982264	33.35451138	0.54651725
LENGHL	4	SEX	9	40	-0.61982264	32.13866009	0.71279459
LENGHL	5	BTHTPE	5	73	-0.57064002	32.17604871	0.37476755
LENGHL	6	BTHTPE	6	19	0.57064002	33.51732876	0.80148022
LENGHL	6	SEX X BTHTPE	8 5	39	-0.24128581	32.54458555	0.54718009
LENGHL	6	SEX X BTHTPE	8 6	13	0.24128581	34.16843721	0.91707497
LENGHL	6	SEX X BTHTPE	9 5	34	0.24128581	31.80751187	0.55959765
LENGHL	6	SEX X BTHTPE	9 6	6	-0.24128581	32.46622031	1.32417350

CIRCHL	1	MU			92	32.44674157	32.46174157	0.94664420
CIRCHL	2	BPFED	1		24	A.74451555	33.17424747	1.27407779
CIRCHL	3	BPFED	2		24	A.44974259	32.42441343	1.48240448
CIRCHL	4	BPFED	4		44	A.87717744	31.58753322	1.40118103
CIRCHL	4	SEX	8		52	A.92071317	34.38095449	1.02053777
CIRCHL	0	SEX	9		40	A.92071317	30.53157336	1.16334115
CIRCHL	5	BTHTPE	5		73	A.61199233	32.45274385	0.91339776
CIRCHL	0	BTHTPE	6		19	A.01199233	32.45274385	1.24510107
CIRCHL	6	SEX X BTHTPE	8	5	39	A.51859455	31.87335227	1.02262450
CIRCHL	0	SEX X BTHTPE	8	6	13	A.51859455	34.90455891	1.35724492
CIRCHL	0	SEX X BTHTPE	9	5	34	A.51859455	31.05211523	1.03252082
CIRCHL	0	SEX X BTHTPE	9	6	6	A.51859455	30.61094140	1.78555745

LENGFL	1	MU			92	17.17446742	17.17446742	0.25718730
LENGFL	2	BPFED	1		24	A.22320584	17.37673226	0.37322447
LENGFL	3	BPFED	2		24	A.30661057	17.48107809	0.40446044
LENGFL	0	BPFED	4		44	A.52461651	16.54165091	0.36334196
LENGFL	4	SEX	8		52	A.62233229	17.17446742	0.29677457
LENGFL	0	SEX	9		40	A.62233229	16.55713513	0.36737392
LENGFL	5	BTHTPE	5		73	A.11121638	17.06225104	0.23654436
LENGFL	0	BTHTPE	6		19	A.11121638	17.28568380	0.40586354
LENGFL	6	SEX X BTHTPE	8	5	39	A.19151237	17.42407096	0.27750166
LENGFL	0	SEX X BTHTPE	8	6	13	A.19151237	18.07052844	0.45069191
LENGFL	0	SEX X BTHTPE	9	5	34	A.19151237	16.63243112	0.30292802
LENGFL	0	SEX X BTHTPE	9	6	6	A.19151237	14.47183914	0.64101043

LENCHE	1	MU			92	A.85073940	A.85073940	0.12443544
LENCHE	2	BPFED	1		24	A.16755467	9.01829407	0.19048152
LENCHE	3	BPFED	2		24	A.21120483	9.25194423	0.20642162
LENCHE	0	BPFED	4		44	A.36875950	8.18197990	0.18602264
LENCHE	4	SEX	8		52	A.33922686	9.18976624	0.15244871
LENCHE	0	SEX	9		40	A.33922686	8.51151254	0.17956138
LENCHE	5	BTHTPE	5		73	A.17135792	8.67935148	0.11052323
LENCHE	0	BTHTPE	6		19	A.17135792	9.02209732	0.22439074
LENCHE	6	SEX X BTHTPE	8	5	39	A.69488536	8.92372227	0.15319675
LENCHE	0	SEX X BTHTPE	8	6	13	A.69488536	9.45628754	0.25675365
LENCHE	0	SEX X BTHTPE	9	5	34	A.69488536	8.43503998	0.15667106
LENCHE	0	SEX X BTHTPE	9	6	6	A.69488536	8.58798511	0.37070136

CIRCFI	1	MU			92	12.65321403	12.65321403	0.38706712
CIRCFI	2	BPFED	1		24	A.37106071	13.02427474	0.52223572
CIRCFI	3	BPFED	2		24	A.07955440	12.57365763	0.56595233
CIRCFI	0	BPFED	4		44	A.29150631	12.36170771	0.57863508
CIRCFI	4	SEX	8		52	A.30495940	12.95817342	0.41104026
CIRCFI	0	SEX	9		40	A.30495940	12.34825443	0.45810799
CIRCFI	5	BTHTPE	5		73	A.21552038	12.43769364	0.37650720
CIRCFI	0	BTHTPE	6		19	A.21552038	12.86473441	0.48502230
CIRCFI	6	SEX X BTHTPE	8	5	39	A.05651187	12.68611417	0.41172573
CIRCFI	0	SEX X BTHTPE	8	6	13	A.05651187	13.23020567	0.52367826
CIRCFI	0	SEX X BTHTPE	9	5	34	A.05651187	12.18924612	0.41493421
CIRCFI	0	SEX X BTHTPE	9	6	6	A.05651187	12.50726314	0.67127071

LENGLO	1	MU			92	2.50501326	2.50501326	0.04631510
LENGLO	2	BPFED	1		24	A.06094900	2.56596226	0.06570448
LENGLO	3	BPFED	2		24	A.01831202	2.52332527	0.07066278
LENGLO	0	BPFED	4		44	A.07926102	2.42575224	0.06710280
LENGLO	4	SEX	8		52	A.07995232	2.58496557	0.05163260
LENGLO	0	SEX	9		40	A.07995232	2.42506094	0.06149372
LENGLO	5	BTHTPE	5		73	A.00915386	2.47585939	0.04387060
LENGLO	0	BTHTPE	6		19	A.00915386	2.51416712	0.06700120
LENGLO	6	SEX X BTHTPE	8	5	39	A.05944083	2.51637080	0.05178722
LENGLO	0	SEX X BTHTPE	8	6	13	A.05944083	2.65356026	0.07440434
LENGLO	0	SEX X BTHTPE	9	5	34	A.05944083	2.47534791	0.05248136
LENGLO	0	SEX X BTHTPE	9	6	6	A.05944083	2.37477398	0.10169692

DEPCHE	1	MU			92	20.23388913	20.23388913	0.33048905
DEPCHE	2	BPFED	1		24	A.32716037	20.58104940	0.42455065
DEPCHE	3	BPFED	2		24	A.05487341	20.25875253	0.53594072
DEPCHE	0	BPFED	4		44	A.40203377	19.83185535	0.45366183
DEPCHE	4	SEX	8		52	A.67148182	20.70537075	0.37475308
DEPCHE	0	SEX	9		40	A.67148182	19.56240730	0.50545136
DEPCHE	5	BTHTPE	5		73	A.27314584	19.73074328	0.29950155
DEPCHE	0	BTHTPE	6		19	A.27314584	20.50703497	0.54456412
DEPCHE	6	SEX X BTHTPE	8	5	39	A.25748473	20.37474037	0.37848937
DEPCHE	0	SEX X BTHTPE	8	6	13	A.25748473	21.43600152	0.64210433
DEPCHE	0	SEX X BTHTPE	9	5	34	A.25748473	19.56474620	0.40456492
DEPCHE	0	SEX X BTHTPE	9	6	6	A.25748473	19.57806641	0.91755675

LENEXT	1	MU			92	34.92715848	34.92715848	0.51845197
LENEXT	2	BPFED	1		24	A.98770076	35.93859224	0.77362456
LENEXT	3	BPFED	2		24	A.33868260	35.28584108	0.85606340
LENEXT	0	BPFED	4		44	A.32282536	33.62477513	0.69505550
LENEXT	4	SEX	8		52	A.79934541	36.74450389	0.63516738
LENEXT	0	SEX	9		40	A.79934541	33.14781307	0.83145020
LENEXT	5	BTHTPE	5		73	A.73284400	34.21429448	0.44084867
LENEXT	0	BTHTPE	6		19	A.73284400	35.68802249	0.93490794
LENEXT	6	SEX X BTHTPE	8	5	39	A.74579904	35.25780095	0.63828003
LENEXT	0	SEX X BTHTPE	8	6	13	A.74579904	36.22516693	1.06074780
LENEXT	0	SEX X BTHTPE	9	5	34	A.74579904	33.15474810	0.82275551
LENEXT	0	SEX X BTHTPE	9	6	6	A.74579904	33.13487804	1.54450259

Table A4.4 (continued)

LLNGSI	1	MU			92	45.62472060	68.65172040	0.65459160		
LLNGSI	2	BPFED	1		24	0.07052763	49.73511723	0.27441776		
LLNGSI	3	BPFED	2		24	0.48120593	49.14592563	1.01817005		
LLNGSI	0	BPFED	4		44	-0.55140285	47.91311725	0.90833720		
LLNGSI	4	SEX	8		52	0.44512605	49.90821665	0.27801767		
LLNGSI	0	SEX	9		40	0.46512605	48.21052455	0.99677519		
LLNGSD	5	BTHTPE	5		73	0.19359969	48.85832029	0.57764508		
LLNGSD	0	BTHTPE	6		19	-0.19359969	48.47112072	1.10441267		
LLNGSI	0	SEX	Y	BTHTPE	8	5	39	-0.59093082	48.71251544	0.78212033
LLNGSD	0	SEX	X	BTHTPE	8	6	13	0.59093082	49.50717226	1.29376024
LLNGSD	0	SEX	Y	BTHTPE	9	5	34	0.59093082	49.00412512	0.72753925
LLNGSD	0	SEX	X	BTHTPE	9	6	6	-0.59093082	47.43506398	1.75572920
WLGTHI	1	MU			92	1.50764285	1.50764285	0.12118993		
WLGTHI	2	BPFED	1		24	0.07202082	1.60466374	0.16257482		
WLGTHI	3	BPFED	2		24	0.05470092	1.56234377	0.17618627		
WLGTHI	0	BPFED	4		44	-0.15172181	1.35592104	0.11852490		
WLGTHI	4	SEX	8		52	0.18103483	1.68867768	0.12783055		
WLGTHI	0	SEX	9		40	-0.18103483	1.32460801	0.14105040		
WLGTHI	5	BTHTPE	5		73	-0.05444183	1.45321102	0.11824091		
WLGTHI	0	BTHTPE	6		19	0.05444183	1.56906467	0.14862313		
WLGTHI	0	SEX	X	BTHTPE	8	5	39	-0.04936742	1.58886843	0.12804072
WLGTHI	0	SEX	X	BTHTPE	8	6	13	0.04936742	1.72248693	0.15262847
WLGTHI	0	SEX	X	BTHTPE	9	5	34	0.04936742	1.32153341	0.12823750
WLGTHI	0	SEX	X	BTHTPE	9	6	6	-0.04936742	1.33168242	0.20195205
WEGTLO	1	MU			92	0.57402918	0.57402918	0.03712772		
WEGTLO	2	BPFED	1		24	0.03236025	0.60630943	0.05334207		
WEGTLO	3	BPFED	2		24	0.60782120	0.58185036	0.05700253		
WEGTLO	0	BPFED	4		44	-0.04018145	0.53384773	0.05290797		
WEGTLO	4	SEX	8		52	0.08178040	0.65581758	0.04236188		
WEGTLO	0	SEX	9		40	-0.08178040	0.49224078	0.05120864		
WEGTLO	5	BTHTPE	5		73	-0.01902426	0.55500492	0.03468412		
WEGTLO	0	BTHTPE	6		19	0.01902426	0.52305344	0.05639391		
WEGTLO	0	SEX	X	BTHTPE	8	5	39	-0.01939681	0.61739651	0.04220637
WEGTLO	0	SEX	X	BTHTPE	8	6	13	0.01939681	0.69423065	0.06390434
WEGTLO	0	SEX	X	BTHTPE	9	5	34	0.01939681	0.42261332	0.04318035
WEGTLO	0	SEX	X	BTHTPE	9	6	6	-0.01939681	0.42186824	0.08828574
WEGTHO	1	MU			92	2.04462418	2.04462418	0.13933526		
WEGTHO	2	BPFED	1		24	0.11704450	2.15166848	0.18999420		
WEGTHO	3	BPFED	2		24	0.05062025	2.10424443	0.20539871		
WEGTHO	0	BPFED	4		44	-0.17666475	1.86795943	0.20678150		
WEGTHO	4	SEX	8		52	0.24154604	2.30617022	0.14977225		
WEGTHO	0	SEX	9		40	-0.24154604	1.78307814	0.16995263		
WEGTHO	5	BTHTPE	5		73	-0.08805193	1.75457225	0.13409722		
WEGTHO	0	BTHTPE	6		19	0.08805193	2.13267512	0.18160973		
WEGTHO	0	SEX	X	BTHTPE	8	5	39	-0.07206121	2.14405708	0.15007463
WEGTHO	0	SEX	X	BTHTPE	8	6	13	0.07206121	2.46428336	0.19758760
WEGTHO	0	SEX	X	BTHTPE	9	5	34	0.07206121	1.75708741	0.15146182
WEGTHO	0	SEX	X	BTHTPE	9	6	6	-0.07206121	1.72906887	0.25857325
WEGTFO	1	MU			92	2.49485321	2.49485321	0.17919590		
WEGTFO	2	BPFED	1		24	0.18681172	2.65166493	0.24363013		
WEGTFO	3	BPFED	2		24	0.04061228	2.53546619	0.26407653		
WEGTFO	0	BPFED	4		44	-0.22742469	2.26742852	0.26648150		
WEGTFO	4	SEX	8		52	0.27354040	2.76839361	0.19197492		
WEGTFO	0	SEX	9		40	-0.27354040	2.22131281	0.21678557		
WEGTFO	5	BTHTPE	5		73	-0.08504867	2.40980454	0.17353727		
WEGTFO	0	BTHTPE	6		19	0.08504867	2.57926168	0.23115512		
WEGTFO	0	SEX	X	BTHTPE	8	5	39	-0.11607098	2.56273396	0.19236470
WEGTFO	0	SEX	X	BTHTPE	8	6	13	0.11607098	2.96051326	0.25090481
WEGTFO	0	SEX	X	BTHTPE	9	5	34	0.11607098	2.25233512	0.19404445
WEGTFO	0	SEX	X	BTHTPE	9	6	6	-0.11607098	2.12029051	0.32660548
WEGTRT	1	MU			92	4.48488760	4.48488760	0.31277777		
WEGTRT	2	BPFED	1		24	0.31060958	4.79549668	0.42400062		
WEGTRT	3	BPFED	2		24	0.08151388	4.56640087	0.46033082		
WEGTRT	0	BPFED	4		44	-0.39223356	4.09276344	0.45545666		
WEGTRT	4	SEX	8		52	0.4552881	4.97541581	0.33418405		
WEGTRT	0	SEX	9		40	-0.4552881	3.92635812	0.37728165		
WEGTRT	5	BTHTPE	5		73	-0.15750580	4.32738120	0.30307144		
WEGTRT	0	BTHTPE	6		19	0.15750580	4.64232280	0.40198400		
WEGTRT	0	SEX	Y	BTHTPE	8	5	39	-0.18791739	4.62792263	0.33530210
WEGTRT	0	SEX	X	BTHTPE	8	6	13	0.18791739	5.31083900	0.43596104
WEGTRT	0	SEX	X	BTHTPE	9	5	34	0.18791739	4.02676977	0.33843206
WEGTRT	0	SEX	X	BTHTPE	9	6	6	-0.18791739	3.96574660	0.56640326
WEGTFL	1	MU			92	0.97385945	0.97385945	0.06543887		
WEGTFL	2	BPFED	1		24	0.05613141	1.02549086	0.06979571		
WEGTFL	3	BPFED	2		24	0.03346219	1.00732864	0.07731482		
WEGTFL	0	BPFED	4		44	-0.08510060	0.88875885	0.02667052		
WEGTFL	4	SEX	8		52	0.12092771	1.02478716	0.07005432		
WEGTFL	0	SEX	9		40	-0.12092771	0.85923174	0.05124497		
WEGTFL	5	BTHTPE	5		73	-0.03917972	0.93437967	0.06301450		
WEGTFL	0	BTHTPE	6		19	0.03917972	1.01333924	0.08712356		
WEGTFL	0	SEX	Y	BTHTPE	8	5	39	-0.04355919	1.01144819	0.07161188
WEGTFL	0	SEX	X	BTHTPE	8	6	13	0.04355919	1.17812614	0.07531467
WEGTFL	0	SEX	X	BTHTPE	9	5	34	0.04355919	0.85731114	0.07173012
WEGTFL	0	SEX	X	BTHTPE	9	6	6	-0.04355919	0.84855234	0.12607314

Table A4.4 (continued)

WEGTCH	1	MU			92	1.54212277	1.54212277	0.11670774
WEGTCH	2	BFFED	1		24	1.12270553	1.17183525	0.15846425
WEGTCH	3	BFFED	2		24	0.00957204	1.53255744	0.17172737
WEGTCH	4	BFFED	4		44	0.12113348	1.42190624	0.17371007
WEGTCH	4	SEX	8		52	0.16519527	1.70737499	0.17484318
WEGTCH	6	SEX	9		40	0.14319527	1.37193444	0.14066797
WEGTCH	5	BTHTPE	5		73	0.04609485	1.47403487	0.11310409
WEGTCH	6	BTHTPE	6		19	0.04609485	1.58822456	0.14954792
WEGTCH	6	SEX X BTHTPE	8	5	39	0.06675701	1.57447314	0.12507493
WEGTCH	6	SEX X BTHTPE	8	6	13	0.06675701	1.82117634	0.15247911
WEGTCH	6	SEX X BTHTPE	9	5	34	0.06675701	1.39759560	0.12616062
WEGTCH	6	SEX X BTHTPE	9	6	6	0.06675701	1.35427228	0.21098225
WEGTLY	1	MU			92	4.48466639	4.48466639	0.31752027
WEGTLY	2	BFFED	1		24	0.34474696	4.82791247	0.43143013
WEGTLY	3	BFFED	2		24	0.07608526	4.56675145	0.40755512
WEGTLY	4	BFFED	4		44	0.42135133	4.06433504	0.42238354
WEGTLY	4	SEX	8		52	0.4958543	4.98425122	0.33943734
WEGTLY	6	SEX	9		40	0.47958543	3.98508097	0.38348223
WEGTLY	5	BTHTPE	5		73	0.17528752	4.30937887	0.30759525
WEGTLY	6	BTHTPE	6		19	0.17528752	4.65995391	0.40872168
WEGTLY	6	SEX X BTHTPE	8	5	39	0.19390967	4.61565463	0.34057552
WEGTLY	6	SEX X BTHTPE	8	6	13	0.19390967	5.35444901	0.44343077
WEGTLY	6	SEX X BTHTPE	9	5	34	0.19390967	4.00370312	0.34356458
WEGTLY	6	SEX X BTHTPE	9	6	6	0.19390967	3.96445581	0.57657420
TOWTLE	1	MU			92	3.04407889	3.04407889	0.19910900
TOWTLE	2	BFFED	1		24	0.16176937	3.14584876	0.27426703
TOWTLE	3	BFFED	2		24	0.07291830	3.12279719	0.27722406
TOWTLE	4	BFFED	4		44	0.1668767	2.86339122	0.27332877
TOWTLE	4	SEX	8		52	0.22838715	3.27244604	0.21653574
TOWTLE	6	SEX	9		40	0.22838715	2.81569174	0.24974947
TOWTLE	5	BTHTPE	5		73	0.06918890	2.97488999	0.17128992
TOWTLE	6	BTHTPE	6		19	0.06918890	3.11826779	0.26870973
TOWTLE	6	SEX X BTHTPE	8	5	39	0.07702515	3.17425159	0.21702819
TOWTLE	6	SEX X BTHTPE	8	6	13	0.07702515	3.36868009	0.29452706
TOWTLE	6	SEX X BTHTPE	9	5	34	0.07702515	2.77357798	0.21933216
TOWTLE	6	SEX X BTHTPE	9	6	6	0.07702515	2.85785549	0.39180806
TOWTFA	1	MU			92	0.43850564	0.43850564	0.04090961
TOWTFA	2	BFFED	1		24	0.08259724	0.52110288	0.06107323
TOWTFA	3	BFFED	2		24	0.00476982	0.43173582	0.06619112
TOWTFA	4	BFFED	4		44	0.07582741	0.35267623	0.05628375
TOWTFA	4	SEX	8		52	0.12959722	0.55910286	0.04873055
TOWTFA	6	SEX	9		40	0.12959722	0.30890847	0.05226064
TOWTFA	5	BTHTPE	5		73	0.00350982	0.44201546	0.03711838
TOWTFA	6	BTHTPE	6		19	0.00350982	0.43439952	0.06949114
TOWTFA	6	SEX X BTHTPE	8	5	39	0.01466614	0.55674654	0.04895135
TOWTFA	6	SEX X BTHTPE	8	6	13	0.01466614	0.57925918	0.07898031
TOWTFA	6	SEX X BTHTPE	9	5	34	0.01466614	0.32708438	0.04993659
TOWTFA	6	SEX X BTHTPE	9	6	6	0.01466614	0.29073246	0.11273239
TOWTBC	1	MU			92	0.82033207	0.82033207	0.05296864
TOWTBC	2	BFFED	1		24	0.04218862	0.86752049	0.07173317
TOWTBC	3	BFFED	2		24	0.04796281	0.86829468	0.07773799
TOWTBC	4	BFFED	4		44	0.00015144	0.73018064	0.07898044
TOWTBC	4	SEX	8		52	0.05818118	0.71851325	0.05649164
TOWTBC	6	SEX	9		40	0.02818118	0.72215090	0.06337160
TOWTBC	5	BTHTPE	5		73	0.03396046	0.78437162	0.05141081
TOWTBC	6	BTHTPE	6		19	0.03396046	0.85429253	0.06737502
TOWTBC	6	SEX X BTHTPE	8	5	39	0.04408432	0.84446847	0.05659218
TOWTBC	6	SEX X BTHTPE	8	6	13	0.04408432	0.97635902	0.07289503
TOWTBC	6	SEX X BTHTPE	9	5	34	0.04408432	0.73227474	0.05706319
TOWTBC	6	SEX X BTHTPE	9	6	6	0.04408432	0.71202703	0.07417487
WTKIDF	1	MU			92	0.13980466	0.13980466	0.01103488
WTKIDF	2	BFFED	1		24	0.01748947	0.15729412	0.01689182
WTKIDF	3	BFFED	2		24	0.00908985	0.13671501	0.01830584
WTKIDF	4	BFFED	4		44	0.00839982	0.13140684	0.01479376
WTKIDF	4	SEX	8		52	0.03797169	0.17777614	0.01351908
WTKIDF	6	SEX	9		40	0.03797169	0.10183317	0.01709701
WTKIDF	5	BTHTPE	5		73	0.00877938	0.13102328	0.00980115
WTKIDF	6	BTHTPE	6		19	0.00877938	0.14858403	0.01929887
WTKIDF	6	SEX X BTHTPE	8	5	39	0.01219824	0.15779852	0.01339542
WTKIDF	6	SEX X BTHTPE	8	6	13	0.01219824	0.12675376	0.02276582
WTKIDF	6	SEX X BTHTPE	9	5	34	0.01219824	0.10525204	0.01389352
WTKIDF	6	SEX X BTHTPE	9	6	6	0.01219824	0.09841430	0.03207363

Table A4.4 (continued)

WTSTOP	1	MU	92	1.52710435	1.52710435	0.11512282
WTSTOP	2	RPFED	24	0.06866651	1.61577086	0.16039242
WTSTOP	3	CPFED	24	0.04484017	1.57494452	0.18357234
WTSTOP	4	RPFED	44	-0.13350666	1.39359767	0.16061265
WTSTOP	6	SEX	52	0.07970439	1.60606874	0.13293077
WTSTOP	9	SEX	40	0.07970439	1.44739996	0.16969532
WTSTOP	5	RTHTPE	75	-0.25161772	1.27648663	0.10566861
WTSTOP	6	RTHTPE	19	0.25161772	1.77572207	0.18646530
WTSTOP	8	SEX X RTHTPE	59	0.06628124	1.40147226	0.13547021
WTSTOP	3	SEX X RTHTPE	13	-0.06628124	1.81214522	0.21371786
WTSTOP	5	SEX X RTHTPE	34	-0.06628124	1.14950100	0.13798473
WTSTOP	6	SEX X RTHTPE	6	0.06628124	1.74527892	0.30165745
WTSPIN	1	MU	92	0.85040858	0.85040858	0.04152382
WTSPIN	2	RPFED	24	0.07413239	0.93354097	0.06356294
WTSPIN	3	CPFED	24	-0.04710933	0.81209006	0.05860283
WTSPIN	4	RPFED	44	-0.07693286	0.83247372	0.05566807
WTSPIN	6	SEX	52	0.07407600	0.93348458	0.05067154
WTSPIN	9	SEX	40	-0.07407600	0.78533239	0.06592866
WTSPIN	5	RTHTPE	75	-0.02805657	0.83635201	0.03668117
WTSPIN	6	RTHTPE	19	0.02805657	0.68245115	0.07467832
WTSPIN	8	SEX X RTHTPE	59	0.03539477	0.94582278	0.05112116
WTSPIN	3	SEX X RTHTPE	13	-0.03539477	0.92114638	0.08567776
WTSPIN	5	SEX X RTHTPE	34	-0.03539477	0.72488124	0.05228052
WTSPIN	6	SEX X RTHTPE	6	0.03539477	0.84378393	0.12370161
WTHFAD	1	MU	92	1.12130245	1.12130245	0.05793664
WTHFAD	2	RPFED	24	0.07957258	1.19387503	0.07797032
WTHFAD	3	CPFED	24	0.03589334	1.12487179	0.08449725
WTHFAD	4	RPFED	44	-0.07416192	1.04514054	0.08676128
WTHFAD	6	SEX	52	0.02452705	1.14782950	0.06134488
WTHFAD	9	SEX	40	-0.02452705	1.09277541	0.05806154
WTHFAD	5	RTHTPE	73	-0.02540390	1.09589855	0.05643828
WTHFAD	6	RTHTPE	19	0.02540390	1.14670635	0.07200047
WTHFAD	8	SEX X RTHTPE	39	-0.00844941	1.11597619	0.06144247
WTHFAD	3	SEX X RTHTPE	13	0.00844941	1.18166281	0.07746073
WTHFAD	5	SEX X RTHTPE	34	-0.00844941	1.07782091	0.06189972
WTHFAD	6	SEX X RTHTPE	6	0.00844941	1.11172990	0.09872862
LISTING OF INVERSE ELEMENTS FOR PROBLEM NO. 2						
0.19160331E-01	-0.47723933E-03	0.31624522E-02	-0.51303636E-02	-0.11797455E-01	0.52105002E-02	0.26621504E-01
-0.16643556E-01	0.62173871E-03	0.43720697E-02	-0.65212857E-03	0.27243496E-01	0.38237421E-02	-0.23479025E-02
-0.62038080E-03	0.19856648E-01	0.56819045E-02	-0.12226033E-01	0.19550056E-01	-0.00950840E-02	0.19189194E-01
LISTING OF DIAGONAL INVERSE ELEMENTS						
0.19160331E-01	0.26691504E+01	0.27243496E+01	0.19856648E-01	0.19550056E-01	0.19189194E-01	

Table A4.5: COMBINED LEAST SQUARES ANALYSIS OF VARIANCE

LWVTRs					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	164.491613	82.245807	1.013	SIZES
SIZES	3	128.983079	42.994360	1.466	REMAINDER
SEY	1	222.762444	222.762444	8.2953	REMAINDER
BTHTPF	1	51.861923	51.861923	1.934	REMAINDER
SEX X BTHTPF	1	52.911753	52.911753	1.976	REMAINDER
REMAINDER	83	2229.823950	26.865349		
LWTSTA					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	142.850869	71.425435	1.793	SIZES
SIZES	3	119.425085	39.831695	1.571	REMAINDER
SEX	1	186.137455	186.137455	7.343	REMAINDER
BTHTPF	1	42.404805	42.404805	1.473	REMAINDER
SEX X BTHTPF	1	46.011018	46.011018	1.894	REMAINDER
REMAINDER	83	2103.941941	25.348698		
WARMDR					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	35.051527	17.525764	0.901	SIZES
SIZES	3	58.358489	19.452830	3.148	REMAINDER
SEX	1	51.412603	51.412603	8.319	REMAINDER
BTHTPF	1	7.431427	7.431427	1.202	REMAINDER
SEX X BTHTPF	1	7.977544	7.977544	1.291	REMAINDER
REMAINDER	83	512.953355	6.180161		
COLDDR					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	34.697363	17.348682	0.878	SIZES
SIZES	3	59.298548	19.766183	3.406	REMAINDER
SEX	1	47.446225	47.446225	6.177	REMAINDER
BTHTPF	1	6.094364	6.094364	1.050	REMAINDER
SEX X BTHTPF	1	8.233387	8.233387	1.419	REMAINDER
REMAINDER	83	461.624451	5.802704		
DRPERC					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	0.878300	0.439150	0.006	SIZES
SIZES	3	235.681237	78.560412	6.330	REMAINDER
SEX	1	27.790818	27.790818	2.239	REMAINDER
BTHTPF	1	2.615777	2.615777	0.211	REMAINDER
SEX X BTHTPF	1	3.559578	3.559578	0.287	REMAINDER
REMAINDER	83	1030.142235	12.411352		
LENGH1					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	42.266657	21.133329	2.434	SIZES
SIZES	3	24.048600	8.016200	0.775	REMAINDER
SEX	1	18.726535	18.726535	1.916	REMAINDER
BTHTPF	1	16.656220	16.656220	1.615	REMAINDER
SEX X BTHTPF	1	3.033939	3.033939	0.294	REMAINDER
REMAINDER	83	855.733611	10.310044		
CIRCHL					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	40.845635	20.422818	0.478	SIZES
SIZES	3	128.100486	42.700162	2.810	REMAINDER
SEX	1	187.417766	187.417766	12.435	REMAINDER
BTHTPF	1	0.000203	0.000203	0.000	REMAINDER
SEX X BTHTPF	1	14.015196	14.015196	0.922	REMAINDER
REMAINDER	83	1261.060284	15.193497		
LENGFL					

Table A4.5 (continued)

LENGFI					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	13.650380	6.825190	2.067	SIRES
SIRES	3	9.907131	3.302377	1.645	REMAINDER
SEX	1	19.502711	19.502711	8.5344*	REMAINDER
BTHYPE	1	0.632688	0.632688	0.277	REMAINDER
SEX X BTHYPE	1	1.911336	1.911336	0.837	REMAINDER
REMAINDER	83	189.642790	2.284853		

LENGHU					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	6.592580	3.296290	27.163*	SIRES
SIRES	3	0.364058	0.121353	0.150	REMAINDER
SEX	1	5.794698	5.794698	7.1702*	REMAINDER
BTHYPE	1	1.501967	1.501967	1.859	REMAINDER
SEX X BTHYPE	1	0.469182	0.469182	0.581	REMAINDER
REMAINDER	83	67.075330	0.808137		

CIRCFI					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	6.525255	3.262627	0.461	SIRES
SIRES	3	21.214849	7.071616	3.547*	REMAINDER
SEX	1	4.683110	4.683110	2.349	REMAINDER
BTHYPE	1	2.375903	2.375903	1.192	REMAINDER
SEX X BTHYPE	1	0.166427	0.166427	0.083	REMAINDER
REMAINDER	83	165.457754	1.993467		

LENGLO					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	0.327240	0.163620	1.565	SIRES
SIRES	3	0.313677	0.104559	1.925	REMAINDER
SEX	1	0.321894	0.321894	5.925*	REMAINDER
BTHYPE	1	0.042866	0.042866	0.079	REMAINDER
SEX X BTHYPE	1	0.184125	0.184125	3.389	REMAINDER
REMAINDER	83	4.509402	0.054330		

DEPCHE					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	8.881280	4.440640	0.794	SIRES
SIRES	3	16.776245	5.592082	1.452	REMAINDER
SEX	1	22.704861	22.704861	4.676*	REMAINDER
BTHYPE	1	3.816288	3.816288	0.786	REMAINDER
SEX X BTHYPE	1	3.454986	3.454986	0.711	REMAINDER
REMAINDER	83	403.043523	4.855946		

LENEXT					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	90.002697	45.001348	3.420	SIRES
SIRES	3	39.473253	13.157751	0.938	REMAINDER
SEX	1	163.034458	163.034458	11.622*	REMAINDER
BTHYPE	1	27.472537	27.472537	1.952	REMAINDER
SEX X BTHYPE	1	28.985908	28.985908	2.066	REMAINDER
REMAINDER	83	1164.371826	14.028576		

LENGSD					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	121.161711	60.580756	2.759	SIRES
SIRES	3	65.875646	21.958549	1.201	REMAINDER
SEX	1	9.977376	9.977376	0.546	REMAINDER
BTHYPE	1	1.917173	1.917173	0.105	REMAINDER
SEX X BTHYPE	1	18.197706	18.197706	0.996	REMAINDER
REMAINDER	83	1517.087782	18.278166		

WEGTHL					
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE
BREED	2	1.139566	0.569783	0.825	SIRES
SIRES	3	2.070825	0.690275	3.974*	REMAINDER
SEX	1	1.650345	1.650345	9.544*	REMAINDER
BTHYPE	1	0.151606	0.151606	0.876	REMAINDER
SEX X BTHYPE	1	0.127066	0.127066	0.736	REMAINDER
REMAINDER	83	14.356962	0.172975		

SECTA

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	2,288772	1,144386	0,225	STRES
SIRFS	3	2,272872	757624	0,152	REMAINDER
SEX	1	2,382568	2,382568	0,475	REMAINDER
BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
SEX X BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
REMAINDER	83	2,222814	2,222814		

SECTSB

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	1,888888	0,944444	0,189	STRES
SIRFS	3	2,272872	757624	0,152	REMAINDER
SEX	1	2,382568	2,382568	0,475	REMAINDER
BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
SEX X BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
REMAINDER	83	2,222814	2,222814		

SECTSC

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	0,222814	0,111407	0,022	STRES
SIRFS	3	2,272872	757624	0,152	REMAINDER
SEX	1	2,382568	2,382568	0,475	REMAINDER
BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
SEX X BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
REMAINDER	83	2,222814	2,222814		

SECTSD

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	0,111407	0,055704	0,011	STRES
SIRFS	3	2,272872	757624	0,152	REMAINDER
SEX	1	2,382568	2,382568	0,475	REMAINDER
BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
SEX X BTHTPF	1	2,222814	2,222814	0,445	REMAINDER
REMAINDER	83	2,222814	2,222814		

SECTSE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	0,222814	0,111407	0,022	STRES
SIRFS	3	0,222814	0,074271	0,015	REMAINDER
SEX	1	0,222814	0,222814	0,045	REMAINDER
BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
SEX X BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
REMAINDER	83	0,222814	0,222814		

SECTSF

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	0,222814	0,111407	0,022	STRES
SIRFS	3	1,222814	0,407605	0,081	REMAINDER
SEX	1	1,222814	1,222814	0,245	REMAINDER
BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
SEX X BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
REMAINDER	83	1,222814	0,222814		

SECTSG

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	0,452201	0,226101	0,045	STRES
SIRFS	3	1,222814	0,407605	0,081	REMAINDER
SEX	1	1,222814	1,222814	0,245	REMAINDER
BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
SEX X BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
REMAINDER	83	1,222814	0,222814		

SECTSH

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	EMPIRICAL
DFEFD	2	1,500628	0,750314	0,150	STRES
SIRFS	3	5,701171	1,900390	0,380	REMAINDER
SEX	1	2,676598	2,676598	0,535	REMAINDER
BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
SEX X BTHTPF	1	0,222814	0,222814	0,045	REMAINDER
REMAINDER	83	62,638212	0,754677		

Table A4.5 (continued)

TOWTHA						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.374261	0.187131	2.188	SIZES	
SIZES	3	0.256569	0.085523	1.162	REMAINDER	
SEX	1	0.845749	0.845749	11.564**	REMAINDER	
BTHYPE	1	0.000630	0.000630	0.009	REMAINDER	
SEX X BTHYPE	1	0.011209	0.011209	0.153	REMAINDER	
REMAINDER	83	6.070234	0.073135			

TOWTBO						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.393753	0.196879	1.483	SIZES	
SIZES	3	0.398378	0.132793	3.305*	REMAINDER	
SEX	1	0.485408	0.485408	12.079***	REMAINDER	
BTHYPE	1	0.058993	0.058993	1.468	REMAINDER	
SEX X BTHYPE	1	0.101277	0.101277	2.520	REMAINDER	
REMAINDER	83	3.335353	0.040185			

WTKIDN						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.011653	0.005828	2.335	SIZES	
SIZES	3	0.007489	0.002496	0.193	REMAINDER	
SEX	1	0.072605	0.072605	11.424***	REMAINDER	
BTHYPE	1	0.003943	0.003943	0.620	REMAINDER	
SEX X BTHYPE	1	0.007754	0.007754	1.220	REMAINDER	
REMAINDER	83	0.527485	0.006355			

WTSTOW						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.889029	0.444515	0.664	SIZES	
SIZES	3	2.007478	0.669159	1.297	REMAINDER	
SEX	1	0.319900	0.319900	0.620	REMAINDER	
BTHYPE	1	3.238429	3.238429	6.275*	REMAINDER	
SEX X BTHYPE	1	0.111623	0.111623	0.216	REMAINDER	
REMAINDER	83	42.832520	0.516054			

WTSMIN						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.205950	0.102975	2.823	SIZES	
SIZES	3	0.109439	0.036480	0.405	REMAINDER	
SEX	1	0.276316	0.276316	3.071	REMAINDER	
BTHYPE	1	0.027192	0.027192	0.302	REMAINDER	
SEX X BTHYPE	1	0.065286	0.065286	0.725	REMAINDER	
REMAINDER	83	7.469046	0.089989			

UTHEAD						
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F	ERROR LINE	
BREED	2	0.338778	0.169389	1.071	SIZES	
SIZES	3	0.474421	0.158140	3.734	REMAINDER	
SEX	1	0.035435	0.035435	0.837	REMAINDER	
BTHYPE	1	0.033011	0.033011	0.772	REMAINDER	
SEX X BTHYPE	1	0.003720	0.003720	0.088	REMAINDER	
REMAINDER	83	3.515436	0.042355			

Table A4.6:

ESTIMATES OF HERITABILITY, GENETIC, PHENOTYPIC, ENVIRONMENTAL CORRELATIONS

JOB	ROW	COL	RHW	RHM	HERITABILITY OR GENETIC R	STANDARD ERRORS	PHENOTYPIC CORRELATION	ENVIRONMENTAL CORRELATION	HWG	VARIANCE OR Cov COMPONENTS WITHIN
2	1	1	LVUTRS	LVUTRS	0.144	0.272	1.000	1.000	0	1.000073357
2	1	2	LVUTRS	LVUTSA	1.000	0.019	0.925	0.290	0	1.031842337
2	1	3	LVUTRS	LARHPR	1.147	0.277	0.954	0.272	0	1.024602997
2	1	4	LVUTRS	COLDPR	1.134	0.311	0.956	0.266	0	1.139815223
2	1	5	LVUTRS	FRPLRC	1.588	1.053	0.508	0.017	0	3.473405422
2	1	6	LVUTRS	LEKHL	0.000	0.000	0.742	0.628	0	0.328513382
2	1	7	LVUTRS	CIRCHL	1.194	0.403	0.826	0.845	0	1.684609864
2	1	8	LVUTRS	LENGFL	1.024	0.325	0.825	0.725	0	0.277022550
2	1	9	LVUTRS	LEKCHU	0.000	0.000	0.581	0.720	0	-0.129172401
2	1	10	LVUTRS	CIRCHL	1.172	0.429	0.604	0.735	0	0.274629103
2	1	11	LVUTRS	LENGIO	1.247	0.525	0.746	0.444	0	0.075194455
2	1	12	LVUTRS	FEPCHE	0.251	2.340	0.551	0.517	0	0.057914550
2	1	13	LVUTRS	LELEYT	0.000	0.000	0.761	0.792	0	0.110522586
2	1	14	LVUTRS	LEKGD	1.905	2.477	0.739	0.538	0	0.224684445
2	1	15	LVUTRS	LEGLHL	1.162	0.375	0.912	0.218	0	0.224684445
2	1	16	LVUTRS	LEGLHO	1.181	0.402	0.905	0.859	0	0.05014575
2	1	17	LVUTRS	LEGLHO	1.696	0.241	0.960	0.264	0	0.270159234
2	1	18	LVUTRS	LEGLFO	1.053	0.243	0.955	0.265	0	0.258272971
2	1	19	LVUTRS	LEGLAT	1.125	0.291	0.935	0.256	0	0.538201445
2	1	20	LVUTRS	LEGLFL	1.053	0.186	0.934	0.233	0	0.101175567
2	1	21	LVUTRS	LEGLTH	1.050	0.334	0.935	0.212	0	0.205444809
2	1	22	LVUTRS	LEGLIT	1.130	0.298	0.935	0.254	0	0.548032228
2	1	23	LVUTRS	TOUFTA	1.084	0.219	0.928	0.210	0	0.31192568
2	1	24	LVUTRS	TOUFTA	0.667	1.048	0.776	0.724	0	0.02575212
2	1	25	LVUTRS	TOUFTO	1.158	0.371	0.847	0.827	0	0.02475420
2	1	26	LVUTRS	LYKIFN	0.000	0.000	0.356	0.547	0	-0.01877732
2	1	27	LVUTRS	LYSTGM	1.697	2.639	0.635	0.492	0	0.139968452
2	1	28	LVUTRS	LTSWJN	0.000	0.000	0.329	0.678	0	-0.113636973
2	1	29	LVUTRS	LTHFAD	1.225	0.471	0.889	0.819	0	0.111209444
2	2	2	LVUTSA	LVUTSA	0.137	0.268	1.000	1.000	0	0.260933862
2	2	3	LVUTSA	LARHPR	1.120	0.297	0.964	0.275	0	1.029822673
2	2	4	LVUTSA	COLDPR	1.136	0.332	0.954	0.262	0	1.022358264
2	2	5	LVUTSA	FRPLRC	1.616	1.142	0.493	0.008	0	3.54761267
2	2	6	LVUTSA	LEKHL	0.000	0.000	0.738	0.682	0	0.356112292
2	2	7	LVUTSA	CIRCHL	1.212	0.449	0.902	0.851	0	1.62054597
2	2	8	LVUTSA	LEKFL	0.915	0.431	0.812	0.792	0	0.22521066
2	2	9	LVUTSA	LEKCHU	0.000	0.000	0.579	0.724	0	-0.19598139
2	2	10	LVUTSA	CIRCHL	1.196	0.473	0.801	0.731	0	0.666790229
2	2	11	LVUTSA	LEKGLD	1.178	0.450	0.741	0.656	0	0.047268117
2	2	12	LVUTSA	FEPCHE	0.499	1.959	0.558	0.573	0	0.10901027
2	2	13	LVUTSA	LELEYT	0.000	0.000	0.784	0.812	0	0.114611565
2	2	14	LVUTSA	LEKGD	1.949	3.640	0.721	0.615	0	0.95301381
2	2	15	LVUTSA	LEGLHL	1.104	0.425	0.913	0.218	0	0.216295752
2	2	16	LVUTSA	LEGLHO	1.195	0.440	0.915	0.866	0	0.04807395
2	2	17	LVUTSA	LEGLHO	1.092	0.252	0.956	0.267	0	0.217429472
2	2	18	LVUTSA	LEGLFO	1.100	0.269	0.955	0.267	0	0.26442148
2	2	19	LVUTSA	LEGLAT	1.127	0.311	0.953	0.258	0	0.510985575
2	2	20	LVUTSA	LEGLFL	1.066	0.216	0.934	0.230	0	0.02706793
2	2	21	LVUTSA	LEGLTH	1.175	0.389	0.935	0.212	0	0.19882831
2	2	22	LVUTSA	LEGLIT	1.134	0.321	0.952	0.253	0	0.52103460
2	2	23	LVUTSA	TOUFTA	1.110	0.321	0.931	0.210	0	0.31275290
2	2	24	LVUTSA	TOUFTA	0.922	1.020	0.788	0.789	0	0.02615042
2	2	25	LVUTSA	TOUFTO	1.116	0.345	0.861	0.832	0	0.06655711
2	2	26	LVUTSA	LYKIFN	0.000	0.000	0.353	0.554	0	-0.03960353
2	2	27	LVUTSA	LYSTGM	1.815	2.419	0.624	0.493	0	-0.18162550
2	2	28	LVUTSA	LTSWJN	0.000	0.000	0.313	0.637	0	-0.15687418
2	2	29	LVUTSA	LTHFAD	0.000	0.000	0.889	0.819	0	0.111209444
2	3	3	LVUTSA	LVUTSA	0.137	0.268	1.000	1.000	0	0.260933862
2	3	4	LVUTSA	LARHPR	1.120	0.297	0.964	0.275	0	1.029822673
2	3	5	LVUTSA	COLDPR	1.136	0.332	0.954	0.262	0	1.022358264
2	3	6	LVUTSA	FRPLRC	1.616	1.142	0.493	0.008	0	3.54761267
2	3	7	LVUTSA	LEKHL	0.000	0.000	0.738	0.682	0	0.356112292
2	3	8	LVUTSA	CIRCHL	1.212	0.449	0.902	0.851	0	1.62054597
2	3	9	LVUTSA	LEKFL	0.915	0.431	0.812	0.792	0	0.22521066
2	3	10	LVUTSA	LEKCHU	0.000	0.000	0.579	0.724	0	-0.19598139
2	3	11	LVUTSA	CIRCHL	1.196	0.473	0.801	0.731	0	0.666790229
2	3	12	LVUTSA	LEKGLD	1.178	0.450	0.741	0.656	0	0.047268117
2	3	13	LVUTSA	FEPCHE	0.499	1.959	0.558	0.573	0	0.10901027
2	3	14	LVUTSA	LELEYT	0.000	0.000	0.784	0.812	0	0.114611565
2	3	15	LVUTSA	LEKGD	1.949	3.640	0.721	0.615	0	0.95301381
2	3	16	LVUTSA	LEGLHL	1.104	0.425	0.913	0.218	0	0.216295752
2	3	17	LVUTSA	LEGLHO	1.195	0.440	0.915	0.866	0	0.04807395
2	3	18	LVUTSA	LEGLHO	1.092	0.252	0.956	0.267	0	0.217429472
2	3	19	LVUTSA	LEGLFO	1.100	0.269	0.955	0.267	0	0.26442148
2	3	20	LVUTSA	LEGLAT	1.127	0.311	0.953	0.258	0	0.510985575
2	3	21	LVUTSA	LEGLFL	1.066	0.216	0.934	0.230	0	0.02706793
2	3	22	LVUTSA	LEGLTH	1.175	0.389	0.935	0.212	0	0.19882831
2	3	23	LVUTSA	LEGLIT	1.134	0.321	0.952	0.253	0	0.52103460
2	3	24	LVUTSA	TOUFTA	1.110	0.321	0.931	0.210	0	0.31275290
2	3	25	LVUTSA	TOUFTA	0.922	1.020	0.788	0.789	0	0.02615042
2	3	26	LVUTSA	TOUFTO	1.116	0.345	0.861	0.832	0	0.06655711
2	3	27	LVUTSA	LYKIFN	0.000	0.000	0.353	0.554	0	-0.03960353
2	3	28	LVUTSA	LYSTGM	1.815	2.419	0.624	0.493	0	-0.18162550
2	3	29	LVUTSA	LTSWJN	0.000	0.000	0.313	0.637	0	-0.15687418
2	3	30	LVUTSA	LTHFAD	0.000	0.000	0.889	0.819	0	0.111209444

Table A4.6 (continued)

2	3	WAPVDR	VARHNR	0.402	0.443	1.000	1.000	1.000	0	0.8886190	6.18019090
2	3	WAPVDR	FOLPNR	1.004	0.064	0.596	0.991	0.991	0	0.91421232	5.94431061
2	3	WAPVDR	REPENC	1.171	0.195	0.701	0.198	0.198	0	2.32777934	3.61757876
2	3	WAPVDR	LEKGR	0.000	0.000	0.747	0.739	0.739	0	0.31929122	5.86462944
2	3	WAPVDR	CIRKFL	1.046	0.061	0.917	0.841	0.841	0	1.33887940	8.469225134
2	3	WAPVDR	IFKGF	1.076	0.459	0.822	0.817	0.817	0	0.21485704	3.04236667
2	3	WAPVDR	IFKCHU	0.000	0.000	0.532	0.766	0.766	0	0.00336444	1.54519853
2	3	WAPVDR	CIRGCL	1.036	0.067	0.561	0.733	0.733	0	0.54979295	2.73676097
2	3	WAPVDR	IFKQLO	1.108	0.226	0.788	0.678	0.678	0	0.04060113	0.41272612
2	3	WAPVDR	FEPCHE	0.468	1.441	0.502	0.565	0.565	0	0.09806564	3.04755147
2	3	WAPVDR	LEK1XT	0.000	0.000	0.754	0.823	0.823	0	0.31748066	7.41881578
2	3	WAPVDR	LEKQSD	1.715	2.880	0.738	0.651	0.651	0	0.88288432	7.184445655
2	3	WAPVDR	VEGTR	1.014	0.022	0.960	0.924	0.924	0	0.17889873	0.64861641
2	3	WAPVDR	VEGTR	1.158	0.368	0.909	0.885	0.885	0	0.04450902	0.44087660
2	3	WAPVDR	VEGTR	1.007	0.010	0.985	0.972	0.972	0	0.15182890	1.346093518
2	3	WAPVDR	VEGTR	1.002	0.006	0.988	0.979	0.979	0	0.24802291	1.71570380
2	3	WAPVDR	VEGTR	1.006	0.008	0.992	0.982	0.982	0	0.47664590	2.978455429
2	3	WAPVDR	VEGTR	1.003	0.024	0.963	0.944	0.944	0	0.08742495	0.65219173
2	3	WAPVDR	VEGTR	1.016	0.023	0.959	0.921	0.921	0	0.08742495	0.65219173
2	3	WAPVDR	VEGTR	1.006	0.008	0.992	0.962	0.962	0	0.44229851	1.05149457
2	3	WAPVDR	TOUITE	1.021	0.038	0.949	0.917	0.917	0	0.44229851	3.01481471
2	3	WAPVDR	TOUIFA	1.330	2.270	0.772	0.787	0.787	0	0.07611947	0.52299620
2	3	WAPVDR	TOUFR	0.997	0.058	0.897	0.828	0.828	0	0.07401926	0.42517537
2	3	WAPVDR	LTXHNR	0.000	0.000	0.320	0.574	0.574	0	0.009211046	0.02834080
2	3	WAPVDR	LTXHNR	1.659	0.000	0.652	0.489	0.489	0	0.15834751	0.928422719
2	3	WAPVDR	LTXHNR	0.000	0.000	0.197	0.662	0.662	0	0.07521479	0.35077654
2	3	WAPVDR	LTXHNR	1.073	0.087	0.892	0.755	0.755	0	0.00910261	0.412035641
4	4	COLPNR	FOLPNR	0.435	0.465	1.000	1.000	1.000	0	0.93514602	5.80270423
4	4	COLPNR	REPENC	1.157	0.174	0.713	0.192	0.192	0	2.35440282	3.54856026
4	4	COLPNR	LEKGR	0.000	0.000	0.749	0.755	0.755	0	0.37810384	5.76534316
4	4	COLPNR	LEKFL	1.042	0.055	0.917	0.842	0.842	0	1.34458440	8.15513796
4	4	COLPNR	LEKFL	1.142	0.509	0.814	0.805	0.805	0	0.23054225	2.92695604
4	4	COLPNR	LEKGR	0.000	0.000	0.520	0.714	0.714	0	0.07727863	1.49862951
4	4	COLPNR	LEKFL	1.036	0.042	0.863	0.724	0.724	0	0.51442975	2.64354344
4	4	COLPNR	LEKFL	1.095	0.208	0.810	0.718	0.718	0	0.06142537	0.41910156
4	4	COLPNR	FEPCHE	0.413	1.427	0.506	0.613	0.613	0	0.08668467	3.054291829
4	4	COLPNR	LEK1XT	0.000	0.000	0.750	0.823	0.823	0	0.34293409	7.15981809
4	4	COLPNR	LEKQSD	1.703	2.855	0.740	0.662	0.662	0	0.81792497	7.011729245
4	4	COLPNR	LEKFL	1.010	0.018	0.961	0.923	0.923	0	0.18116351	0.93911867
4	4	COLPNR	LEKTR	1.161	0.381	0.905	0.882	0.882	0	0.04587709	0.44637464
4	4	COLPNR	LEKTR	1.009	0.013	0.984	0.973	0.973	0	0.129717738	1.32095091
4	4	COLPNR	LEKTR	1.001	0.005	0.990	0.984	0.984	0	0.25431909	1.61953721
4	4	COLPNR	LEKTR	1.004	0.004	0.996	0.992	0.992	0	0.44660675	2.98839437
4	4	COLPNR	LEKTR	1.006	0.024	0.961	0.941	0.941	0	0.02017915	0.63420414
4	4	COLPNR	VEGTR	1.007	0.017	0.944	0.934	0.934	0	0.14731415	1.02980267
4	4	COLPNR	TOUITE	1.003	0.044	0.935	0.921	0.921	0	0.44256899	2.95239843
4	4	COLPNR	TOUITE	1.023	0.042	0.946	0.913	0.913	0	0.127412473	1.93213650
4	4	COLPNR	TOUITE	1.384	2.451	0.761	0.775	0.775	0	0.073855415	0.44983021
4	4	COLPNR	TOUITE	0.596	0.054	0.903	0.833	0.833	0	0.07582113	0.4476326
4	4	COLPNR	STRKHA	0.000	0.000	0.362	0.555	0.555	0	0.00859837	0.07137919
4	4	COLPNR	LTXHNR	1.677	1.984	0.647	0.476	0.476	0	0.14425280	0.91031045
4	4	COLPNR	LTXHNR	0.000	0.000	0.186	0.675	0.675	0	0.07498565	0.38052343
4	4	COLPNR	WREAO	1.072	0.084	0.892	0.743	0.743	0	0.091332853	0.39622925

2	7	CIRCHL	CIRCHL	0.356	0.411	1.000	1.000	1.000	0	1.84214470	15.193369740
2	7	CIRCHL	LEHGL	0.951	0.440	0.772	0.771	0.771	0	0.33560157	4.53374465
2	7	CIRCHL	LEHCUU	0.000	0.000	0.483	0.768	0.768	0	-0.14634903	2.23915058
2	7	CIRCHL	LEHCUU	1.052	0.123	0.762	0.572	0.572	0	0.83252336	3.51982559
2	7	CIRCHL	LEHGL	1.029	0.246	0.724	0.621	0.621	0	0.08161390	0.52299856
2	7	CIRCHL	LEHGL	0.947	2.015	0.546	0.551	0.551	0	0.28547403	4.62829093
2	7	CIRCHL	LEHXT	0.000	0.000	0.762	0.624	0.624	0	0.39949845	1.70325404
2	7	CIRCHL	LEHGL	1.920	3.476	0.680	0.536	0.536	0	1.29403501	9.61216616
2	7	CIRCHL	LEHGL	1.043	0.064	0.902	0.813	0.813	0	0.24350426	1.34997783
2	7	CIRCHL	LEHGL	1.287	0.578	0.854	0.743	0.743	0	0.07154233	0.64924849
2	7	CIRCHL	LEHGL	1.024	0.051	0.909	0.844	0.844	0	0.28052991	1.89323523
2	7	CIRCHL	LEHGL	1.019	0.043	0.922	0.865	0.865	0	0.73532356	7.42456659
2	7	CIRCHL	LEHGL	1.046	0.056	0.916	0.842	0.842	0	0.64813853	4.11144479
2	7	CIRCHL	LEHGL	1.014	0.064	0.892	0.829	0.829	0	0.12730741	0.91951662
2	7	CIRCHL	LEHGL	1.084	0.105	0.904	0.796	0.796	0	0.25271635	1.64984962
2	7	CIRCHL	LEHGL	1.048	0.064	0.913	0.833	0.833	0	0.66359749	4.156639560
2	7	CIRCHL	LEHGL	1.079	0.109	0.881	0.783	0.783	0	0.46552975	2.74059493
2	7	CIRCHL	LEHGL	1.074	2.121	0.738	0.738	0.738	0	0.04970313	0.77529324
2	7	CIRCHL	LEHGL	0.974	0.115	0.836	0.751	0.751	0	0.10412715	0.67974601
2	7	CIRCHL	LEHGL	0.000	0.000	0.272	0.539	0.539	0	-0.01635144	0.14322577
2	7	CIRCHL	LEHGL	1.582	1.790	0.603	0.448	0.448	0	0.21745654	1.38257104
2	7	CIRCHL	LEHGL	0.000	0.000	0.181	0.591	0.591	0	-0.16718464	0.55382701
2	7	CIRCHL	LEHGL	1.072	0.104	0.827	0.664	0.664	0	0.12181554	0.59773521
2	8	LEHGL	LEHGL	0.110	0.251	1.000	1.000	1.000	0	0.04814446	2.224495289
2	8	LEHGL	LEHGL	0.000	0.000	0.607	0.678	0.678	0	-0.03725312	0.83526147
2	8	LEHGL	LEHGL	1.164	0.689	0.636	0.568	0.568	0	0.12718581	1.254427694
2	8	LEHGL	LEHGL	1.648	1.471	0.703	0.541	0.541	0	0.024274290	0.26671826
2	8	LEHGL	LEHGL	1.477	3.289	0.358	0.492	0.492	0	-0.01563706	1.56058635
2	8	LEHGL	LEHGL	0.000	0.000	0.612	0.683	0.683	0	-0.05467459	3.75986743
2	8	LEHGL	LEHGL	1.636	2.491	0.629	0.423	0.423	0	0.21208371	4.17576179
2	8	LEHGL	LEHGL	1.050	0.552	0.741	0.723	0.723	0	0.05106837	0.44221931
2	8	LEHGL	LEHGL	0.865	0.559	0.752	0.734	0.734	0	0.09943516	0.23447202
2	8	LEHGL	LEHGL	1.114	0.446	0.840	0.823	0.823	0	0.05875683	0.419872010
2	8	LEHGL	LEHGL	1.034	0.437	0.815	0.817	0.817	0	0.07026950	0.84429540
2	8	LEHGL	LEHGL	1.096	0.476	0.821	0.809	0.809	0	0.13144348	1.44734956
2	8	LEHGL	LEHGL	0.960	0.416	0.803	0.842	0.842	0	0.02317861	0.31824364
2	8	LEHGL	LEHGL	0.997	0.487	0.759	0.754	0.754	0	0.04442558	0.54484077
2	8	LEHGL	LEHGL	1.122	0.508	0.810	0.786	0.786	0	0.13652151	1.45048040
2	8	LEHGL	LEHGL	0.850	0.492	0.786	0.864	0.864	0	0.041429567	1.04651668
2	8	LEHGL	LEHGL	1.501	1.980	0.584	0.525	0.525	0	0.00374459	0.24214974
2	8	LEHGL	LEHGL	1.591	0.914	0.805	0.763	0.763	0	0.02858541	0.22146117
2	8	LEHGL	LEHGL	0.000	0.000	0.332	0.391	0.391	0	-0.00204955	0.04252425
2	8	LEHGL	LEHGL	2.545	4.871	0.578	0.393	0.393	0	0.04728199	0.47251013
2	8	LEHGL	LEHGL	0.000	0.000	0.250	0.511	0.511	0	-0.03845881	0.23958517
2	8	LEHGL	LEHGL	1.205	0.637	0.798	0.765	0.765	0	0.02771416	0.23956669

Table A4.6 (continued)

2	9	10	IFNCHU	LFNCHU	0.275	0.031	1.000	1.060	0	-0.063926449	0.80113650
2	9	9	IFNCHU	CIRFL	0.000	0.000	0.329	0.475	0	-0.017744224	0.54779077
2	9	11	IFNCHU	LEKLU	0.000	0.000	0.415	0.455	0	-0.002276352	0.09292412
2	9	12	IFNCHU	TEPCHE	0.000	0.000	0.289	0.457	0	-0.09954345	0.82771505
2	9	13	IFNCHU	LEWXT	2.557	21.267	0.557	0.642	0	-0.13241272	2.07442179
2	9	14	IFNCHU	LEKSD	0.000	0.000	0.492	0.592	0	-0.14264350	2.18266829
2	9	15	IFNCHU	LETHL	0.000	0.000	0.476	0.752	0	-0.01350551	0.24516284
2	5	15	IFNCHU	LEGLD	0.000	0.000	0.443	0.574	0	-0.00668069	0.11138656
2	5	17	IFNCHU	VEGTR	0.000	0.000	0.534	0.735	0	-0.01662292	0.33889252
2	9	18	IFNCHU	VEGTR	0.000	0.000	0.540	0.744	0	-0.02281486	0.43879262
2	9	19	IFNCHU	VECTPT	0.000	0.000	0.522	0.745	0	-0.03556022	0.73756266
2	9	20	IFNCHU	VEGTR	0.000	0.000	0.547	0.738	0	-0.00871102	0.16964750
2	9	21	IFNCHU	VEGTR	0.000	0.000	0.485	0.729	0	-0.01677093	0.26540976
2	9	22	IFNCHU	LEGLT	0.000	0.000	0.514	0.735	0	-0.01295156	0.24040638
2	9	23	IFNCHU	TOATLE	0.000	0.000	0.532	0.733	0	-0.03147421	0.52630450
2	9	24	IFNCHU	TOATFA	0.000	0.000	0.431	0.495	0	-0.006642243	0.11613998
2	9	25	IFNCHU	TOATRO	0.000	0.000	0.506	0.695	0	-0.00441563	0.11464182
2	9	26	IFNCHU	TVKIDM	0.065	0.378	0.305	0.260	0	-0.00022241	0.01934115
2	9	27	IFNCHU	VTSGM	0.000	0.000	0.465	0.507	0	-0.01290273	0.32037145
2	9	28	IFNCHU	VTSTIN	6.524	0.829	0.255	0.303	0	-0.009673345	0.07882702
2	9	29	IFNCHU	VTLEAD	0.000	0.000	0.503	0.738	0	-0.00534584	0.12142462
2	10	10	CIRCEL	CIRCEL	0.451	0.426	1.000	1.000	0	0.34008709	1.92346691
2	10	11	CIRCEL	LEKLU	1.166	0.323	0.676	0.482	0	0.03945457	0.17933947
2	10	12	CIRCEL	TEPCHE	0.329	1.271	0.328	0.388	0	0.04520625	1.13586232
2	10	13	CIRCEL	LEWXT	0.000	0.000	0.662	0.590	0	0.35792223	3.20375532
2	10	14	CIRCEL	LEKSD	1.453	2.322	0.624	0.557	0	0.42064690	3.44197729
2	10	15	CIRCEL	VEGTR	1.086	0.099	0.852	0.604	0	0.11787206	0.40627013
2	10	16	CIRCEL	LEGLD	1.149	0.423	0.791	0.733	0	0.02735435	0.21978408
2	10	17	CIRCEL	VEGTR	1.051	0.076	0.863	0.736	0	0.11327469	0.61030624
2	10	18	CIRCEL	VEGTR	1.079	0.097	0.861	0.704	0	0.14528281	0.75374443
2	10	19	CIRCEL	VEGTR	1.042	0.078	0.842	0.730	0	0.27952744	1.34636254
2	10	20	CIRCEL	LEGLT	1.126	0.159	0.848	0.580	0	0.04074704	0.25842281
2	10	21	CIRCEL	VEGTR	1.034	0.089	0.810	0.645	0	0.10365870	0.45076411
2	10	22	CIRCEL	LEGLT	1.032	0.049	0.855	0.727	0	0.24076509	1.35330463
2	10	23	CIRCEL	TOATFA	1.081	0.415	0.685	0.748	0	0.17423405	0.94015391
2	10	24	CIRCEL	TOATRO	2.091	2.649	0.650	0.491	0	0.07513014	0.26301736
2	10	25	CIRCEL	TOATFA	0.995	0.441	0.730	0.525	0	0.06566764	0.17601727
2	10	26	CIRCEL	VTSTIN	0.000	0.000	0.510	0.334	0	-0.00217253	0.03272027
2	10	27	CIRCEL	VTSGM	1.420	1.907	0.546	0.351	0	0.02565320	0.41679738
2	10	28	CIRCEL	VTSTIN	0.000	0.000	0.546	0.351	0	-0.03858617	0.20280506
2	10	29	CIRCEL	VTLEAD	1.093	0.410	0.768	0.563	0	-0.05610704	0.19079646

Table A4.6 (continued)

2	11	LENGIO	LENGIO	0.209	0.314	1.000	1.000	1.000	0	0.00335396	0.05633015
2	11	LENGIO	NEPCHE	0.283	2.167	0.386	0.543	0.480	0	-0.01265275	0.25612634
2	11	LENGIO	LENEXT	0.000	0.000	0.000	0.000	0.000	0	0.006351003	0.52534466
2	11	LENGIO	LEHSGD	1.575	2.434	0.681	0.597	0.617	0	0.00533726	0.61794506
2	11	LENGIO	VEGTAL	1.057	0.231	0.754	0.655	0.647	0	0.01445346	0.06652421
2	11	LENGIO	VEGTLO	1.076	0.397	0.717	0.647	0.647	0	0.00255055	0.03258039
2	11	LENGIO	VEGTHO	1.154	0.263	0.757	0.575	0.575	0	0.01351463	0.03233139
2	11	LENGIO	VEGTFO	1.066	0.216	0.739	0.585	0.585	0	0.01665865	0.11759136
2	11	LENGIO	VEGTFT	1.083	0.201	0.814	0.728	0.728	0	0.02916159	0.21273427
2	11	LENGIO	VEGTFL	1.101	0.213	0.760	0.445	0.445	0	0.00590815	0.07469745
2	11	LENGIO	VEGTCH	1.014	0.226	0.753	0.668	0.668	0	0.01011229	0.02526697
2	11	LENGIO	VEGILT	1.106	0.217	0.801	0.595	0.595	0	0.02922744	0.21089434
2	11	LENGIO	TOWTLE	1.047	0.247	0.724	0.619	0.619	0	0.01682485	0.11152135
2	11	LENGIO	TOWTFA	1.349	2.466	0.549	0.485	0.485	0	0.01285300	0.01172118
2	11	LENGIO	TOWT20	1.120	0.374	0.786	0.515	0.515	0	0.00566343	0.01138255
2	11	LENGIO	TXIPLN	0.000	0.000	0.320	0.394	0.394	0	-0.00079056	0.00693167
2	11	LENGIO	LYSTOW	2.429	4.029	0.479	0.262	0.262	0	0.01438046	0.01667797
2	11	LENGIO	LYSTWH	0.000	0.000	0.147	0.482	0.482	0	-0.01558747	0.02789876
2	11	LENGIO	LYTHAD	1.216	0.329	0.747	0.585	0.585	0	0.01420732	0.02992411
2	12	NEPCHE	NEPCHE	0.039	0.208	1.000	1.000	1.000	0	0.04292964	4.85534605
2	12	NEPCHE	LENEXT	0.000	0.000	0.446	0.480	0.480	0	-0.04010625	3.620271409
2	12	NEPCHE	LEHSGD	0.804	2.441	0.516	0.502	0.502	0	0.008829905	4.74458053
2	12	NEPCHE	VEGTAL	0.378	1.649	0.508	0.517	0.517	0	0.02387180	0.57053244
2	12	NEPCHE	VEGTLO	1.227	2.543	0.428	0.442	0.442	0	0.01117762	0.211127018
2	12	NEPCHE	VEGTHO	0.167	1.850	0.493	0.619	0.619	0	0.007468725	0.20588013
2	12	NEPCHE	VEGTFO	0.297	1.706	0.505	0.510	0.510	0	0.01754607	0.08294174
2	12	NEPCHE	VEGTFT	0.383	1.655	0.504	0.601	0.601	0	0.03917034	1.52026692
2	12	NEPCHE	VEGTFL	0.021	2.112	0.542	0.620	0.620	0	-0.00042292	0.32531144
2	12	NEPCHE	VEGTCH	0.630	1.504	0.632	0.730	0.730	0	0.02414542	0.62350061
2	12	NEPCHE	VEGILT	0.421	1.641	0.509	0.599	0.599	0	0.016354732	1.55213415
2	12	NEPCHE	TOWTLE	0.595	1.683	0.516	0.553	0.553	0	0.05054931	1.05509369
2	12	NEPCHE	TOWTFA	0.545	3.259	0.402	0.442	0.442	0	-0.01346525	0.25727005
2	12	NEPCHE	TOWT20	0.065	1.906	0.441	0.563	0.563	0	-0.00113937	0.22059272
2	12	NEPCHE	TXIPLN	0.000	0.000	0.095	0.353	0.353	0	-0.01641156	0.04850024
2	12	NEPCHE	LYSTOW	0.548	2.867	0.279	0.328	0.328	0	-0.01252728	0.42081574
2	12	NEPCHE	LYSTWH	0.000	0.000	0.172	0.272	0.272	0	-0.01862919	0.15388093
2	12	NEPCHE	LYTHAD	0.384	1.718	0.383	0.465	0.465	0	0.00743291	0.119220352
2	13	LENEXT	LENEXT	0.017	0.174	1.000	1.000	1.000	0	-0.05831291	14.02827422
2	13	LENEXT	LEHSGD	0.000	0.000	0.583	0.518	0.518	0	-0.02675891	9.27503223
2	13	LENEXT	VEGTAL	0.000	0.000	0.767	0.814	0.814	0	0.08862195	1.22560355
2	13	LENEXT	VEGTLO	0.000	0.000	0.747	0.759	0.759	0	0.01737993	0.352908733
2	13	LENEXT	VEGTHO	0.000	0.000	0.765	0.833	0.833	0	0.06192581	1.64262356
2	13	LENEXT	VEGTFO	0.000	0.000	0.765	0.833	0.833	0	0.10965587	2.14522808
2	13	LENEXT	VEGTFT	0.000	0.000	0.762	0.831	0.831	0	0.15300813	3.65310500
2	13	LENEXT	VEGTFL	0.000	0.000	0.776	0.769	0.769	0	0.04088272	0.72927358
2	13	LENEXT	VEGTCH	0.000	0.000	0.733	0.777	0.777	0	0.04450314	1.29438152
2	13	LENEXT	VEGILT	0.000	0.000	0.739	0.800	0.800	0	0.11562326	3.65011607
2	13	LENEXT	TOWTLE	0.000	0.000	0.779	0.775	0.775	0	0.11793799	2.52277502
2	13	LENEXT	TOWTFA	0.000	0.000	0.712	0.515	0.515	0	0.002697874	0.66479049
2	13	LENEXT	TOWT20	0.000	0.000	0.653	0.464	0.464	0	0.01274513	0.55272108
2	13	LENEXT	TXIPLN	2.506	20.501	0.359	0.464	0.464	0	-0.00973050	0.13174001
2	13	LENEXT	LYSTOW	0.000	0.000	0.502	0.502	0.502	0	0.01621500	1.35049005
2	13	LENEXT	LYSTWH	3.168	25.292	0.287	0.421	0.421	0	-0.04551457	0.437273366
2	13	LENEXT	LYTHAD	0.000	0.000	0.645	0.647	0.647	0	0.04664252	0.49224633

Table A4.6 (continued)

2	14	14	IEGSD	IEGSD	0.052	0.215	1.000	1.000	1.000	0	0.26647835	18.27816605
2	14	15	IEGSD	IEGHL	1.632	2.716	0.695	0.628	0.601	0	0.15085382	1.14221543
2	14	16	IEGSD	IEGTL	2.100	4.165	0.678	0.553	0.06754026	0	0.07440268	0.52201857
2	14	17	IEGSD	IEGTR	1.636	2.647	0.727	0.572	0.14408470	0	0.14408470	1.65041556
2	14	18	IEGSD	IEGTT	1.580	2.516	0.730	0.665	0.26602737	0	0.26602737	2.06626978
2	14	19	IEGSD	IEGTT	1.670	2.748	0.750	0.676	0.34153010	0	0.34153010	3.61049103
2	14	20	IEGSD	IEGTT	1.444	2.443	0.721	0.555	0.06614783	0	0.06614783	0.72475065
2	14	21	IEGSD	IEGTH	1.774	3.052	0.722	0.619	0.15142505	0	0.15142505	1.25228096
2	14	22	IEGSD	IEGTH	1.755	2.992	0.731	0.654	0.46642008	0	0.46642008	3.42687899
2	14	23	IEGSD	TOULE	1.503	2.273	0.724	0.660	0.26645306	0	0.26645306	2.51429341
2	14	24	IEGSD	TOULE	1.610	4.067	0.413	0.553	0.023502225	0	0.023502225	0.47665977
2	14	25	IEGSD	TOUFA	1.811	3.165	0.706	0.582	0.07080794	0	0.07080794	0.53517576
2	14	26	IEGSD	TRIM	0.000	0.000	0.187	0.317	-0.01215301	0	-0.01215301	0.69724693
2	14	27	IEGSD	TRIM	3.037	8.400	0.514	0.347	0.14526814	0	0.14526814	1.20072586
2	14	28	IEGSD	TRIM	0.000	0.000	0.135	0.388	-0.05667642	0	-0.05667642	0.41984204
2	14	29	IEGSD	TRHEAD	1.729	2.962	0.688	0.520	0.07556558	0	0.07556558	0.54184686
2	15	15	IEGHL	IEGTL	0.500	0.510	1.000	1.000	1.000	0	0.03464400	0.172297544
2	15	16	IEGHL	IEGTL	1.236	0.515	0.850	0.801	0.00940241	0	0.00940241	0.07020591
2	15	17	IEGHL	IEGTR	1.018	0.633	0.944	0.261	0.03827472	0	0.03827472	0.21364003
2	15	18	IEGHL	IEGTT	1.025	0.631	0.953	0.223	0.05010261	0	0.05010261	0.27389943
2	15	19	IEGHL	IEGTT	1.018	0.627	0.953	0.209	0.08722275	0	0.08722275	0.44735498
2	15	20	IEGHL	IEGTT	1.049	0.665	0.941	0.268	0.01805247	0	0.01805247	0.16446962
2	15	21	IEGHL	IEGTH	1.026	0.636	0.936	0.271	0.03281456	0	0.03281456	0.17433661
2	15	22	IEGHL	IEGTH	1.011	0.623	0.955	0.220	0.08773550	0	0.08773550	0.48040757
2	15	23	IEGHL	TOULE	1.070	0.625	0.930	0.260	0.05192445	0	0.05192445	0.31994012
2	15	24	IEGHL	TOUFA	1.632	3.170	0.781	0.280	0.06874757	0	0.06874757	0.08671404
2	15	25	IEGHL	TOUFA	0.929	0.131	0.869	0.623	0.01364118	0	0.01364118	0.07001119
2	15	26	IEGHL	TRIM	0.000	0.000	0.503	0.607	-0.00156044	0	-0.00156044	0.04674509
2	15	27	IEGHL	TRIM	1.525	1.697	0.626	0.485	0.02875088	0	0.02875088	0.15730288
2	15	28	IEGHL	TRIM	0.000	0.000	0.118	0.574	-0.01125173	0	-0.01125173	0.05339327
2	15	29	IEGHL	TRHEAD	1.058	0.668	0.874	0.700	0.01733374	0	0.01733374	0.04577382
2	16	16	IEGTL	IEGTL	0.138	0.249	1.000	1.000	1.000	0	0.00166523	0.04314907
2	16	17	IEGTL	IEGTR	1.110	0.298	0.904	0.887	0.00916172	0	0.00916172	0.16285422
2	16	18	IEGTL	IEGTT	1.133	0.335	0.900	0.879	0.01215952	0	0.01215952	0.12916287
2	16	19	IEGTL	IEGTT	1.151	0.358	0.906	0.884	0.02193302	0	0.02193302	0.22475453
2	16	20	IEGTL	IEGTH	1.136	0.343	0.856	0.807	0.00442272	0	0.00442272	0.04740785
2	16	21	IEGTL	IEGTH	1.236	0.423	0.888	0.831	0.00888290	0	0.00888290	0.07967680
2	16	22	IEGTL	IEGTT	1.147	0.349	0.914	0.824	0.02185263	0	0.02185263	0.07967680
2	16	23	IEGTL	TOULE	1.176	0.386	0.879	0.824	0.01331315	0	0.01331315	0.23173406
2	16	24	IEGTL	TOUFA	0.936	1.076	0.772	0.770	0.00110174	0	0.00110174	0.04337313
2	16	25	IEGTL	TOUFA	1.089	0.349	0.816	0.783	0.0030512	0	0.0030512	0.03297275
2	16	26	IEGTL	TRIM	0.000	0.000	0.525	0.528	-0.00005547	0	-0.00005547	0.00790364
2	16	27	IEGTL	TRIM	1.837	2.476	0.560	0.418	0.006760564	0	0.006760564	0.04835739
2	16	28	IEGTL	TRIM	0.000	0.000	0.514	0.638	-0.00509254	0	-0.00509254	0.03476554
2	16	29	IEGTL	TRHEAD	1.256	0.555	0.791	0.697	0.00452019	0	0.00452019	0.03100493
2	17	17	IEGTR	IEGTR	0.374	0.423	1.000	1.000	1.000	0	0.04079392	0.31444375
2	17	18	IEGTR	IEGTR	1.005	0.009	0.963	0.370	0.05231578	0	0.05231578	0.38420402
2	17	19	IEGTR	IEGTR	1.006	0.008	0.990	0.360	0.023522252	0	0.023522252	0.07016010
2	17	20	IEGTR	IEGTR	1.007	0.024	0.960	0.236	0.014881937	0	0.014881937	0.14685198
2	17	21	IEGTR	IEGTR	0.899	0.030	0.949	0.218	0.01468727	0	0.01468727	0.23546275
2	17	22	IEGTR	IEGTT	1.015	0.019	0.977	0.255	0.00559552	0	0.00559552	0.64872767
2	17	23	IEGTR	IEGTT	1.003	0.035	0.948	0.222	0.053132227	0	0.053132227	0.45316750
2	17	24	IEGTR	TOUFA	1.310	2.491	0.772	0.781	0.06761877	0	0.06761877	0.11748428
2	17	25	IEGTR	TOUFA	1.016	0.048	0.907	0.355	0.01616310	0	0.01616310	0.02678574
2	17	26	IEGTR	TRIM	0.000	0.000	0.551	0.579	-0.00182841	0	-0.00182841	0.028282152
2	17	27	IEGTR	TRIM	1.692	2.007	0.668	0.505	0.03461603	0	0.03461603	0.2225015
2	17	28	IEGTR	TRIM	0.000	0.000	0.240	0.712	-0.017288338	0	-0.017288338	0.03688243
2	17	29	IEGTR	TRHEAD	1.111	0.000	0.882	0.700	0.01733374	0	0.01733374	0.04577382

Table A4.6 (continued)

2	16	18	WEFTFO	WEFTFO	0.394	0.437	1.000	1.000	1.000	0	0.04828924	0.42415822
2	18	19	WEFTFO	WEFTFO	1.001	0.005	0.991	0.984	0.984	0	0.12025657	0.84229296
2	16	20	WEFTFO	WEFTFO	1.016	0.025	0.974	0.952	0.952	0	0.02473419	0.18703024
2	16	21	WEFTFO	WEFTFO	0.995	0.023	0.966	0.947	0.947	0	0.044291038	0.30328560
2	16	22	WEFTFO	WEFTFO	1.002	0.009	0.982	0.962	0.962	0	0.12229142	0.84607008
2	16	23	WEFTFO	WEFTFO	1.031	0.045	0.953	0.916	0.916	0	0.07504711	0.54656998
2	16	24	WEFTFO	WEFTFO	1.476	2.447	0.789	0.782	0.782	0	0.01114475	0.14622586
2	18	25	WEFTFO	WEFTFO	0.959	0.000	0.904	0.867	0.867	0	0.01985552	0.12400478
2	18	26	WEFTFO	WEFTFO	0.000	0.000	0.323	0.555	0.555	0	-0.00230252	0.02712316
2	18	27	WEFTFO	WEFTFO	1.633	1.887	0.634	0.472	0.472	0	-0.04341962	0.24220841
2	18	28	WEFTFO	WEFTFO	0.000	0.000	0.221	0.677	0.677	0	-0.02073922	0.11428409
2	16	29	WEFTFO	WEFTFO	1.079	0.523	0.850	0.751	0.751	0	0.024294504	0.11602155
2	19	19	WEFTFO	WEFTFO	0.401	0.442	1.000	1.000	1.000	0	0.21118775	1.42723641
2	19	20	WEFTFO	WEFTFO	1.016	0.026	0.959	0.933	0.933	0	0.042296140	0.31729295
2	19	21	WEFTFO	WEFTFO	1.007	0.016	0.963	0.933	0.933	0	0.079664303	0.51903675
2	19	22	WEFTFO	WEFTFO	1.010	0.012	0.967	0.971	0.971	0	0.21684662	1.427135234
2	19	23	WEFTFO	WEFTFO	1.026	0.044	0.941	0.921	0.921	0	0.13072483	0.95569664
2	19	24	WEFTFO	WEFTFO	1.389	2.449	0.752	0.751	0.751	0	0.01841766	0.24558066
2	19	25	WEFTFO	WEFTFO	1.000	0.054	0.901	0.833	0.833	0	0.01642296	0.20891745
2	19	26	WEFTFO	WEFTFO	0.000	0.000	0.315	0.558	0.558	0	-0.0421713	0.04683258
2	19	27	WEFTFO	WEFTFO	1.662	1.920	0.647	0.478	0.478	0	0.07837253	0.44054651
2	19	28	WEFTFO	WEFTFO	0.000	0.000	0.200	0.566	0.566	0	-0.03686823	0.12224115
2	19	29	WEFTFO	WEFTFO	1.082	0.026	0.886	0.739	0.739	0	0.043822257	0.12852268
2	20	20	WEFTFO	WEFTFO	0.333	0.326	1.000	1.000	1.000	0	0.02854605	0.07696073
2	20	21	WEFTFO	WEFTFO	0.988	0.045	0.946	0.925	0.925	0	0.01570162	0.11701350
2	20	22	WEFTFO	WEFTFO	1.004	0.029	0.953	0.926	0.926	0	0.04332228	0.32141813
2	20	23	WEFTFO	WEFTFO	1.051	0.070	0.933	0.877	0.877	0	0.01627246	0.21573279
2	20	24	WEFTFO	WEFTFO	1.408	3.000	0.788	0.743	0.743	0	0.04283229	0.05653411
2	20	25	WEFTFO	WEFTFO	0.936	0.135	0.879	0.851	0.851	0	0.00641544	0.04783013
2	20	26	WEFTFO	WEFTFO	0.000	0.000	0.340	0.538	0.538	0	-0.00082233	0.01062405
2	20	27	WEFTFO	WEFTFO	1.624	1.921	0.590	0.420	0.420	0	0.01552923	0.09550471
2	20	28	WEFTFO	WEFTFO	0.000	0.000	0.255	0.668	0.668	0	-0.00759527	0.04581252
2	20	29	WEFTFO	WEFTFO	1.089	0.115	0.875	0.746	0.746	0	0.00886951	0.04518372

Table A4.6 (continued)

2	21	21	WEGTCH	VEGTT	0.403	0.443	1.000	1.000	1.000	0	0.02954593	0.20474468
2	21	22	WEGTCH	VEGTT	1.013	0.022	0.959	0.922	0.922	0	0.00121045	0.52425537
2	21	23	WEGTCH	VEGTT	1.041	0.059	0.934	0.861	0.861	0	0.04957466	0.35332043
2	21	24	WEGTCH	VEGTT	1.591	2.470	0.740	0.735	0.735	0	0.00468815	0.009938221
2	21	25	WEGTCH	VEGTT	0.938	0.124	0.879	0.828	0.828	0	0.01269424	0.07734193
2	21	26	WEGTCH	VEGTT	0.000	0.000	0.270	0.548	0.548	0	-0.00193418	0.01671858
2	21	27	WEGTCH	VEGTT	1.581	1.725	0.606	0.645	0.645	0	0.02752220	0.15034507
2	21	28	WEGTCH	VEGTT	0.000	0.000	0.198	0.550	0.550	0	-0.01322784	0.04993066
2	21	29	WEGTCH	VEGTT	1.056	0.077	0.856	0.704	0.704	0	0.01598505	0.07082229
2	22	22	WEGTT	VEGTT	0.398	0.440	1.000	1.000	1.000	0	0.24757118	1.53503881
2	22	23	WEGTT	VEGTT	1.016	0.038	0.944	0.911	0.911	0	0.17128478	0.92235753
2	22	24	WEGTT	VEGTT	1.268	2.144	0.767	0.785	0.785	0	0.01730755	0.25988165
2	22	25	WEGTT	VEGTT	1.008	0.051	0.900	0.825	0.825	0	0.03701554	0.21168575
2	22	26	WEGTT	VEGTT	0.000	0.000	0.310	0.556	0.556	0	-0.00440003	0.04748827
2	22	27	WEGTT	VEGTT	1.705	2.037	0.643	0.658	0.658	0	0.06042071	0.44225085
2	22	28	WEGTT	VEGTT	0.000	0.000	0.203	0.572	0.572	0	-0.03722846	0.130812843
2	22	29	WEGTT	VEGTT	1.081	0.096	0.885	0.735	0.735	0	0.04439256	0.20126288
2	23	23	TOUPE	TOUPE	0.312	0.382	1.000	1.000	1.000	0	0.07472238	0.75467726
2	23	24	TOUPE	TOUPE	1.603	2.981	0.769	0.718	0.718	0	0.01278587	0.17164336
2	23	25	TOUPE	TOUPE	0.931	0.164	0.840	0.797	0.797	0	0.02050781	0.14123414
2	23	26	TOUPE	VEGTT	0.000	0.000	0.320	0.546	0.546	0	-0.00521590	0.03334927
2	23	27	TOUPE	VEGTT	1.481	1.573	0.618	0.690	0.690	0	0.04152954	0.32843515
2	23	28	TOUPE	VEGTT	0.000	0.000	0.275	0.576	0.576	0	-0.02337292	0.14691237
2	23	29	TOUPE	VEGTT	1.082	0.115	0.860	0.738	0.738	0	0.02639253	0.15939567
2	24	24	TOUPE	TOUPE	0.044	0.210	1.000	1.000	1.000	0	0.00082961	0.073135534
2	24	25	TOUPE	TOUPE	0.945	1.610	0.672	0.731	0.731	0	0.00214305	0.01838727
2	24	26	TOUPE	VEGTT	0.000	0.000	0.463	0.583	0.583	0	-0.00000877	0.01193156
2	24	27	TOUPE	VEGTT	1.477	3.056	0.466	0.408	0.408	0	0.00430753	0.08230325
2	24	28	TOUPE	VEGTT	0.000	0.000	0.391	0.595	0.595	0	-0.00467656	0.04428677
2	24	29	TOUPE	VEGTT	1.610	3.193	0.684	0.636	0.636	0	0.00410431	0.03589615

Table A4.6 (continued)

2	25	25	TOUTRO	TOUTRO	0.422	0.456	1.000	1.000	0.000	0.00620201	0.56018297
2	25	26	TOUTRO	UTRIN	0.000	0.000	0.316	0.316	0	-0.00069521	0.00723804
2	25	27	TOUTRO	UTSTOM	2.012	2.754	0.587	0.316	0	0.00466552	0.05719268
2	25	28	TOUTRO	UTSMIN	0.000	0.000	0.131	0.513	0	-0.00632728	0.02851553
2	25	29	TOUTRO	UTHEAD	1.068	0.031	0.823	0.625	0	0.00740925	0.02857243
2	26	26	UTKIDN	UTKIDN	0.185	0.679	1.000	1.000	0	-0.00025846	0.00635822
2	26	27	UTKIDN	UTSTOM	0.000	0.000	0.240	0.291	0	-0.00085113	0.00521285
2	26	28	UTKIDN	UTSMIN	0.793	1.641	0.466	0.515	0	-0.00076327	0.01208172
2	26	29	UTKIDN	UTHEAD	0.000	0.000	0.257	0.460	0	-0.00050265	0.006665237
2	27	27	UTSTOM	UTSTOM	0.075	0.239	1.000	1.000	0	0.01025357	0.00605645
2	27	28	UTSTOM	UTSMIN	0.000	0.000	0.001	0.235	0	-0.01276765	0.05856567
2	27	29	UTSTOM	UTHEAD	1.900	2.495	0.566	0.263	0	0.00673284	0.05257972
2	28	28	UTSMIN	UTSMIN	0.161	0.061	1.000	1.000	0	-0.00328352	0.00739830
2	28	29	UTSMIN	UTHEAD	0.000	0.000	0.215	0.743	0	-0.00662602	0.03521338
2	29	29	UTHEAD	UTHEAD	0.473	0.431	1.000	1.000	0	0.00775427	0.04235465