GENETIC AND PHENOTYPIC PARAMETERS FOR GROWTH TRAITS OF DORPER AND DORPER X RED MAASAI SHEEP

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This thesis is dedicated to my beloved parents.

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ABSTRACT

Data on 3343 lambs collected over a 10 year period, 1978 to 1987 inclusive, on Dorper and Dorper x Red Maasai crosses at Ol'Magogo was used in this study. Lamb traits studied were weights from birth to yearling and growth rates between adjacent stages of growth.

The respective average weights and standard deviations in kilograms were : Birth weight (BIRTHW), 4.02 and .73; adjusted 90 day weaning weight (ADJWWT), 19.06 and 4.33; adjusted six months weight (ADJSMW), 24.72 and 4.88; adjusted nine months weight (ADJNWW), 29.89 and 5.01; adjusted twelve months weight (ADJTMW), 37.88 and 5.60; and the average rates of growth and their standard deviations in kilograms were: preweaning growth rate (GRATE1), .17 and .04; rate of growth weaning to six months (GRATE2), .06 and .04; six to nine months (GRATE3), .05 and .04; nine to twelve months (GRATE4), 0.09 and .05; and birth to yearling (OVRGRT), .09 and 0.02.

A paternal half-sib analysis using a model in which sires were cross-classified with fixed effects gave heritability estimates of .18±.07, .15±.07, 0.31±.09, .52±.12, .47±.11, .11±.06, .25±.08, .06±.13, 0.51±.12 and .45±.11 for BIRTHW, ADJWWT, ADJSMW, ADJNMW, ADJTMW, GRATE1, GRATE2, GRATE3, GRATE4 and OVRGRT, respectively. Post-weaning heritability estimates were generally higher than those for preweaning suggesting a lower direct-genetic influence early in life. All the repeatability estimates were high (.55 for birth weight, .57 for weaning weight and 0.56 for preweaning growth rate). This indicates that preliminary selection of replacement ewes could be conducted for these traits in the preweaning period on the basis of initial lamb performance with a considerably high accuracy, since repeatability estimates are favourable. Genetic and phenotypic correlations estimated between weights were mainly positive (.21 to .90 and .18 to .74, respectively). There were generally high genetic correlations between adjacent weights, between weights and rates of growth, and among growth rates themselves. Selection for postweaning gain would be expected to yield a greater response than selection for preweaning gain.

All the environmental factors considered in this study (sex, type of birth, dam breed, season of birth, period of birth and parity) were found to influence growth to varying degrees from birth to one year of age. Type of birth effect was highly significant at practically all stages of growth. Dam breed effect on growth merits special mention in that lambs born to Dorper x Red Maasai ewes were superior in performance to their pure Dorper counterparts at all stages of growth. However, its effect was significant only at six months, yearling and GRATE2. Sex of the lamb was highly significant at all stages except GRATE2. Season of birth effect was significant for all traits except birth weight and GRATE2, whereas period of birth effect was highly significant at all stages except yearling weight. The effect of parity was confined to preweaning traits only.

1.0 INTRODUCTION

World wide sheep and goat numbers have been increasing steadily over the past twenty years unlike most other livestock species used by man (Jasiorowski, 1986). Sheep numbers are now in excess of one billion and goat numbers are steadily approaching half that level. Of particular significance is the fact that sheep and goat numbers are increasing much more rapidly in the developing countries than in the more developed regions. This may well reflect the particular ability of small ruminants to survive and produce on low cost feed and their adaptability to difficult, and in particular arid, environments. Perhaps more than anything else it reflects their suitability to the developing countries that so badly need extra food and additional income.

Sheep have the ability to forage and survive in many areas where cattle would perform very poorly. They have a superior water and nitrogen economy (Coop and Devendra, 1982). The agility of sheep in mountainous terrains is noteworthy. They are able to supply meat required in small amounts within small communities. Sheep can easily be managed by unpaid family labour (women and children) and occupy little housing space. Their fertility coupled with short generation interval are factors of economic importance (Coop and Devendra, 1982).

In Kenya, the sheep population is composed of exotic and indigenous breeds and crosses between the two. Useful products from these sheep include, among others, mutton, milk, wool, and skins.

The Dorper breed was developed in South Africa around 1942 mainly at Grootfontein College of Agriculture from initial crosses between Blackhead Persian ewes and Dorset Horn rams (Haas, 1971). The Dorper has by now obtained a world wide reputation for its adaptability to rather harsh environmental conditions. Some of the important characteristics of the breed include the ability to walk long distances and forage well in times of drought and in permanently dry areas, good mothering ability in the ewes, high ram fertility and vigour, excellent carcass conformation for good mutton production (in comparison with the indigenous sheep of Kenya), a faster growth rate than indigenous breeds and an unrestricted breeding season.

From the national economic point of view, because of the characteristics mentioned above, the Dorper breed is emerging as an important national asset, although its numbers are less than those for indigenous types. The breed is eminently suitable for crossing with and upgrading the indigenous sheep (Kiriro, 1986). Traits of particular significance, in this regard, relate to the need to speed up the growth rates of indigenous breeds without depressing the performance of other economic traits.

Body weight and rate of gain are among the most economically important and easily-measured traits of meat animals (Mavrogenis *et al.*, 1980). Knowledge of these particular traits and phases of the animals' growth upon which to base selection is, therefore, of utmost importance. The potential for genetic improvement is largely dependent on the heritability of the trait and its relationship with other traits of economic importance.

Magid *et al.*, (1981) noted that postweaning growth rate was important in sheep production because rapidly gaining animals reached a fixed market weight at younger ages or produced more liveweight at a given age end point.

Selection for ewe lambs to be retained for breeding purposes normally takes place at weaning stage. The efficiency of selection at weaning is often reduced by inability to identify the genetic value because of overriding environmental, especially maternal effects, and an inadequate knowledge of the relationships among the traits of economic importance. Selection at yearling age should permit a greater opportunity for the genetic value to be expressed in measurable or identifiable units, but economic considerations of keeping a large number of ewe lambs makes this practice impractical for the commercial operator (Bassett et al., 1967). However, if it can be shown that genetic value is more easily identified at yearling age, then it is possible that some of the economic disadvantage is partially balanced by more efficient selection.

An improvement in the trend of sheep outputs in specific farming areas, increased rates of weight gain and optimal slaughtering age could have beneficial effects nationally in three major respects (UNDP/FAO, 1976), namely;

i) An increase in traded surpluses could relieve pressure on the local market for beef, facilitating an increase in the total amount of beef available for export, or the increase could itself be exported.

ii) Output increases could serve as a means of stabilizing the financial bases of small scale farms.

iii) Sheep could be the source of fundamental improvement in the level of security experienced in the more marginal areas, where vulnerability to drought is an ever-present threat.

Knowledge of genetic parameters is essential for efficient selection in all classes of animals. A large amount of information has been reported concerning heritabilities, genetic and phenotypic correlations of various traits in sheep in the temperate region, but very few studies have been reported in the tropics. Of the studies reported, most have been on weaning traits while fewer have reported on yearling traits.

As a result, there is an extreme paucity of information concerning the phenotypic and genetic relationships among lamb growth traits. In addition, there is a dearth of information on the genetic parameters and environmental sources of variation pertaining to production traits of the sheep breeds in this country. Knowledge of these parameters is imperative since they are the prerequisites for development of successful breeding programmes and aid in the improvement of management systems.

Using data on the Dorper and Dorper x Red Maasai sheep the objectives of this study were:

i) To estimate repeatability of those traits known to be influenced by the dam, such as birth and weaning weights,

ii) To estimate heritability of lamb weights and growth rates between birth and yearling stages, and

iii) To estimate genetic, phenotypic and environmental correlations among these traits.

2.0 LITERATURE REVIEW

2.1 Growth Traits

2.1.1 Birth Weight

Lamb weight is a major component of profitability of sheep and is an important objective in selection (Hazel and Terrill, 1945a). Birth weight is an important component in overall sheep productivity since the subsequent growth of the lamb largely depends on it. Undoubtedly birth weight is influenced by a multiplicity of factors such as year of birth, age of dam, type of birth and rearing, sex and differences between breeds. Birth weight is often influenced by the maternal environment provided prenatally (Eltawil *et al.*, 1970; Ercanbrack and Price 1972; Thrift *et al.*, 1973; Martin *et al.*, 1980; Magid *et al.*, 1981; Stobart *et al.*, 1987).

2.1.2 Weaning Weight and Preweaning growth

Growth rate is important economically because of its desirable genetic and phenotypic correlations with feed efficiency. A lot of importance is associated with it due to the positive correlation that exists between rate of growth and weight of lambs at various stages. Also, more rapidly gaining animals reach a fixed market weight at a younger age (and therefore reduce fixed costs per unit of output) or produce more liveweight at the end of a fixed feeding period. Hohenboken, (1977) observed that genetic and environmental sources of variation on growth rate should be characterized in order that they may be manipulated to increase production efficiency.

The method of calculating rate of gain has little effect on the heritability estimate (Harrington *et al.*, 1962). Consequently, selection should be just as effective on a weight per day of age basis which is easier to calculate, than on an average daily gain basis for growth.

Factors influencing weaning weight and preweaning growth are numerous and include, among others, breed of dam and sire, sex of lamb, age of dam, type of birth and rearing, and year of birth (Magid *et al.*, 1981 and Stobart *et al.*, 1986).

2.1.3 Yearling Weight and Postweaning Growth

It is worth noting that postweaning gain largely reflects the potential inherent in the lamb since the obscuring effect of the dam's milk is removed. As the lamb approaches yearling weight maternal effect appears less likely to be significant. Bodisco *et al.*, (1973) reported that during the 90-day period postweaning, the average daily gain dropped to less than one-half (50g) that of the preweaning daily gain. Apparently, it is necessary to pay more attention to the overall nutrition of the lambs to prevent heavy drops in daily gains during the postweaning period.

2.2 Factors Affecting Growth Traits of Lambs

Factors affecting growth traits are both genetic and non-genetic (Turner and Young, 1969). Non-genetic factors obscure genetic differences between individuals or groups. Identifying, evaluating and correcting for such factors is, therefore, necessary in making more accurate genetic comparisons.

Accuracy of selection of genetically superior individuals to be parents of the next generation is reduced by environmental factors that tend to mask the actual breeding values of the individuals being selected, and whose contribution to the phenotypic variation should be minimized before estimating the genetic parameters (Hazel and Terrill, 1945a).

A number of identifiable non-genetic or environmental effects are known to influence the productive traits of sheep. If it is possible to adjust for these known effects so that animals are compared on a similar basis, then the environmental variation in the trait is reduced and heritability increased. Consequently, estimates of breeding values would be more accurate and selection response much greater.

Because selection is commonly carried out within flocks, the non-genetic effects which can usefully be identified are: sex, age of dam, type of birth and rearing (or litter size in which the animal is born and reared), the animal's own age at which the trait is measured, and reproductive status of the female (parity). Inbreeding of the animal or its dam may also be considered as an effect for which correction can be made.

Lambs born in multiple births have lower body weights at birth and weaning than do singles, this reduction usually being greater in conditions which favour lamb growth (Osman and Bradford, 1965; Harrington and Whiteman, 1967; Vogt, *et al.*, 1967; Olson, *et al.*, 1976; Magid, *et al.*, 1981).

Stobart, *et al.*, (1986) noted a significant age of dam effect on lamb weaning weights but not later weights. In general, the birth and rearing rank effect is a more severe handicap to the lamb than is the effect of age of dam. These maternal handicaps are the result of poorer nutrition of the lamb both pre- and post-natally.

2.2.1 Breed Effects

Information on the influence of dam breed on lamb performance is scanty. Hence no conclusive breed comparisons have been reported. However, a majority of studies have reported birth weights (in kilograms) of different breeds of sheep in differing localities and standards of management: 3.20±.02 for Bikaneri sheep, (Dass and Acharya, 1970); 3.61±.54 for Navajo sheep, (Eltawil *et al.*, 1970); 4.67±.61 for crossbred lambs consisting of all possible two-way crosses among the three breeds Rambouillet, Targhee and Columbia flocks, (Ercanbrack and Price, 1972); 4.2±.8 for Western and Dorset x Western lambs, (Thrift *et al.*, 1973);

5.80±.76 for Hampshire sheep, (Dzakuma *et al.*, 1978); and 4.03±.85 for Chios lambs, (Mavrogenis *et al.*, 1980). Bodisco *et al.*, (1973) reported a range of lamb birth weights of 2.49 to 2.79 kg for purebreds: West African lambs weighing the highest followed, in descending order, by Criollo, Barbados Blackbelly, and Blackhead Persian lambs. In a study conducted in Kenya, breed of lamb was shown to affect birth weight: Red Maasai sheep were .74 kg lighter at birth than Dorpers (Kiriro, 1986).

Breed effect in as far as its influence on weaning weight and preweaning growth are concerned has received little attention. Some of the workers who have reported significant breed effects include Vesely and Robison (1970), Magid *et al.*, (1981) and Kiriro (1986). However, Bodisco *et al.*, (1973) and Fitzhugh and Bradford (1983) reported that breed averages for weaning weights were remarkably similar. Kiriro (1986) reported average weaning weights and standard deviations in kilograms of 19.50±.23 in Dorpers, 15.56±.28 in Red Maasai, and a range from 17.51±.32 to 20.82±.70 for various crosses between Dorper and Red Maasai. The lambs produced by Dorper and Dorper x Red Maasai ewes weaned heavier probably due to the greater maternal ability of their dams. This observation was further corroborated by low weaning weights obtained in F_1 where Red Maasai was the dam breed.

Fitzhugh and Bradford (1983) reported a significant breed effect on postweaning gain.

Barbados Blackbelly lambs had the fastest gains:- 2.6 and 1.6 times the daily gain of Criollo and West African lambs, respectively. Magid *et al.*, (1981), on the other hand, reported that although breed of dam did not significantly influence postweaning gain, the rates of gain in the four breeds studied ranked as follows in ascending order: Rambouillet, 163 g/day; 1/2Finn, 164g/day; Targhee, 175g/day; and finally Hampshire, 178g/day.

Vesely and Robison (1970) also reported a significant ($P<0.01$) effect of breed on total postweaning gain and final weight. Rambouillet lambs grew faster than Romnelet by 1.46kg and consequently attained a final weight that was 4.05kg heavier.

2.2.2 Sex of Lamb

Several workers have reported a significant sex of lamb effect on birth weight, male lambs weighing more than their female counterparts in all cases (Blackwell and Henderson, 1955; Dass and Acharya, 1970; Thrift *et al.*, 1973; Wright *et al.*, 1975; Smith, 1977; Martin *et al.*, 1980; Magid *et al.*, 1981; Fitzhugh and Bradford, 1983; and Kiriro, 1986). The effect of sex was reported to increase with age showing significance at each stage (Blackwell and Henderson, 1955). Such a trend in the effect of sex on body weights might be attributed to different physiological functions in the two sexes, mainly of a hormonal nature that tend to become more pronounced as animals approach maturity.

However, other workers have reported sex of lamb having a significant effect on birth weights only in certain breeds and not others or the effect not being significant altogether (Vesely and Robison, 1970; Bodisco *et al.*, 1973).

The effect of sex of lamb on weaning weight and preweaning growth rate has been extensively investigated, in most cases males having superior weaning weights and growing faster to weaning (Dass and Acharya, 1970; Vesely *et al.*, 1970; Vesely and Robison, 1970; Magid *et al.*, 1981; and Kiriro, 1986). To account for these phenotypic differences the most plausible explanation that has been advanced is based on hormonal differences. The dominant hormones in males and females are androgens and estrogens, respectively. Velardo (1958) stated that androgens increase the rate of synthesis of new protein and organic elements. This anabolic effect, which comes as a result of increased retention of nitrogen and other tissue forming materials such as potassium, calcium and phosphorus, has also been reported by Bell, *et al.*, (1970). Male animals have also been shown to have a higher metabolic rate than females (Mitchell, 1967). This makes the male animals have higher appetites than females. The overall effect of all these factors is that males grow faster than females. It was not surprising, therefore, that in all the studies reported males grew more rapidly than females.

Several workers have reported that the effect of sex on yearling weight and postweaning gain is significant, in all cases males grew faster and consequently weighed more at yearling than females (Dass and Acharya, 1970; Vesely *et al.*, 1970; and Magid *et al.*, 1981).

2.2.3 Age of Dam

Several studies have reported that age of dam has a significant effect on birth weight (Dass and Acharya, 1970; Eltawil *et al.*, 1970; Vesely and Robison, 1970; Thrift *et al.*, 1973; Wright et al, 1975; Kiriro, 1986; and Stobart *et al.*, 1986). Although the magnitude of age effect depended on breed studied, location of study and other differences in experimental conditions, younger ewes tended to be associated with smaller lambs in most of these studies suggesting that the higher birth weight of the lamb born to older ewes was probably due to the increase in body size of the dam. The effect of age of dam exerts most of its influence on preweaning traits. The study by Kiriro (1986) suggests that the increase in birth weight with age reverses in the oldest ewe age classes such that, for example lambs out of ewes older than 9 years are smaller than those out of 8 year-old or younger ewes.

It was suggested in the study by Kiriro (1986) that the reduced birth weights of lambs of older ewes may be attributed to the association of advancing age with poor health and reduced grazing efficiency, resulting in poor body condition during the gestation period.

Other interesting results include reports that 8-year or older ewes produced the heaviest lambs but that lambs of this age group were lighter at weaning than those of 4 to 7 year-old ewes (Eltawil *et al.*, 1970). This was explained to be due to a possible negative phenotypic relationship between the effect of intra-uterine environment and the maternal environment provided between birth and weaning.

The influence of age of dam on weaning weight and preweaning growth is known to be significant and has been extensively studied (Hazel and Terrill, 1946; Blackwell and Henderson 1955; Dass and Acharya, 1970; Eltawil *et al.*, 1970; Vesely *et al.*, 1970; Vesely and Robison, 1970; Notter *et al.*, 1975; Wright *et al.*, 1975; Kiriro, 1986; and Stobart *et al.*, 1986). In general, older ewes were associated with better performance in terms of growth, with the exception that the very old ewes produced poor performers.

Kiriro (1986) reported that daily gains were high for lambs born to 2-5 year-old ewes, with the highest average daily gains (167.13±2.17g/d) coming from lambs born to 4 year-old ewes, whereas the lowest lamb average daily gains were from lambs of 7-9 year-old ewes. The highest lamb weaning weight (20.21±.22 kg) was from ewes that were 4 years of age, whereas the lowest record of weaning weight was from ewes that were 7-9 years. old. The results indicated that ewes that were 2 to 5 years of age probably had a superior maternal ability and although their lambs were lighter at birth, they were heavier at weaning. As a ewe gets older (7 yr.++) the ability to support fast rate of lamb growth diminishes possibly due to the decreased milking ability (Blackwell and Henderson, 1955; and Kiriro, 1986).

Age of dam effect on growth is known to diminish as the lamb matures. Thus, it is often highly significant on preweaning traits and less significant on postweaning traits (Dass and Acharya, 1970; Eltawil *et al*., 1970; and Vesely *et al*., 1970). In general, older ewes produce superior lambs as far as growth is concerned. However, the very old ewes are associated with poor performance in the lambs.

2.2.4 Type of Birth and Rearing

That type of birth has a significant influence on birth weights has been reported by several workers (Eltawil *et al*., 1970; Vesely and Robison, 1970; Bodisco *et al*., 1973; Thrift *et al*., 1973; Wright *et al*., 1975; Smith et al., 1977; Martin *et al*., 1980; Magid *et al*., 1981; Kiriro, 1986; and Stobart *et al*., 1986). In most cases, lambs born as singles were reported to weigh considerably more than multiples. Some workers have reported average individual birth weights of twins, triplets, and quadruplets to be progressively lighter than those of singles and exhibiting poorer livability compared to singles, as would be expected (Bodisco *et al.*, 1973; Magid *et al.*, 1981). One possible reason that has been advanced to explain this trend is the sharing of limited uterine space and nutrients prenatally (Kiriro, 1986).

Many workers are in agreement that type of birth and rearing has a significant effect on both the weaning weight and the rate of gain preweaning. It is generally accepted that lambs born single weigh more at weaning and grow faster to weaning (Vesely *et al.*, 1970; Bodisco *et al.*, 1973; Magid *et al.*, 1981; Fitzhugh and Bradford, 1983; Kiriro, 1986; and Stobart *et al.*, 1986). Stobart *et al.*, (1986) noted that differences in weights between lambs born and raised single and twins tended to decrease with age. The fact that lambs born as multiples perform poorly preweaning reflects effects of competition for milk and carry-over effects of weight at birth (Fitzhugh and Bradford, 1983).

A majority of studies have indicated that the effects of type of birth and rearing have little or no influence on yearling weight and postweaning gain (Eltawil *et al.*, 1970; Bodisco *et al.*, 1973; and Stobart *et al.*, 1986). Apparently, the effect of birth and rearing rank diminishes as the lamb grows to maturity. However, in some cases it was evident that lambs born as multiples had faster gains than singles, although this difference was not significant. On the contrary, Vesely *et al.*, (1970) reported that type of birth and rearing significantly influenced total postweaning gain and final weight in two breeds of sheep, namely Rambouillet and Romnelet.

2.2.5 Year and Season of Birth

Year and season of birth effects on birth weight and weaning weight can arise due to changes in the physical environment from year to year, season to season or in management regimes over time. Rainfall changes in amount and distribution affect the amount and quality of forage available to dams and their lambs. In the case of birth weight, the year and season of birth effect is indirect, mainly through its effect on the dam especially in late gestation. Some workers have reported a significant year and season effect on birth weight (Eltawil *et al.*, 1970; Magid *et al.*, 1981). On the contrary, other workers reported that year of birth did not significantly influence lamb birth weight (Vesely and Robison, 1970; and Dass and Acharya, 1970).

Few studies have reported the influence of year or date of birth on preweaning performance in sheep. However, some workers have reported a significant year of birth effect on weaning weight, preweaning growth rate, postweaning gain and yearling weight, the general tendency being that better performance among the lambs was attributable to the years when conditions in the general physical environment e.g. forage availability was optimum (Dass and Acharya, 1970; and Vesely *et al.*, 1970).

2.3 Repeatability

Many important characteristics in livestock occur more than once in the lifetime of an individual (Hohenboken, 1985). Examples are milk yield per lactation in cattle, wool production in sheep and litter size in swine . It is important to know what proportion of total differences among individuals are attributable to 'permanent' (as opposed to 'temporary' effects), that is what proportion of an individual's superiority or inferiority (based upon a single measurement of trait) is expected to be expressed in future measurements as well. Knowledge of the repeatability of traits is necessary to predict producing abilities of individuals and to predict the change in production that will result from culling the poorer producers from a population.

In evaluating ewes rearing lambs, the question arises as to whether or not one record on the ewe is sufficient information to evaluate the ewe's performance (Harrington and Whiteman, 1967). A repeatability estimate of lamb growth rate as a characteristic of the ewe would give an indication of the reliability of a single record as an index of the ewe's ability to rear a lamb. However, much of the observed variation in the growth rate of the lamb is the result of influences which are not usually considered to be permanent differences among ewes. Examples of such factors are the sex of the lamb, lamb birth and rearing type, age of the ewe, year the record was made, and within-season time trends. Consequently, it would be desirable to adjust the data for these influences before estimating the repeatability of lamb growth rate as a characteristic of the ewe.

By definition, repeatability is the proportion of total phenotypic variance for a trait attributable to permanent differences among individuals.

There are two assumptions implicit in the idea of repeatability (Falconer, 1981). The first is that the variances of the different measurements are equal and have their components in the same proportions. The second is that the different measurements reflect what is genetically the same character.

Like heritability, repeatability is not a biological constant. It may vary for different traits and for the same trait within a population over time or the same trait measured in different populations. This variance may be a function of differences in genetic components, in permanent environmental components, in temporary environmental components or in any combination thereof.

If there are only two records per individual, the product - moment correlation is used to estimate repeatability (Hohenboken, 1985). Conceptually, the two records per individual are drawn at random from a population of all possible records of that individual. Thus, there is no basis for assuming that the variances in the two records differ, hence correlation rather than regression is the appropriate mathematical method. In many instances, it will be appropriate to compute sums of squares and cross-products within subclasses and then pool them to compute the correlation.

If there are more than two records per individual, the product-moment correlation could still be used to compute repeatabilities of all possible pairs of records and these combined into a pooled estimate of average or overall repeatability (Hohenboken, 1985). More often, though, the inter-class correlation of repeated records on an individual is computed using variance components estimated from an analysis of variance in which repeated records are nested within individuals. The procedure and the rationale are similar to those for estimating heritability from intraclass correlation of paternal half sibs. The simplicity of repeatability computations compared to the relative complexity of heritability computation and the fact that to estimate heritability, but not repeatability, the family structure of the population must be known, explains why repeatability sometimes is used to estimate the upper limit of heritability.

In the literature, few studies have reported repeatability estimates in sheep. Harrington and Whiteman (1967) reported repeatability estimate for birth weight as ranging between .35-.37 depending on the number of factors adjusted for in estimation. Repeatability of 70-day weight was

0.21-.24, while that for growth rate from 70 to 140 days was .07-.14. Magid *et al.*, (1976) reported repeatability of total weight of lambs weaned per ewe year as .15 and .16 for Hampshires and Columbias respectively. These estimates were higher than that of .08 reported by Blackwell and Henderson (1955), possibly because differences in suckling ability of ewes, ability to produce and rear singles, twins or triplets, and the average effect of genes transmitted to the lambs which influence growth to weaning were included in the latter study.

Repeatability estimates in other species such as beef cattle have indicated a wide range of values. Minyard and Dinkel (1965) reported, for weaning weight, estimates of .42 , .52 and .42 for the Hereford, Angus and the breeds combined, respectively. They suggested selection for high-producing cows could be practiced early in their productive life based on the relatively high repeatability of weaning weight. Sellers *et al.*, (1970) reported values of .19 in Hereford and .27 in Angus. Itulya *et al.*, (1987) reported a repeatability estimate for adjusted weaning weight ratio of .25 in unsupplemented Hereford range cows. Alenda and Martin (1987) analysed repeatabilities of calf weights and gains as traits of the dam. The estimated repeatabilities for male and female data sets, respectively, were 0.26 and .29 for birth weight; and .43 and .28 for weaning weight. Cantet *et al.*, (1988) reported repeatability estimates of Hereford calves as .21

for birth weight and .30 for weaning weight.

2.4 Heritability

In order to draw conclusions about a population, it is necessary to define some parameters which summarize the nature of the population (Cunningham, 1969). The trait observed in any individual is invariably produced by both genetic and environmental factors. The population parameters must, therefore, be based on the components of genetic variance and covariance and also on the environmental contribution to the overall observed phenotypic variance. This joint effect of genotype and environment means that the absolute phenotypic value of a trait in an individual does not give us much information, since there is no way of separating the two contributions from each other. The differences between phenotypes can however be analysed in such a way that the effects can be separated. Parameters of the population are therefore built on the genetic and environmental components of the phenotypic variance.

Knowledge of the heritability of traits is necessary to predict breeding values of individuals, to formulate effective breeding plans and to predict response from selection (Hohenboken, 1985). Heritability could very well be considered the cornerstone upon which much of quantitative genetic theory, practice and accomplishment is built.

The heritability (narrow sense) of a metric character is one of its most important properties (Falconer, 1981). It expresses the proportion of the average effect of genes, and this is what determines the degree of resemblance between relatives. But the most important function of heritability in the genetic study of metric characters is its predictive role, expressing the reliability of the phenotypic value as a guide to the breeding value. Only the phenotypic values of individuals can be directly measured, but it is the breeding value that determines their influence on the next generation. Therefore, if the breeder chooses individuals to be parents according to their phenotypic values, his success in changing the characteristics of the population can be predicted only from a knowledge of the degree of correspondence between phenotypic values and breeding values. This degree of correspondence is measured by the heritability. The level of heritability indicates whether selection will be effective with or without aids, or whether other avenues of improvement should be sought.

The heritability of liveweights are generally low-medium in magnitude. A pattern often observed is that of low-medium heritability for birth weight, low heritability in the first 6-8 weeks, low-medium at weaning, followed by an increase to medium-high as the animal grows through to maturity (Rae, 1982). Weaning and pre-weaning weights are complex because they depend not only on the inherent ability of the lamb to grow but also the maternal ability of the dam (Rae, 1982). The latter trait is controlled by both a genetic and environmental component. However, there is some evidence that heritability increases in the postweaning period as maternal carry-over effects become less important (Rae, 1982). Table 2.1 presents heritability estimates for body weights in sheep that have been reported by various workers.

Rates of gain in liveweight between specific ages or weights are generally medium in heritability and in most cases about the same as those of liveweights themselves. Heritability estimates for preweaning and postweaning growth rates are presented in Tables 2.2 and 2.3, respectively.

2.5 Correlations

In selection it is important to know how the improvement of one character will cause simultaneous changes in other characters (Turner and Young, 1969). The size of the genetic correlation measures the extent to which one character is additively related to another, and consequently the change in one which will accompany changes in the other. In formulating breeding plans estimates not only of direct response to selection, that is, the genetic gain in the character under selection, but also of the indirect response, that is, genetic changes in

Table 2.1 Heritability Estimates of Body Weights in Sheep.

Traits					
Birth weight	Weaning weight	6mo weight	12mo weight	Mature weight	Source
0.10-.30	.10-.30	.20-.40	.30-.50	.40-.60	[1] Rae, (1982)
0.10-.35	.10-.40			.20-.40	[1] Bowman, (1984)
0.30-.50	.10-.30			.30-.70	[1] Carles, (1983)
0.46±.12	.28±.11		.26±.11	.53±.12	[2] Stobart *et al.*, (1986)
0.21±.08	-.09±.06	.28±.10	.11±.10		[3] Dzakuma *et al.*, (1978)
0.10±.07					[4] Thrift *et al.*, (1973)
0.31±.20					[5] Vogt *et al.*, (1967)
0.13±.07	.36±.12				[6] Mavrogenis *et al.*, (1980)
0.45±.20			.38±.23		[7] Dass and Acharya, (1970)
		0.02			[8] Ercanbrack and Price (1972)
		0.80			[7] Bhasin (1969)
0.22±.15	-.10±.11[m]			0.05±.13	[9] Vesely and Robison (1970)
0.40±.18	.12±.14[f]			-0.01±.12	[9] Vesely and Robison (1970)
0.30±.16	.07±.13[m]			0.23±.15	[10] Vesely and Robison (1970)
0.39±.16	.06±.12[f]			0.30±.15	[10] Vesely and Robison (1970)
0.31±.10	.34±.10				[11] Ercanbrack and Price (1972)
0.26±.13	.45±.14				[10] "
0.30±.10	.16±.09				[12] "
0.12±.11	.15±.11				[13] "

Key: Sex m = males f = females. Breeds [1]breed not indicated, [2]Columbia, Rambouillet, and Targhee, [3]Hampshire, [4]Rambouillet and Rambouillet x Dorset, [5]Hampshire and Hampshire x Rambouillet, [6]Chios, [7]Bikaneri, [8]Rambouillet, Targhee and Columbia, [9]Romnelet, [10]Rambouillet, [11]Crossbreds, [12]Targhee, and [13]Columbia.

Table 2.2 Heritability Estimates of Preweaning Growth Rate in Sheep.

Traits	Estimate	Source
Birth-Weaning	0.37±0.15	[1]Hundley and Carter, (1956)
	0.04±0.14	[2]Hundley and Carter, (1956)
	0.33±0.10	[3]Ercanbrack and Price (1972)
	0.39±0.14	[4] "
	0.17±0.09	[5] "
	0.14±0.11	[6] "
	0.18	[7]Givens *et al.*, (1960)
	0.37	[8]Vogt *et al.*, (1967)
	0.35	[9]Mavrogenis *et al.*, (1980)
	0.15-0.40	[10]Rae, (1982)
	0.21±0.11	[11]Stobart *et al.*, (1986)
	0.14±0.14	[12]Vesely and Robison (1970)
	0.29±0.17	[12] "
	0.27±0.16	[13] "
	0.15±0.13	[13] "

ey: Breeds [1]Hampshire, [2]Southdown, [3]Crossbreds, [4]Rambouillet, [5]Targhee, [6]Columbia, Hampshire and Rambouillet, [8]Hampshire and Hampshire x Rambouillet, [9]Chios, [10]Not ndicated, [11]Columbia, Rambouillet and Targhee, [12]Romnelet, and [13]Rambouillet.

Table 2.3 Heritability Estimates of Postweaning Gain and Overall Growth Rate.

Weaning-12months	0.52±0.12	[1]Stobart *et al.*, (1986)
	0.43±0.11	[2]Ercanbrack and Price (1972)
	0.40±0.14	[3] "
	0.52±0.12	[4] "
	0.58±0.14	[5] "
12-18months	0.43±0.12	[1]Stobart *et al.*, (1986)
Weaning-20weeks	0.56	[6]Mavrogenis *et al.*, (1980)
Postweaning ADG	0.20-0.40	[7]Rae, (1982)
Total Postweaning Gain	0.15±0.14	[8]Vesely and Robison (1970)
	0.31±0.17	[8] "
	0.28±0.16	[3] "
	0.16±0.13	[3] "
Birth-12months	0.29±0.11	[1]Stobart *et al.*, (1986)
Birth-18months	0.35±0.12	[1] "
Overall ADG	0.10-0.30	[7]Carles, (1983)

Key :Breeds [1]Columbia, Rambouillet, Targhee, [2]Crossbreds, [3]Rambouillet, [4]Targhee, [5]Columbia, [6]Chios, [7]Not indicated, and [8]Romnelet.

other characters which occur because of genetic correlations with those under selection are required.

The genetic cause of correlation is chiefly pleiotropy, though linkage is a cause of transient correlation particularly in populations derived from crosses between divergent strains (Falconer, 1981).

Genes that increase growth rate increase both stature and weight, so that they tend to cause correlation between these two characters. The degree of correlation arising from pleiotropy expresses the extent to which two characters are influenced by the same genes. But the correlation resulting from pleiotropy is the overall, or net, effect of all the segregating genes that affect both characters. Some genes may increase both characters, while others increase one and reduce the others; the former tend to cause a positive correlation, the latter a negative one. Thus, pleiotropy does not necessarily cause a detectable correlation. The environment is a cause of correlation in so far as two characters are influenced by the same differences of environmental conditions. Again the correlation resulting from environmental causes is the overall effect of all the environmental factors that vary; some may tend to cause a positive correlation, others a negative one.

The association between two characters that can be directly observed is the correlation of phenotypic values or the phenotypic correlation

(Hohenboken, 1985). This is determined from measurements of the two characters in a number of individuals of the population. If, however, we know not only the phenotypic values of the individuals measured, but also their genotypic values and their environmental deviations for both characters, we could then compute the correlation between the genotypic values of the two characters and the correlation between the environmental deviations, and so assess, independently, the genetic and environmental causes of correlation. If, in addition, we know the breeding values of the individuals, we could determine also the correlation of breeding values. In principle, there are also correlations between dominance deviations, and between the various interaction deviations. To deal with all these would be unmanageably complex, but fortunately is not necessary since the practical problems can be quite adequately dealt with in terms of two correlations. These are the genetic correlation, which is the correlation of breeding values, and the environmental correlation which is not strictly speaking the correlation of environmental deviations, but the correlation of environmental deviations together with non-additive genetic deviations.

If both characters have low heritability, then the phenotypic correlation is determined chiefly by the environmental correlation (Falconer, 1981). If, on the other hand, they have high heritabilities, then the genetic correlation is the more important.

In some cases the genetic and environmental correlations are different in magnitude, or even in sign (Falconer, 1981). A large difference, and particularly a difference of sign, shows that the genetic and environmental sources of variation affect the characters through different physiological mechanisms.

2.5.1 Correlations among growth traits

Breeding programmes designed to improve production efficiency require knowledge of the genetic parameters for characters of economic importance such as those of growth (Fitzhugh and Taylor, 1971). One way is to improve efficiency of mutton production by exploiting the genetic variation in rate of growth, which is independent of mature size, by increasing early growth relatively more than subsequent mature size.

The amount of genetic gain that can be expected to result from selection depends in part on the correlation between the true breeding value of the individuals available for selection and the criterion, or index, used to estimate their breeding value (Blackwell and Henderson, 1955). Good estimates of heritability and repeatability of the traits that are considered in selection as well as estimates of the effects of tangible environmental factors which affect these traits are needed to maximize that correlation.

Information on heritabilities is essential for planning efficient breeding programmes and for predicting response to selection (Dzakuma *et al*., 1978). Genetic correlations, on the other hand, are essential in predicting indirect response to selection and for determining the optimum weighting and expected response in selection to improve more than one trait.

Bodisco et al, (1973) noted that there is good evidence of a positive correlation between birth weight and subsequent weights in tropical sheep. For this reason, considerable attention has been given to birth weights as an important factor in improving the productivity of these sheep. In addition, birth weights are easily obtained and readily available. Eltawil *et al*., (1970) noted a regression of 2.41±.11 of weaning weight on birth weight. Such a relationship could be beneficial for early selection and culling of lambs, especially those to be kept for breeding purposes. Lambs that have heavier birth weights that might be due to being males, singles and / or from mature ewes, tend to achieve higher weights at weaning, partly because of the close relationship between both traits.

As animals mature, growth and maturing rates over the various age intervals decline. The decrease in growth in the postweaning period is attributed to the stress of postweaning adaptation. The weaning - twelve months interval reflects the individual's own ability for growth and development rather than the dam's milking ability.

Stobart *et al.*, (1986) observed that growth and maturing rates were generally positively correlated over most age intervals. Exceptions occurred with adjacent age intervals, where there was a tendency for negative / positive relationships in the genetic correlations for these intervals. Fitzhugh and Taylor (1971) noted the same trends and attributed negative genetic correlations between growth rates in adjacent age intervals to "transient genetic associations which appear only when the growth rate intervals have a common end point". Preweaning absolute growth rate was negatively correlated to postweaning absolute growth rate. This observed relationship tends to support the hypothesis that faster growth during one interval will tend to result in slower growth in a subsequent interval. The concept of compensatory gain is illustrated by these observations; i.e. lambs that grow faster preweaning have a reduced growth rate impetus postweaning (Stobart *et al.*, 1986).

Genetic and phenotypic correlations among growth traits have been extensively investigated. Table 2.4 gives some of the estimates reported.

Table 2.4 <u>Genetic and Phenotypic Correlations Between Traits.</u>

Trait	Genetic correlation	Phenotypic correlation	Source
BW-WW	0.57-0.77		[1]Osman and Bradford (1965)
	0.68	0.23	[2]Stobart *et al.*, (1986)
	0.21	0.42	[3]Mavrogenis *et al.*, (1980)
		0.36-0.46	[4]Ercanbrack and Price (1972)
	0.6		[5]Dzakuma *et al.*, (1978)
BW-6MW	-0.11		"
BW-12MW	0.13		"
	0.22	0.37	[2]Stobart *et al.*, (1986)
WW-6MW	0.83		[5]Dzakuma *et al.*, (1978)
WW-12MW	0.72		"
	0.21	0.59	[2]Stobart *et al.*, (1986)
6MW-12MW	0.76		[5]Dzakuma *et al.*, (1978)
BW-70DWT	0.59	0.49	[6]Thrift *et al.*, (1973)
BW-ADG70D	0.40	0.28	"
BW-ADG70MKT	0.42	0.24	"
BW-ADGWW	1.00	0.27	[7]Vogt *et al.*, (1967)

where BW=birth weight, WW=weaning weight, 6MW=six month weight,
12MW=twelve month weight, 70DWT=70 day weight,
ADG70D=average daily gain from birth to 70 days
ADG70MKT=average daily gain from 70 days to market age
ADGWW=preweaning average daily gain

<u>BREEDS:</u> 1= Corriedale, Targhee, Rambouillet and Merino.
2= Columbia, Rambouillet and Targhee 3= Chios
4= Rambouillet, Targhee and Columbia. 5= Hampshire
6= Rambouillet and Rambouillet x Dorset.
7= Hampshire and Hampshire x Rambouillet.

3.0 MATERIALS AND METHODS

The data used in this study were collected at the National Animal Husbandry Research Centre (NAHRC), Naivasha by the Sheep and Goat Development Project (SGDP) of the Ministry of Livestock Development and FAO/UNDP between 1978 and 1987. The study was conducted at Ol'Magogo, a substation of the NAHRC. Ol'Magogo is located about 130km from Nairobi and 40km North East of Naivasha town at a latitude of 0° 5' S and longitude 36° 2' E and at an altitude of 1854-1900 metres above sea level.

3.1 Rainfall and Vegetation

The station is situated in a medium potential area (ecological Zone IV) (Pratt *et al.*, 1962). The soils are sandy clay loam phaezems and andosols. The land is of marginal agricultural potential, carrying as natural vegetation, shrubs and grasses. These are described in detail by Gumedze (1979). The annual rainfall pattern over the past 10 years of this study is given in figure 3.1. The average rainfall recorded at Ol'Magogo over the 10 year-period of the study was 656mm per year, ranging from 276.5mm in 1984 to 961.4mm in 1978. Figure 3.2 presents the monthly rainfall pattern at Ol'Magogo in a period of 16 years (1972-1987).

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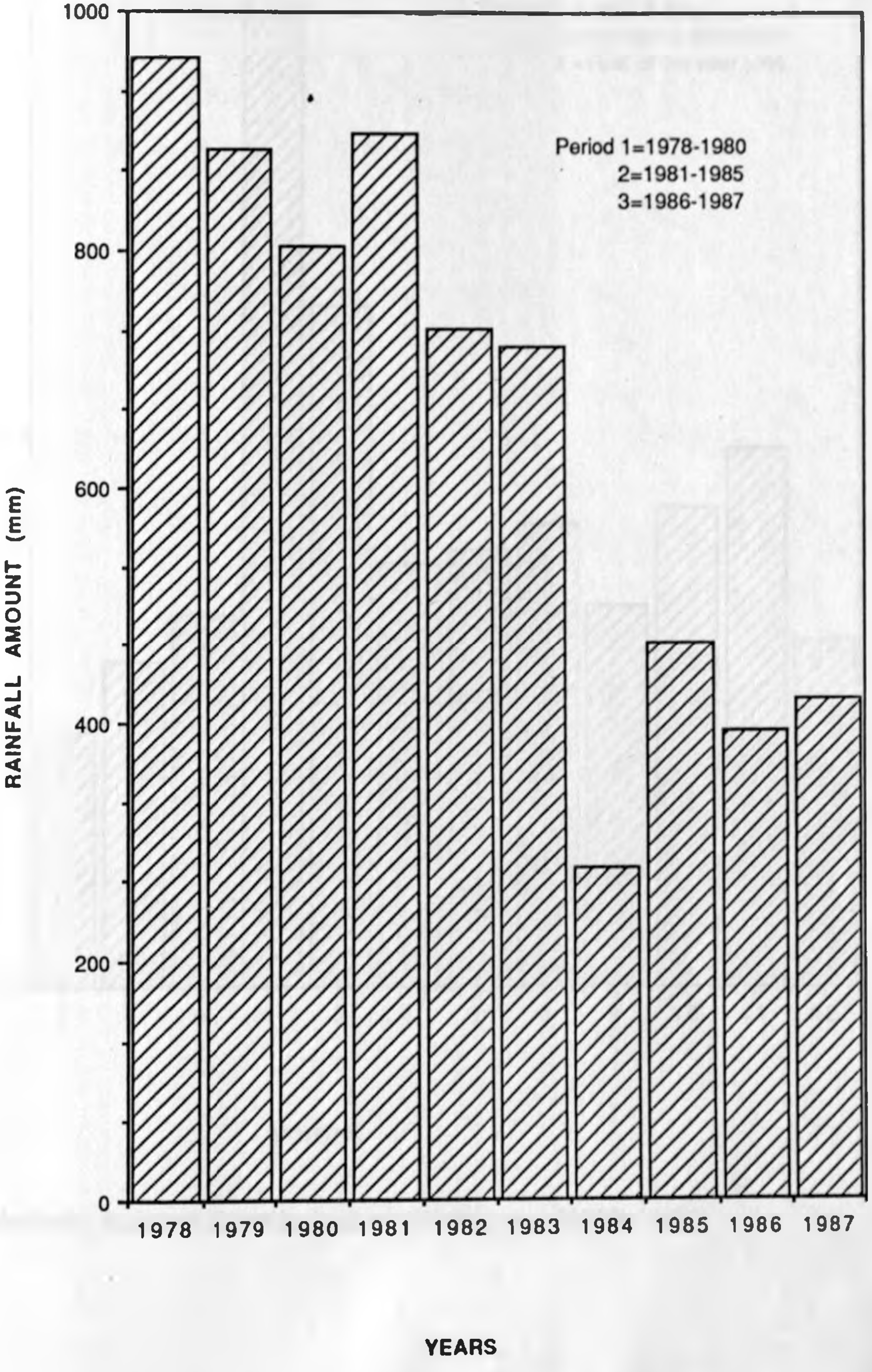
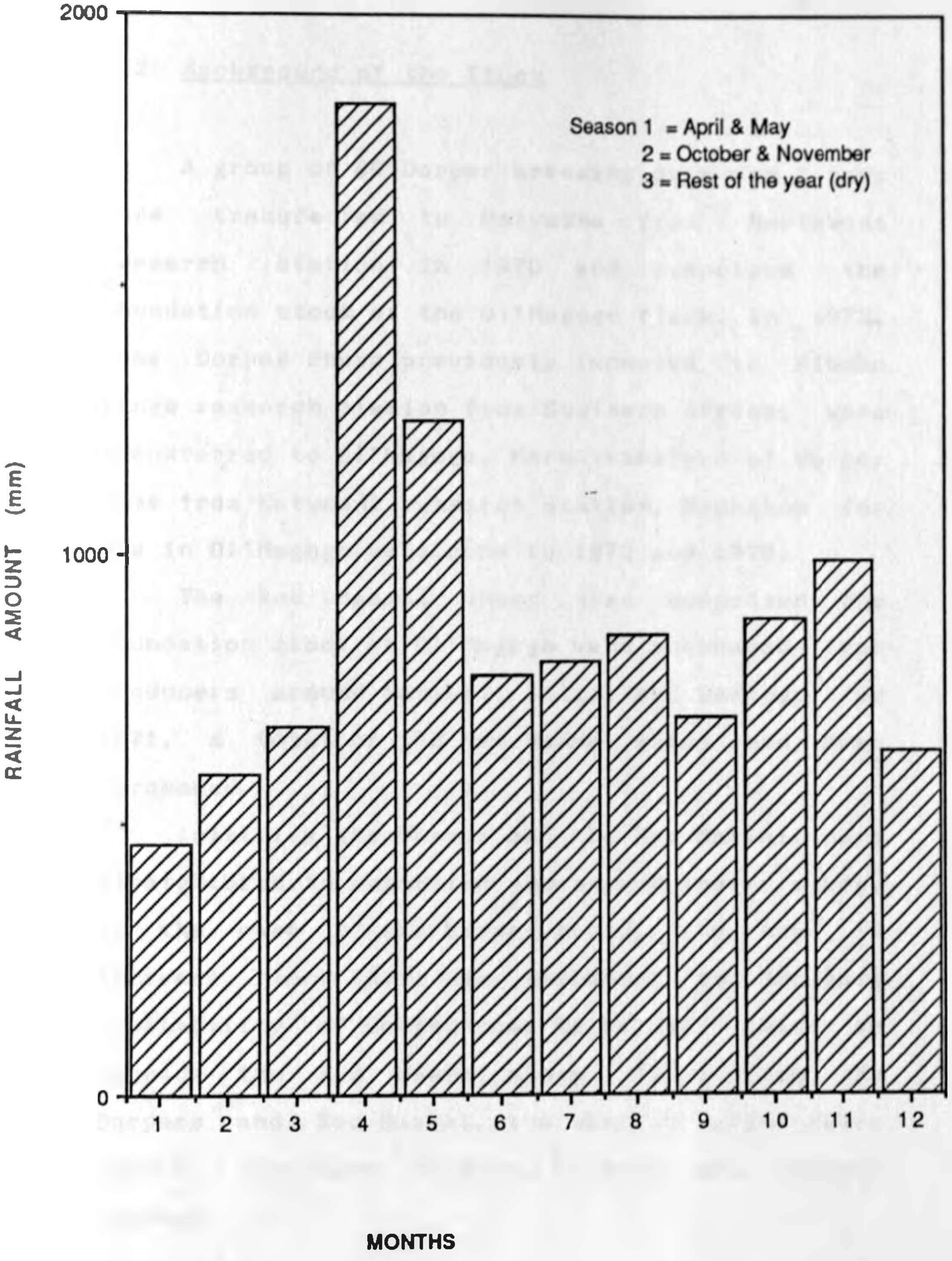


Fig. 3.1 Annual Rainfall Distribution at Ol'Magogo (1978-1987)



ig 3.2 Monthly Rainfall Distribution at Ol'Magogo (1972-1987)

3.2 Background of the Stock

A group of 69 Dorper breeding ewes and 6 rams were transferred to Naivasha from Mariakani research station in 1970 and comprised the foundation stock of the Ol'Magogo flock. In 1973, some Dorper sheep previously imported to Kiboko range research station from Southern Africa, were transferred to Ol'Magogo. More transfers of Dorper rams from Katumani research station, Machakos for use in Ol'Magogo were done in 1972 and 1979.

The Red Maasai sheep that comprised the foundation stock at Ol'Magogo were purchased from producers around Nanyuki, Gilgil and Baringo. By 1971, a total of 170 Red Maasai sheep had been purchased.

Initially the Dorper and the Red Maasai were straightbred to establish and expand their studs. In the case of the Dorper breed, the need to increase flock size was paramount to increase availability of Dorper rams to be used later to upgrade the Red Maasai sheep. Apart from the Dorpers and Red Maasai, the station also rears Merino, Blackhead Persian, Suffolk and various crosses.

3.3 Breeding Management

Strict measures to prevent inbreeding were instituted. The rams were used on the same flocks for not more than three breeding seasons. The sires used for breeding or their subsequent replacements were selected for conformation, breed character and performance based on the performance of their own sires and dams. The selection criteria adopted was based on increased liveweights at various ages, mothering and milking ability in relation to survival rates, improved reproductive performance and conformation scores. Initially ewes were bred once a year but from 1985 the frequent mating system was practised with the aim of obtaining 3 lamb crops per ewe in 2 years. The replacement hoggets were generated from within the flock and about 20% of top quality ewe lambs were retained for replacement. About 5% of breeding rams were selected from the flock on the basis of the parent performance records and individual performance. The trait given most attention was growth rate of the ram. Rams used for breeding were selected from well-managed flocks, such as from Agricultural Development Corporation farms. Only rams that were above average of their age class were considered.

All sheep were herded in the following flocks: Breeding ewes, Weaners and Hoggets, Cull sheep, and Rams.

It was common practice to breed maiden ewes when they were over 12 months of age, however, some were bred much earlier than this. Prior to mating, ewes were flushed in order to increase conception rates. The flock was drenched, mating records taken and crutching in females and ringing in males conducted routinely. In view of the frequent mating system, ewes were rested for 1 month after weaning before they were joined again.

The breeding flock was screened before mating and all the undesirable ewes and rams were culled. Ewes to be joined were selected on the basis of such factors as body condition score and condition of the feet. Rams were examined for defects that have an hereditary basis, for instance, undershot or overshot jaws, and cryptorchidism. The selection included a detailed manual examination of the external genitalia. The resulting breeding flock was moved into a clean joining paddock where they were footpared, weighed and placed into mating groups with a sire:dam ratio not exceeding 1:50. Each ram was fitted with a sire harness with a crayon to enable identification of matings. Records of matings were taken every day. Mating lasted approximately one month.

Pregnant ewes were vaccinated against clostridial diseases before lambing. All the ewes were transferred into lambing paddocks just before lambing. Lambs were ear-tagged for identification purposes within 24 hours of birth. The following information was recorded:- Dam's identity, sire's identity, date of birth, type of birth (singles, twin or triplets), sex, birth weight, and breed of lamb.

The eartags were serialized to indicate the year of birth, breed of sheep and serial number. The orphan lambs were fostered and all the lambs were weighed monthly until they were 1 year of age. Docking was performed using a rubber ring one week after birth.

3.4 Pasture Management and Flock Health

The sheep were grazed extensively on open paddocks. They were taken out for grazing early in the morning and returned to the night sheds late in the evening where they were penned at night (in open sheds or bomas) except during the cold months (around July and August) when they were kept indoors.

Some rotational grazing was practised to reduce worm infestation and facilitate grass re-establishment. The common pasture species grazed was Naivasha stargrass (*Cynodon* spp). Minerals were provided *ad libitum* (red oxide with Maclick Plus from Welcome Kenya Ltd.) in troughs on pastures and in the night shed.

Water supply was properly distributed within the grazing paddocks and sheep were watered twice a day. Apart from mineral salt, no form of supplementation was provided, except occasionally to breeding rams with lucerne hay one month before joining to condition them and, during drought spells.

Routine management of the flock included drenching to get rid of helminths, dipping to rid the flock of ticks, vaccinations against clostridial diseases, hoof trimming and footbathing to prevent incidence of footrot.

3.5 The Data

The data set available for use in this study spanned the years 1978-1987. In total 3343 records were gathered out of which only 1550 records had complete information from birth to yearling weight. The type of records used in this study included sire, dam and lamb eartag number, type of birth and rearing, sex of lamb, date of birth and birth weight; date of weaning and weaning weight, six months date and six months weight; date of nine months and nine months weight; date of twelve months and twelve months weight; and dam breed.

Weaning of the lambs occurred at about 3-4 months of age with some above or below that range. This necessitated the standardization of lamb weights listed above based on average daily gain (ADG) in kilograms per day. Growth rates were assumed linear between the intervening growth stages and were defined as follows:-

i) GRATE1 = ADG from birth to weaning
ii) GRATE2 = ADG from weaning to six months
iii) GRATE3 = ADG from six to nine months
iv) GRATE4 = ADG from nine to twelve months
v) OVRGRT = ADG from birth to twelve months

The recorded information was used to generate additional variables such as adjusted weaning, six months, nine months and yearling weights. The growth rates defined above were also generated. Adjusted weights were derived at 3-months intervals as follows:-

i) ADJWWT (Adjusted weaning weight)
   = GRATE1 X 90 days + birth weight (BIRTHW).

ii) ADJSMW (Adjusted six months weight)
   = GRATE2 X 90 days + ADJWWT.

iii) ADJNMW (Adjusted nine months weight)
   = GRATE3 X 90 days + ADJSMW.

iv) ADJTMW (Adjusted twelve months weight)
   = GRATE4 X 90 days + ADJNMW.

In all, the 10 traits analysed were :- BIRTHW, ADJWWT, ADJSMW, ADJNMW, ADJTMW, GRATE1, GRATE2, GRATE3, GRATE4, and OVRGRT. The fixed effects investigated were:-

i) Sex: 1 = male and 2 = female

ii) Dam breed: 1 =Dorper and 2 =Dorper x Red Maasai

iii) Dam breed: 1 = Dorper, 2 = Return 3 x F_1 (Dorper x Red Maasai), 3 = Return 4 x F_1, 4 = Return 1 x Return 1, 5 = Return 2 x Return 2.

iv) Season of birth: 1 = long rains (April and May), 2 = short rains (October and November), and 3 = rest of the year.

v Parity: 1 = ewes that had lambed once, 2 = ewes that had lambed twice, 3 = ewes that had lambed three times, and 4 = ewes that had lambed four or more times.

vi) Period of birth: 1 = years 1978-1980, 2 = years 1981-1985, and 3 = years 1986-1987.

vii) Type of birth: 1 = singles 2 = multiples.

The Dorper x Red Maasai was made up of several genotypes. Preliminary analysis indicated that these genotypes were not significantly different from each other. It, therefore, became necessary to group them together. These genotypes were developed as follows:-

Rams		Ewes		%Dorper
Dorper	X	Red Maasai	---F_1 (DRM)	1/2D
Dorper	X	F_1	---F_2	3/4D
Dorper	X	F_2	---F_3 (Return 1)	7/8D
Dorper	X	Return 1	---Return 2	15/16D
Dorper	X	Return 2	---Return 3	31/32D
Dorper	X	Return 3	---Return 4	63/64D

DRM represents a Dorper x Red Maasai first cross. The dam genotypes used in this study were :- Dorper, Return 3 x DRM, Return 4 x DRM, Return 1 x Return 1, and Return 2 x Return 2. These were coded 1, 2, 3, 4 and 5 respectively. In all cases the sires were pure Dorpers. The dams were either pure Dorpers or various crosses between Dorper and Red Maasai as stated above.

The resultant lambs were thus of the following genotypes:-

Rams		Ewe Genotype Code	Lamb Genotype
Dorper	X	Pure Dorper (1)	Pure Dorper
Dorper	X	47/64 Dorper (2)	86.72% Dorper
Dorper	X	95/128 Dorper (3)	87.11% Dorper
Dorper	X	7/8 Dorper (4)	93.75% Dorper
Dorper	X	15/16 Dorper (5)	96.88% Dorper

The use of a single sire breed in this study provides a one-to-one correspondence between the genotype of the dam and that of the lamb. Lambs were nursed by their dams up to weaning.

Season of birth was determined from the rainfall pattern over 16 years (1972-1987). Monthly totals (mm) were plotted against time (Fig. 3.2). Four months received more rain than the average. These were April, May, October and November. April and May were classified as Season 1 (long rains), October and November as Season 2 (short rains), and the remaining months were classified as the rest of the year (dry).

Ewes that had lambed four or more times were classified under parity 4. Period of birth was based on year of birth. The records available were not consistent such that discontinuity in the data existed due to lack of complete records in 1981, 1983 and 1984. Looking at the annual rainfall pattern it was evident that 1978, 1979 and 1980 had higher rainfall whereas 1986 and 1987 had the lowest. The years 1982 and 1985 appeared intermediate between these two extremes. It was, therefore logical to divide the years into 3 periods to counter the problem of disconnectedness in the data.

3.6 Statistical Analyses

Analyses for the genetic parameters i.e. heritability and genetic and phenotypic correlations were conducted using the Least Squares Maximum Likelihood programme (LSML76) of Harvey (1982). The models for the analyses had one set of cross-classified non-interacting random effects. An IBM Personal Computer was used to analyze the data using the following general model:

$$Y_{ijk} = u + a_i + F_j + e_{ijk}$$

where Y_{ijk} = the weight of lamb at a certain age or the average daily gain between intervening stages in the lamb's growth.

u = an overall constant

a_i = effect of the i^{th} random effect (sires or dams)

F_j = a constant for the j^{th} fixed effect (other than u)

e_{ijk} = random error.

Interactions of a_i and all fixed effects were assumed to be negligible. The fixed effects for Model 1a were :

i) Sex (1,2)
ii) Dam breed (1,2)
iii) Season of birth (1,2,3)
iv) Parity (1,2,3,4)
v) Period of birth (1,2,3).

In order to study the influence of type of birth and rearing on the performance of lambs, this effect was included in Model 1b, which had the following fixed effects:

i) Sex (1, 2)
ii) Type of birth (1, 2)
iii) Dam breed (1, 2, 3, 4, 5)
iv) Season of birth (1, 2, 3).

The effects due to Parity and Period of birth were not included in this model. The random effects in the estimation of heritability and repeatability were sires and dams, respectively. Repeatability was calculated as a trait of the dam whereas heritability, genetic and phenotypic correlations were calculated as direct traits of the lamb.

A paternal half-sib model (model 1a) was used to estimate heritability, genetic and phenotypic correlations.

$$Y_{ijklmnp} = u + a_i + S_j + D_k + SB_l + P_m + PB_n + e_{ijklmnp}$$

where $Y_{ijklmnp}$ = the measure on the p^{th} offspring of the n^{th} period of birth of m^{th} parity of the l^{th} season of birth of the k^{th} dam breed of the j^{th} sex and i^{th} sire.

u = the overall mean of the trait

a_i = the random effect of the i^{th} sire, assumed to be normally distributed with mean 0, and variance, σ_a^2

S_j = the fixed effect of the j^{th} sex

D_k = the fixed effect of the k^{th} dam breed

SB_l = the fixed effect of the l^{th} season of birth

P_m = the fixed effect of the m^{th} parity

PB_n = the fixed effect of the n^{th} period of birth, and

$e_{ijklmnp}$ = the random residual, assumed to be normally distributed with mean 0, variance σ_e^2.

In the estimation of heritability, only lambs born as singles were used because Model 1a was based on paternal half-sibs. However, Model 1b included type of birth as one of the fixed effects in order to examine its influence on growth performance of lambs. Type of rearing was ignored on the basis that lambs born single were invariably reared single whereas those born as twins were reared as twins.

The size of the variance component σ_S^2 is due to the fact that the sire groups differ. These groups are made up of half-sibs, and therefore, the variance component σ_S^2 is equivalent to the covariance among half-sibs.

$$\sigma_S^2 = (MS_S - MS_W)/k$$

where MS_S = the mean square between sires

MS_W = the mean square of progeny within sires

$k = (S-1)^{-1}[n. - (En_i^2)/n]$

S = number of sires

$n.$ = total number of observations

n_i = number of observations within the i^{th} sire = number of dams mated to the i^{th} sire.

$$\sigma_W^2 = MS_W$$

σ_S^2 estimates 1/4 of the additive genetic variance. The variance component, σ_W^2, estimates the remainder of the genetic variance plus all the environmental variance.

$$4\sigma_S^2 = V_A$$

$$\sigma_S^2 + \sigma_W^2 = V_P \text{ (individual basis)}$$

$$h_S^2 = 4\sigma_S^2/(\sigma_S^2 + \sigma_W^2)$$

The standard error is estimated using the approximate method of Swiger *et al.*, (1964) which assumes normality of the intraclass correlation, t.

$$S.E.(h_S^2) = \frac{4\sqrt{2(n.-1)(1-t)^2[1+(k-1)t]^2}}{k^2\ (n.-S)(S-1)}$$

$$t = \sigma_S^2/(\sigma_S^2 + \sigma_W^2)$$

The lambs born as twins were included in the estimation of repeatability where Model 2 was similar to model 1 except dams (random) were used instead of sires and type of birth was included as an additional fixed effect.

Repeatability estimation was based on the statistical model $Y_{km} = u + a_k + e_{km}$, where Y_{km} was the m th measurement on the k th dam. Thus, the variance component σ_a^2 represents differences among dams while σ_e^2 represents the differences among measurements within the individuals, these variances having been adjusted for fixed effects by including the latter in the model. The component, σ_a^2, estimates all the genetic variance and the portion of the environmental variance peculiar to the dam.

$$\sigma_e^2 = MS_e$$

$$\sigma_W^2 = (MS_W - MS_e)/k_1$$

Repeatability,

$$R = \sigma_W^2 / (\sigma_W^2 + \sigma_e^2)$$

$$k_1 = (D-1)^{-1}\ [m. - (Em_k^2)/m.]$$

where m. = total number of observations

m_k = number of observations taken on the k th individual

D = number of dams.

The estimation of standard error for repeatability is described by Swiger *et al.*, (1964).

$$\text{S.E. }(R) \simeq \frac{\sqrt{2(m.-1)(1-R)^{2}[1+k_{1}-1)R]^{2}}}{k_{1}^{2}(m.-N)(N-1)}$$

Estimation of genetic correlation between traits x and y was based on the formula:-

$$r_G = \frac{4\text{cov}_s}{\sqrt{4\sigma^2_{s(x)}4\sigma^2_{s(y)}}}$$

whereas environmental correlation is based on the formula :-

$$r_E = \frac{\text{cov}_W - 2\text{cov}_S}{\sqrt{\sigma^2_{W(X)}-2\sigma^2_{S(X)}}\sqrt{\sigma^2_{W(Y)}-2\sigma^2_{S(Y)}}}$$

The objective was to obtain an estimate of the environmental correlation as free as possible of genetic variances and covariance. This estimate contains 3/4 dominance covariance and varying amounts of epistatic covariance in its numerator.

The formula used to estimate phenotypic correlation was:-

$$r_P = \frac{\text{cov}_W + \text{cov}_S + \text{cov}_D}{\sqrt{\sigma^2_{W(X)}+\sigma^2_{S(X)}+\sigma^2_{D(X)}}\sqrt{\sigma^2_{W(Y)}+\sigma^2_{S(Y)}+\sigma^2_{D(Y)}}}$$

where cov_W = covariance among sibs, cov_S = covariance among sires, cov_D = covariance among dams, σ^2_W = variance component due to differences among individuals. It estimates all the genetic variance and the portion of the environmental variance peculiar to the individual, σ^2_S = the variance component due to the differences among sire groups. These groups are made up of half sibs and therefore, the variance component is equivalent to the covariance among half sibs, and σ^2_D = the variance component due to differences between dam groups. These groups are composed of full sibs so that σ_D^2 is the covariance of full sibs minus the covariance of sires half sib groups because the sire effect is removed in the analysis of variance (Becker, 1967).

4.0 RESULTS AND DISCUSSION

4.1 Factors Affecting Growth Characters

4.1.1 Dam Breed

The analysis of variance for body weights and growth rates are presented in Tables 4.1 and 4.2, respectively. The influence of dam breed on six and twelve months weights was significant (P<.01). Although dam breed did not affect birth, weaning and nine months weights significantly (Table 4.1), lambs from Dorper x Red Maasai ewes had consistently higher weights than their counterparts from Dorper ewes (Table 4.3). The lambs born of Dorper x Red Maasai ewes weighed more by .03, .31, 1.09, .81, and 1.22 kg at birth, weaning, six months, nine months and twelve months, respectively. Similarly, growth rates of lambs born by the Dorper x Red Maasai ewes were consistently superior (Table 4.4), except growth rate between six and nine months. Lambs born of Dorper x Red Maasai ewes were superior by .003, 0.008, .004 and .001 kg/day during preweaning, weaning to six months, nine to twelve months and overall growth rate from birth to yearling. Dorper x Red Maasai ewes produced lambs that were significantly (P<.05) faster growing between weaning and six months.

This superiority may be attributed to the fact that the Dorper x Red Maasai ewes are adapted to the environment in which the study was conducted. Although the lambs in this category

Table 4.1 ANALYSIS OF VARIANCE OF BODY WEIGHTS (For Model 1a)

Source of variation	df	Mean squares BIRTHW	ADJWWT	ADJSMW	ADJNMW	ADJTMW
Sires	62	0.73**	17.56**	40.63**	71.68**	98.21**
Sex	1	11.65**	446.46**	707.12**	1162.86**	2372.02**
Dam breed	1	0.07	9.58	117.82**	64.95	148.09**
Season of birth	2	0.09	116.64**	178.90**	104.62**	222.93**
Parity	3	1.63**	48.14**	30.09	4.41	2.47
Period of birth	2	2.17**	387.89**	709.82**	1285.41**	71.62
Error	1127	0.40	10.21	15.90	17.87	26.89

Key ** P<.01 * P<.05

Table 4.2 ANALYSIS OF VARIANCE OF GROWTH RATES (For Model 1a)

Source of variation	df	Mean squares x 10^{-3} GRATE1	GRATE2	GRATE3	GRATE4	OVRGRT
Sires	62	2*	3**	6**	6**	1**
Sex	1	39**	4	7*	26**	11**
Dam breed	1	1	7*	1	2	0
Season of birth	2	14**	1	13**	9**	7**
Parity	3	4*	0	2	0	0
Period of birth	2	42**	7**	13**	136**	2**
Error	1127	1.2	1.2	1.2	1.5	0.2

Key ** P<.01 * P<.05

Table 4.3 <u>LEAST SQUARES MEANS AND STANDARD ERRORS OF BODY WEIGHTS</u> (For Model 1a)

Category	No. of observ.	BIRTHW (kg)	ADJWWT (kg)	ADJSMW (kg)	ADJNMW (kg)	ADJTMW (kg)
Overall mean	1199	4.17±0.68	20.35±3.84	25.74±5.17	30.77±5.16	36.46±6.17
Males	579	4.25±0.10	20.18±0.49	25.79±0.80	31.24±1.11	36.55±1.29
Females	620	4.05±0.10	18.92±0.49	24.20±0.80	29.20±1.11	35.64±1.29
Dam breed 1	969	4.13±0.10	19.39±0.48	24.45±0.79	29.82±1.11	36.48±1.29
Dam breed 2	230	4.16±0.11	19.70±0.53	25.54±0.83	30.63±1.14	37.70±1.33
Season of birth 1	465	4.14±0.10	20.51±0.47	26.26±0.78	30.12±1.09	36.11±1.27
Season of birth 2	21	4.13±0.17	17.33±0.83	22.20±1.16	29.37±1.43	34.33±1.69
Season of birth 3	713	4.17±0.09	20.60±0.43	26.53±0.75	31.18±1.07	36.84±1.24
Parity 1	731	4.04±0.10	18.77±0.48	24.36±0.79	29.99±1.10	36.96±1.28
Parity 2	310	4.22±0.10	19.57±0.49	24.96±0.80	30.09±1.11	36.93±1.29
Parity 3	117	4.15±0.11	19.84±0.55	25.32±0.86	30.34±1.16	37.16±1.36
Parity 4	41	4.17±0.14	20.01±0.69	25.32±1.01	30.48±1.29	37.30±1.52
Period of birth 1	578	4.41±0.17	19.99±0.82	24.39±1.15	31.03±1.42	39.40±1.68
Period of birth 2	259	3.92±0.12	17.41±0.61	22.64±0.92	28.34±1.21	35.77±1.42
Period of birth 3	362	4.12±0.13	20.24±0.63	27.94±0.94	33.30±1.23	36.10±1.44

Key: Dam breed 1 = Dorper, Dam breed 2 = Dorper x Red Maasai

Season of birth 1 = Long rains (April & May), Season 2 = Short rains (October & November), Season 3 = Rest of the year(Dry season).

Parities 1, 2, 3 = Ewes that lambed once, twice, and three times.

Parity 4 = Ewes that lambed four or more times.

Period of birth 1 = 1978-1980, Period 2 = 1981-1985, Period 3 = 1986-1987.

Table 4.4 LEAST SQUARES MEANS AND STANDARD ERRORS OF RATES OF GROWTH (For Model 1a)

Category	No. of observ.	GRATE1 (kg/d)	GRATE2 (kg/d)	GRATE3 (kg/d)	GRATE4 (kg/d)	OVRGRT (kg/d)
Overall mean	1199	0.179±0.040	0.059±0.040	0.055±0.040	0.085±0.048	0.092±0.018
Males	579	0.176±0.005	0.062±0.006	0.060±0.010	0.081±0.010	0.104±0.004
Females	620	0.165±0.005	0.058±0.006	0.055±0.010	0.071±0.010	0.097±0.004
Dam breed 1	969	0.169±0.005	0.056±0.006	0.059±0.010	0.074±0.010	0.100±0.004
Dam breed 2	230	0.172±0.005	0.064±0.007	0.056±0.010	0.078±0.010	0.101±0.004
Season of birth 1	465	0.181±0.005	0.063±0.006	0.042±0.010	0.088±0.010	0.090±0.004
Season of birth 2	21	0.146±0.009	0.054±0.010	0.079±0.012	0.055±0.013	0.119±0.005
Season of birth 3	713	0.184±0.004	0.063±0.006	0.051±0.010	0.085±0.010	0.093±0.004
Parity 1	731	0.163±0.005	0.082±0.006	0.062±0.010	0.077±0.010	0.100±0.004
Parity 2	310	0.170±0.005	0.059±0.006	0.056±0.010	0.076±0.010	0.099±0.004
Parity 3	117	0.174±0.005	0.060±0.007	0.055±0.010	0.078±0.011	0.102±0.004
Parity 4	41	0.175±0.007	0.058±0.008	0.057±0.011	0.075±0.012	0.102±0.004
Period of birth 1	578	0.173±0.009	0.048±0.010	0.073±0.012	0.093±0.013	0.103±0.005
Period of birth 2	259	0.149±0.006	0.058±0.008	0.041±0.011	0.104±0.011	0.095±0.004
Period of birth 3	362	0.190±0.006	0.074±0.008	0.059±0.011	0.031±0.011	0.103±0.004

Key: Dam breed 1 = Dorper, Dam breed 2 = Dorper x Red Maasai

Season of birth 1 = Long rains (April & May), Season 2 = Short rains (October & November), Season 3 = Rest of the year(Dry season).

Parities 1, 2, 3 = Ewes that lambed once, twice, and three times.

Parity 4 = Ewes that lambed four or more times.

Period of birth 1 = 1978-1980, Period 2 = 1981-1985, Period 3 = 1986-1987.

were not first crosses between Dorper and Red Maasai, the heterotic effect cannot be ruled out completely. It is possible that the adaptability of the Red Maasai sheep combined with the fast growth rate inherent in Dorper sheep may have been responsible for the results obtained. Differences in the maternal abilities of the breeds would appear to be the main reasons for the observed differences in body weight. Similarly, Sidwell *et al.*, (1962, 1964) found that crossbred individuals were superior in all aspects of performance. They observed that there was an additional gain in the progeny from crossbred ewes when compared to averages computed from purebreds making up the crosses. Holtmann and Bernard (1969) stated that the superiority in the performance of crossbred lambs could be attributed to heterosis in the individual and the superior maternal influence and overall reproductive ability of the crossbred dam. In addition, Bonsma (1939, 1944a, 1944b) showed that the crossbred ewe provided more milk for lambs than the purebred ewe. Furthermore, the crossbred ewe had a more favourable lactation curve.

Tables 4.3 and 4.4 indicate that lambs from Dorper x Red Maasai ewes had an edge over their counterpart Dorpers in as far as growth traits were concerned. Kiriro (1986) who studied the Dorper, Red Maasai and their crosses reported that breed of lamb had a highly significant effect (P<.001) on birth weight, weaning weight and average daily gain of all the breed groups studied. Other workers who have reported a significant breed effect on weaning and preweaning average daily gain include Vesely *et al.*, (1970) and Stobart *et al.*, (1986). The superior six months weight in Dorper x Red Maasai lambs may be attributed to the faster growth rate between weaning and six months. It is evident that the superiority of lambs born of Dorper x Red Maasai ewes is not clearly manifested during the preweaning growth stages. This may be due to the masking effects of maternal influence in the preweaning period. In the postweaning period maternal effects are minimal hence allowing individual lamb superiority to be expressed. In addition, the crossbred seems to exhibit a better adaptability to postweaning stress than the pure Dorper.

4.1.2 Sex of Lamb

The effect of sex of lamb was highly significant ($P<.01$) for birth, weaning, six months, nine months and twelve month weights, with male lambs weighing .2, 1.26, 1.59, 2.04 and 2.91 kg heavier than females at the respective stages. These results agree with those reported elsewhere (Blackwell and Henderson, 1955; Dass and Acharya,1970; Vesely and Robison, 1970; Thrift *et al.*, 1973; Wright *et al.*, 1975; Smith, 1977; Martin *et al.*, 1980; Magid *et al.*, 1981; Fitzhugh and Bradford, 1983; Kiriro, 1986). However, Bodisco *et al.*, (1973) reported that sex of the new born lamb had no significant effect on birth weights analysed. The effect of sex of lamb on growth rates was highly significant ($P<.01$) during preweaning, nine to twelve months and birth to yearling growth periods. The effect was significant ($P<.05$) for six to nine months growth period but was not significant for weaning to six months growth period. Males grew faster than females by .011, .004, .005, .010 and .007 kg/day during preweaning, weaning to six months, six to nine months, nine to twelve months and birth to yearling period, respectively.

Sex of lamb effect may be attributed to hormonal differences in the two sexes and their resultant effects on growth (Velardo, 1958; and Bell *et al.*, 1970).

4.1.3 Parity

The effect of parity on lamb weight was significant ($P<.01$) at birth and weaning. Subsequent weights were not significantly influenced by parity. At birth, lamb weights were: 4.22±.01, 4.17±.14, 4.15±.11 and 4.04±.01 kg for parity 2, 4, 3 and 1, respectively. Thus, lambs born to ewes in parity 1 had the lowest birth weights. This may indicate that in parity 1 the ewe is still not yet fully developed hence not yet mature, and the uterine environment is limited by this immaturity. In subsequent parities the ewe appears to have fully developed so that the differences between lamb weights due to parities

2, 3 and 4 appears negligible. Basuthakur, *et al.*, (1973) suggested that lambs born to young dams compared with those from mature dams may have poor maternal environment, at least up to weaning.

Parity 4 ewes bore lambs that weaned heaviest, whereas parity 1 had the lowest weaning weights (Table 4.3). These results appear to support the notion that older ewes (higher parity) are better milkers and in effect better mothers than lower parity ewes (Dass and Acharya, 1970; Eltawil *et al.*, 1970; Wright *et al.*, 1975; Stobart *et al.*, 1986).

Among the rates of gain, only preweaning growth rate was significantly influenced by parity. Preweaning growth rates were .175±.007, 0.174±.005, .170±.005 and .163±.005 kg/day for parities 4, 3, 2 and 1. This finding also adds weight on the fact that higher parity ewes provide a superior maternal environment conducive to faster lamb growth rates.

Wilson, (1987) reported that parity (related to the dams age) had a significant effect on weight of lambs managed traditionally in Central Mali. Offspring from primiparous ewes were lighter than those from older ewes. Further, the generally non-significant reduction in weight of young from 4th parity and older females compared with those of third parity dams may be attributed to the decreasing ability of older females to cope with the combined effects of multiple pregnancies and lactations, and to normal environmental stress.

One can relate age of dam to parity. In most cases, the older the ewe the higher the likelihood of it having a high parity. In as far as age of dam and parity are positively correlated a study on age of dam effect on growth traits could very well give reliable results from which one could deduce the effect of parity. Dass and Acharya (1970) suggested that the higher birth weight of lambs born to older ewes was probably due to the increase in body size of the dam. Notter *et al.*, (1975), Vesely and Robison (1970), Stobart *et al.*, (1986); Wright *et al.*, (1975), Blackwell and Henderson (1955) all reported significant age of dam effect on weaning weight. In most cases older dams had heavier lambs at weaning.

In this study, the fact that parity did not significantly influence postweaning growth traits can be attributed to decreasing maternal effect as the lamb matures.

4.1.4 Season of Birth

Season of birth influenced all weights significantly except birth weight. This effect was highly significant for weaning, six months, nine months, and yearling weights $(P<.01)$. Even though season of birth did not have any significant influence on birth weight, season 2 (October-November) lambs had the highest birth weights followed by season 3 (rest of the year), and lastly season 1 (Table 4.1).

Seasonal influence on a trait such as birth weight operates through its effect on the dam's uterine environment mostly in late gestation (Eltawil *et al.*, 1970). Such factors operating in seasons prior to lambing will be manifested in birth weight. This may explain the higher (albeit non-significant) birth weight of lambs born in the dry season. That is, lambs born in the long dry season may be those whose ewes enjoyed the wet season during the critical stages of gestation. Such lambs would be expected to weigh more at birth compared to those whose dams underwent a nutritionally stressful period during gestation. It is, therefore, expected that the season when the ewe is in the latter stages of gestation is likely to play a more important role in birth weight than season of birth. On the other hand, season of birth plays an important role in the lamb's growth performance through its influence on the dam's nutrition (and hence amount of milk available to the unweaned lamb) and later, directly, through its effect on the pasture availability and quality on which the lamb is subsequently weaned. Season 3 had the highest birth weights possibly due to the benefits accruing from the favourable long and short rains occurring while the ewes were in gestation.

The effect of season of birth on weaning and subsequent weights was significant (P<.01). Season of birth effect was significant on weights from weaning to yearling, this happening at a time when the lamb was likely to derive maximum benefit from the pastures. During the preweaning stage, the lamb is largely dependent on the ewe's milk production to sustain its growth. At weaning and subsequent stages of growth it becomes crucial to utilize the pasture production to the full. As the dam responds to lush pastures, milk production increases. This is reflected in the lamb growth rate before weaning. Otherwise the significant influence of season of birth on growth rates (GRATE3, GRATE4 and OVRGRT) most likely operates directly on the lamb itself. This is corroborated by least squares means at weaning (Table 4.4): Season 3, 20.80±.43 kg; Season 1, 20.51±.47 kg; and Season 2, 17.33±.83 kg. Apparently the lead taken by season 3 lambs at birth gives these lambs an advantage over the other lambs. This superiority was maintained all the way up to yearling age.

The fact that season 3 results in the highest weaning weights seems to suggest that what matters is not the season in which the lambs are born but rather the prevailing season (hence conditions) during the preweaning growth of the lamb. There is normally a time lag between the onset of rains and the response of pastures to the rains received. Thus, lambs born at the end of the rainy season are likely to benefit more than those born within the rainy season.

The effect of season of birth was highly significant ($P<.01$) on all growth rates except during weaning to six months. What was surprising, however, was the fact that season of birth did not significantly influence weaning to six months growth rate, although it was a significant source of variation for growth rate before and after this period. This may be due to the postweaning stress which may have obscured the effect of season of birth. It was clear that no particular season of birth was associated with superior performance in all the phases of growth studied (Table 4.4).

The ranking of seasons differed between traits due to the variability in rainfall amounts received (Fig 3.2). During preweaning growth period, season 3 contributed to the highest weight gains, followed by seasons 1 and 2. The respective gains were .184±.004, .181±.005 and 0.146±.009 kg/day. Between weaning and six months, season 1 and 3 had the highest weight gains (.063±.006 kg/day) followed by season 2 (.054±.010 kg/day). Season 2 was superior followed by seasons 3 and 1 during six to nine months and overall growth rate. The weight gains were 0.079±.012, .051±.010 and .042±.010 for six to nine months and .119±.005, .093±.004 and .090±.004 kg/day for overall growth rate, respectively. During the nine to twelve months period of growth, season 1 was responsible for highest weight gains (.088±.010) followed by season 2 (.055±.013 kg/day). This change in rank may be attributed to the fact that, season 1 being the long rains, was responsible for good quality pastures and the efficiency of utilization by the lambs could be due to the stage of maturity attained.

Some workers have reported a significant year and season effect on birth weight (Eltawil *et al.*, 1970; Magid *et al.*, 1981). On the contrary, other workers reported that year of birth did not significantly influence lamb birth weight (Vesely and Robison,1970; and Dass and Acharya,1970).

Few studies have reported the influence of year or date of birth on preweaning performance in sheep. However, some workers have reported a significant year of birth effect on weaning weight, preweaning growth rate, postweaning gain and yearling weight, the general tendency being that better performance among the lambs was attributable to the years when conditions in the general physical environment e.g. forage availability was optimal (Dass and Acharya, 1970; and Vesely *et al.*, 1970). It is not realistic to compare the effect of season on growth based on experiments conducted in diverse areas. The main reason being that the criteria of classifying seasons are quite varied from place to place.

4.1.5 Period of Birth

Period of birth was a significant source of variation for all traits except weight at twelve months. As has been alluded to (chapter 3), period of birth was defined by grouping adjacent years which, from meteorological data, generally had the same rainfall pattern. To this end, the significance of this factor was only important because it facilitated the adjustments of records for the effect of 'periods'. Any particular period, on its own, has no important bearing on the interpretation of the results. That this effect was significant for all but one trait indicates that the 'groups' were different (indicating the necessity to include this source of variation in the model).

The effect of period of birth was highly significant (P<.01) for birth, weaning, six months and nine months weights. However, period of birth did not significantly influence yearling weights. The highest birth weights were recorded in period 1 (1978-1980) followed by period 3 (1986-87) and lastly period 2 (1982 and 1985). The birth weights recorded being 4.41±.17, 4.12±.13 and 3.92±.12 kg, respectively.

Period 1 received the highest rainfall (Figure 3.1). In addition, the annual rainfall distribution was uniform in this period. It may be inferred that the high birth weights were indirectly due to the nutrition of the ewes. Period 2 may have had the lowest birth weights due to the fluctuations in annual rainfall, which was not the case in period 3. Contradicting reports appear in the literature as far as the effect of year of birth on birth weights is concerned. Eltawil *et al.*, (1970) and Magid *et al.*, (1981) reported significance whereas Dass and Acharya (1970) and Vesely and Robison (1970) reported non-significant year effects.

At weaning, six and nine months, period 3 had consistently the highest weights followed closely by period 1 and lastly period 2, although period 3 received the least amount of rainfall. At one year of age , period 1 was associated with the highest weight followed by periods 3 and 2.

The effect of period of birth was highly significant (P<.01) on all growth rates. The greatest weight gains from birth to six months, six to nine months, and nine to twelve months were attributed, respectively to, period 3, period 1, and period 2. What seems most conclusive, however, is the overall growth rate (birth to yearling) in which it was evident that periods 1 and 3 influenced growth rates to about the same extent (.103kg/day) followed by period 2 (.095kg/day).

Apparently, the rainfall amount received *per se* is not critical, but rather its distribution which has the most favourable effect on growth rate of lambs. This seems to be the crux of the matter. Periods 1 and 3 had the most favourable distribution patterns, while period 2 (1982, 1985) had a wide fluctuation in its distribution of rain (Fig 3.1). Period 1 received the most whereas period 3 received the least rainfall, however, both periods had a better distribution compared to period 2.

4.1.6 Type of Birth and Rearing

The effect of type of birth had a highly significant (P<.01) influence on all body weights studied (Tables 4.5 and 4.6). In all cases, lambs born and reared as singles far exceeded lambs born and reared as multiples in weight. The superiority in weight of single born lambs over lambs born as multiples was .74, 5.84, 4.77, 3.93 and 3.04 kg for birth, weaning, six months, nine months and twelve months weights, respectively (Table 4.7). That the greatest difference in weight occurred at weaning is noteworthy. This may be as a result of the superior maternal influence of ewes on their single-born lambs expressed in the absence of within-litter competition.

Other studies (Bichard and Cooper 1966, Louca *et al.*, 1974, and Mavrogenis and Louca, 1979) have reported that single lambs were heavier than multiples, but no differences were found in growth rate after weaning between lambs from different sizes of litter. It is apparent that, after weaning, rate of growth may be more indicative of growth potential than is live weight at a fixed age.

Type of birth was highly significant (P<.01) on all growth rates. Single lambs grew faster than multiples during the preweaning and birth to yearling growth stages. It is interesting that whereas the single lambs had an edge over the multiples in terms of weight at specific points, the multiples grew faster at all stages except during preweaning growth periods (Table 4.8). The slower growth rate in the preweaning stage for the multiples is to be expected due to the competition for milk. The high overall growth rate (.01 g/day) estimated for singles is attributable mainly to the faster rate of growth preweaning (.056

Table 4.5 <u>ANALYSIS OF VARIANCE OF BODY WEIGHTS</u> (For Model 1b)

Source of variation	df	Mean squares				
		BIRTHW	ADJWWT	ADJSMW	ADJNMW	ADJTMW
Sires	63	3.16**	5.12**	9.24**	5.81**	5.55**
Sex	1	31.96**	43.73**	53.45**	72.07**	128.86**
Type of birth	1	311.64**	708.51**	312.76**	184.47**	85.05**
Dam breed	4	0.51	0.53**	4.61**	2.22	2.55*
Season of birth	2	3.31*	32.62**	31.30**	17.70**	10.95**
Error	1478	0.43	11.88	18.00	20.76	26.80

Key ** P<.01 * P<.05

Table 4.6 <u>ANALYSIS OF VARIANCE OF GROWTH RATES</u> (For Model 1b)

Source of variation	df	Mean squares				
		GRATE1	GRATE2	GRATE3	GRATE4	OVRGRT
Sires	63	4.51	5.09	6.65	4.21	4.61
Sex	1	33.42**	6.49*	5.77*	25.18**	69.40**
Type of birth	1	591.58**	26.95**	17.47**	12.52**	57.52**
Dam breed	4	0.54	5.32**	3.08*	0.93	0.31
Season of birth	2	31.51**	1.56	2.25	14.24**	62.08**
Error	1478	0.0013	0.0013	0.0012	0.0020	0.000002

Key ** P<.01 * P<.05

Table 4.7 <u>LEAST SQUARES MEANS AND STANDARD ERRORS OF BODY WEIGHTS</u> (For Model 1b

Category	No. of observ.	BIRTHW (kg)	ADJWWT (kg)	ADJSMW (kg)	ADJNMW (kg)	ADJTMW (kg)
Males	762	3.81±0.13	16.86±0.93	23.22±1.57	28.73±1.32	37.76±1.46
Females	788	3.62±0.13	15.67±0.93	21.60±1.57	26.72±1.31	34.70±1.46
Singles	1199	4.08±0.13	19.19±0.92	24.80±1.57	29.69±1.31	37.75±1.45
Multiples	351	3.34±0.14	13.35±0.93	20.03±1.58	25.76±1.32	34.71±1.47
Dam breed 1	1243	3.74±0.13	16.16±0.92	21.64±1.57	27.50±1.30	35.63±1.44
Dam breed 2	30	3.75±0.18	15.86±1.14	22.00±1.77	26.06±1.58	34.82±1.77
Dam breed 3	52	3.79±0.16	16.64±1.03	22.20±1.66	28.20±1.44	37.44±1.60
Dam breed 4	197	3.73±0.14	16.51±0.93	23.35±1.58	28.42±1.32	36.74±1.47
Dam breed 5	28	3.57±0.18	16.18±1.12	22.87±1.75	28.44±1.55	36.52±1.73
Season of birth 1	579	3.83±0.13	18.20±0.92	24.74±1.57	29.62±1.31	37.23±1.45
Season of birth 2	40	3.53±0.17	13.32±1.06	18.84±1.70	24.89±1.49	33.68±1.66
Season of birth 3	931	3.78±0.13	17.28±0.91	23.65±1.56	28.66±1.30	37.78±1.44

Key: Dam breed 1 = Dorper, 2 = Return 3 x DRM, 3 = Return 4 x DRM,

4 = Return 1 x Return 1, 5 = Return 2 x Return 2

(For details see Chapter 3).

Season of birth 1 = Long rains (April & May), Season 2 = Short rains (October & November), Season 3 = Rest of the year (Dry season).

Multiples = lambs born as twins or triplets.

Table 4.8 LEAST SQUARES MEANS AND STANDARD ERRORS OF RATES OF GROWTH

Category	No. of observ.	GRATE1 (kg/d)	GRATE2 (kg/d)	GRATE3 (kg/d)	GRATE4 (kg/d)	OVRGRT (kg/d)
Males	762	0.145±0.009	0.070±0.010	0.081±0.011	0.100±0.011	0.101±0.004
Females	788	0.134±0.009	0.065±0.010	0.056±0.011	0.088±0.011	0.095±0.004
Singles	1199	0.167±0.009	0.062±0.010	0.054±0.011	0.089±0.011	0.102±0.004
Multiples	351	0.111±0.009	0.074±0.010	0.063±0.011	0.099±0.011	0.094±0.004
Dam breed 1	1243	0.138±0.009	0.060±0.010	0.065±0.011	0.090±0.011	0.098±0.004
Dam breed 2	30	0.134±0.012	0.068±0.012	0.045±0.013	0.097±0.014	0.098±0.005
Dam breed 3	52	0.142±0.010	0.061±0.011	0.068±0.012	0.102±0.012	0.099±0.004
Dam breed 4	197	0.141±0.009	0.076±0.010	0.056±0.011	0.092±0.011	0.098±0.004
Dam breed 5	28	0.140±0.011	0.740±0.012	0.061±0.012	0.089±0.013	0.099±0.005
Season of birth 1	579	0.159±0.009	0.722±0.010	0.054±0.011	0.084±0.011	0.089±0.004
Season of birth 2	40	0.108±0.011	0.061±0.011	0.067±0.012	0.097±0.013	0.117±0.005
Season of birth 3	931	0.150±0.009	0.070±0.010	0.055±0.011	0.101±0.010	0.088±0.004

Key: Dam breed 1 = Dorper, 2 = Return 3 x DRM, 3 = Return 4 x DRM,

4 = Return 1 x Return 1, 5 = Return 2 x Return 2

(For details see Chapter 3).

Season of birth 1 = Long rains (April & May), Season 2 = Short rains (October & November), Season 3 = Rest of the year(Dry season).

Multiples = lambs born as twins or multiples.

kg/day). Lambs born as multiples grew faster by 0.012, .009 and .01 kg/day at weaning to six months, six to nine months and nine to twelve months stages, respectively. This observed relationship appears to be a classical example of compensatory growth. Stobart *et al*., (1986) observed that a relationship like this tends to support the hypothesis that faster growth during one interval will tend to result in slower growth in a subsequent interval. Lambs that grow faster preweaning have a reduced growth impetus postweaning. It seems that the potential of growth inherent in the lambs born as multiples was hampered in the preweaning period due to limitations associated with maternal effects. Several studies have reported an accelerated rate of growth after a period of undernutrition. When the restriction was removed, the animals exhibited a growth rate greater than normal for animals of the same chronological age (Osborne and Mendel, 1916; Bohman 1955). This results from a homeostatic mechanism essential for survival in a fluctuating environment (Wilson and Osbourn, 1960).

Type of birth and rearing is often considered to be primarily an environmental source of variation in productivity traits of sheep, nevertheless, Basuthakur *et al*., (1973) reported a relatively small hereditary component associated with it. It was further suggested that lambs born and reared as twins compared to singles are considered to have poorer maternal environment for growth, at least up to weaning.

Comparing Tables 4.1 vs 4.5, 4.2 vs 4.6, 4.3 vs 4.7, and 4.4 vs 4.8, it is evident that inclusion of type of birth effect in the model did not significantly change the trend of the other fixed effects. For instance, the effects of sex and season of birth on growth traits were highly significant in both models. The influence of dam breed on growth performance of lambs in both models was essentially similar.

4.2 Repeatability Estimates

In order to estimate the effectiveness of selection, it is necessary to know the repeatability of the traits which measure production (Botkin and Whatley, 1953). Further, repeatability of the traits must be known in order to compare accurately the producing ability of ewes with varying numbers of records.

The repeatability fraction includes all differences due to permanent differences between ewes, and thus measures the accuracy of past production in predicting future production of the same flock of ewes. Since some of the permanent differences between ewes may be non-transmissible, repeatability will be at least as great, and probably greater, than heritability. Thus, repeatability can be used to indicate the immediate gain in future production of the flock which may be achieved by selection; but to the extent that it contains non-hereditary differences between ewes, it tends to overestimate what can be gained in future generations by selection.

Repeatability was estimated for three traits, namely birth weight, weaning weight and preweaning growth rate. These are the traits usually considered to have a high enough maternal component to be analysed as traits of the dam (Cunningham and Henderson, 1965; Minyard and Dinkel, 1965; Sellers *et al.*, 1970). In the postweaning stage, the ability of the lamb to grow is largely an expression of its genetic potential and not maternal effects of the dam. All the repeatability estimates were high (.55 for birth weight, .57 for weaning weight and .56 for preweaning growth rate). Preliminary selection could be conducted during the preweaning period since repeatability estimates are favourable. This indicates that replacement ewes can be selected for these traits on the basis of initial lambs with a considerably high accuracy. However, the high maternal influence preweaning must not be ignored as it tends to mask the true genetic merit in the lambs.

Harrington and Whiteman (1967) reported repeatability estimates of lamb birth weight ranging from .35 to .37, and .21 to .24 for 70-day weight, for adjusted and unadjusted data, respectively, and .07 to .14 for rate of gain from 70-140 days. The repeatability estimate for the adjusted data should be somewhat higher than in the unadjusted data since the influence of sex, type of birth and year should be relatively independent of the ewe effect. In general, while comparing repeatability estimates of lamb birth weight, 70-day weight and rate of gain from 70-140 days as a characteristic of the ewe, there was a steady decline in the magnitude of the estimates as the lambs grew older, which, reflects a decline in maternal influence on the lamb.

Comparison of repeatabilities is not straightforward. Sellers *et al.*, (1970) stated that this difficulty stems from the fact that repeatability is due to at least two components and the relationship between them. The dam gives to her offspring 1/2 of her genes. Thus, 1/4 of the genes for growth of the offspring are, on average, common for maternal half-sibs. The second component involves maternal environment created for offsprings of the same dam. This involves the expression of genes for maternal performance of the dam in the weaning weight of her progeny and permanent environmental effects common to progeny of the same dam. If a covariance exists between genes for growth and maternal ability, it may be either positive or negative. A negative covariance can cover up a positive variance, making comparison of repeatability difficult.

Minyard and Dinkel (1965) reported repeatability values for weaning weight of .42, 0.52 and .42 for the Hereford, Angus and the breeds combined, respectively. They suggested selection for high-producing cows could be practiced early in their productive life based on the relatively high repeatability of weaning weight. Sellers *et al.*, (1970) reported values of 0.19 in Hereford and .27 in Angus. Itulya *et al.*, (1987) reported repeatability estimate for adjusted weaning weight ratio of .25 in unsupplemented Hereford range cows. Alenda and Martin (1987) analysed repeatabilities of calf weights and gains as traits of the dam. The estimated repeatabilities for male and female data sets, respectively, were 0.26 and .29 for birth weight; and .43 and .28 for weaning weight. Cantet *et al.*, (1988) reported repeatability estimates of Hereford calves as .21 for birth weight and .30 for weaning weight.

Botkin and Whatley (1953) observed that if birth weight is used as a measure of a cow's production, selection on the basis of the first record would not be very accurate. However, birth weight is not nearly as useful as weaning weight as a measure of production. Gain from birth to weaning makes up the greatest portion of weaning weight, so is quite comparable to weaning weight as a measure of production. Likewise, repeatability of gain from birth to weaning seems to be quite comparable to that of weaning weight. An estimate of repeatability is merely a description of a certain population under certain conditions of environment. The application of the estimate, therefore, is limited to those situations where cattle are handled under conditions similar to those from which the estimate was obtained, and weights corrected for the same sources of variation. However, the similarity of different estimates of repeatability of the various traits in beef cattle indicates that the same estimate can be used with confidence under quite a variety of conditions.

The relatively high repeatability of preweaning performance obtained in this study indicates that selection for high performance in this flock of sheep can be practiced early in their productive life. Since ewes at both extremes, i.e. very high or very low performers, contribute much more to the repeatability of weaning weight than those near the average, the very low performers can be culled on the basis of their first records with little risk of culling good ewes (Minyard and Dinkel, 1965).

4.3 Heritability Estimates

The heritability estimates and their respective standard errors (S.E.) are presented in Table 4.9. Heritability estimate obtained for birth weight was low (.18±.07). This result is consistent with results obtained by other workers such as Dzakuma *et al.*, (1978), Thrift *et al.*, (1973), Mavrogenis *et al.*, (1980), and Kiriro (1986), who reported similarly low heritability estimates for birth weight (.21±.08, .10±.07, 0.13±.07, and 0.14±.06, respectively). On the other hand, Stobart *et al.*, (1986), Vogt *et al.*, (1967) and Dass and Acharya (1970) reported higher heritability estimates (.46±.12, .31±.20 and 0.45±.20, respectively).

Table 4.9. Heritabilities and Genetic, Phenotypic, and Environmental Correlations from Paternal Half-sib analyses.

Trait	BIRTHW	ADJWWT	ADJSMW	ADJNMW	ADJTMW	GRATE1	GRATE2	GRATE3	GRATE4	OVRGRT
BIRTHW	0.18[a]	0.90[b]	0.35	0.21	0.64	0.85	-0.20	-0.03	0.64	0.38
	±0.07	±0.18	±0.22	±0.21	±0.17	±0.27	±0.28	±0.21	±0.18	±0.21
ADJWWT	0.34[c]	0.15	0.74	0.47	0.63	0.99	0.29	-0.04	0.31	0.41
	0.23[d]	±0.07	±0.13	±0.18	±0.16	±0.01	±0.27	±0.22	±0.22	±0.20
ADJSMW	0.18	0.64	0.31	0.59	0.37	0.81	0.86	-0.11	-0.21	0.31
	0.13	0.63	±0.09	±0.12	±0.16	±0.14	±0.08	±0.19	±0.18	±0.17
ADJNMW	0.19	0.53	0.69	0.52	0.72	0.52	0.48	0.74	-0.21	0.86
	0.20	0.62	0.77	±0.12	±0.08	±0.19	±0.16	±0.09	±0.17	±0.08
ADJTMW	0.25	0.47	0.56	0.74	0.47	0.61	0.04	0.58	0.53	0.90
	0.10	0.45	0.69	0.76	±0.11	±0.19	±0.20	±0.12	±0.12	±0.04
GRATE1	0.15	0.98	0.63	0.52	0.45	0.11	0.39	-0.03	0.22	0.40
	0.03	0.98	0.62	0.60	0.45	±0.08	±0.31	±0.25	±0.25	±0.22
GRATE2	-0.10	-0.16	0.65	0.36	0.25	-0.15	0.25	-0.12	-0.53	0.14
	-0.07	-0.28	0.58	0.31	0.37	-0.27	±0.08	±0.20	±0.17	±0.20
GRATE3	0.04	-0.05	-0.26	0.52	0.33	-0.05	-0.29	0.60	-0.08	0.80
	0.08	-0.06	-0.41	0.26	0.04	-0.08	-0.44	±0.13	±0.17	±0.08
GRATE4	0.14	0.05	-0.02	-0.13	0.57	0.03	-0.07	-0.16	0.51	0.22
	-0.08	-0.06	0.11	-0.05	0.61	-0.04	0.20	-0.26	±0.12	±0.18
OVRGRT	0.13	0.35	0.38	0.67	0.80	0.35	0.14	0.44	0.37	0.45
	0.03	0.36	0.43	0.49	0.72	0.36	0.15	0.05	0.50	±0.11

[a] Heritabilities with standard errors below them on primary diagonal.

[b] Genetic correlations with standard errors below them are reported above the diagonal.

[c] Phenotypic and [d] Environmental correlations are reported below the diagonal.

Heritability estimates for birth weight appear to vary considerably. There are, however, no popular attributes attached to high estimates of heritability for birth weights because the consequences may be undesirable if the trait was transmitted extensively through direct or indirect selection. Above average birth weights of lambs have been considered a major cause of lamb and ewe mortality at lambing (Shelton, 1964; Thrift *et al.*, 1967; Olson *et al.*, 1976; Martin *et al.*, 1980; Mavrogenis *et al.*, 1980).

The heritability estimate for weaning weight (.15±.07) was lower than that for birth weight. Dass and Acharya (1970), Mavrogenis *et al.*, (1980), and Stobart *et al.*, (1986) reported higher estimates of .68, .36, and .28, respectively. Kiriro (1986) reported a lower estimate of .08.

The heritability estimate for six months weight can be considered as moderate (.31±.09). This result compares favourably with that reported by Dzakuma *et al.*, (1978) of .28±.10. It is, however, much lower than that .80 reported by Bhasin (1969).

The estimates of heritability obtained for nine month weight and twelve month weight were high (.52±.12 and .47±.11, respectively). The heritability estimate for yearling weight was much higher than the estimate of .38±.23 reported by Dass and Acharya (1970), .11±.10 by Dzakuma *et al.*, (1978), and .26±.11 by Stobart *et al.*, (1986).

It is clear from these results that postweaning growth generally had higher heritability estimates than preweaning growth , a conclusion also reached by Hundley and Carter (1956); Givens *et al.*, (1960); Carter and McClure (1962); Harrington *et al.*, (1962); Butcher *et al.*, (1964); Vogt *et al.*, (1967); Thrift *et al.*, (1971; 1973) and Mavrogenis *et al.*, (1980). This would indicate that environmental factors, such as milk production of the ewe, in relation to additive genetic factors, had more influence on early lamb gain than on gains later in the lamb's life. This may be attributed to the high maternal influence associated with lamb growth performance early in life. High maternal influence has a tendency to increase the environmental component of variance (to the lamb) thereby lowering heritability estimates. Thus, heritability estimates for preweaning gain would be expected to be lower than those for postweaning gain.

Heritability estimates for growth rates are presented in Table 4.9. Preweaning growth rate had a low heritability estimate (.11±.06). This value was consistent with estimates of .18 by Givens *et al.*, (1960), .10±.055 by Kiriro (1986) and .21±.11 by Stobart *et al.*, (1986). However, Hundley and Carter (1956), Vogt *et al.*, (1967) and Mavrogenis *et al.*, (1980) reported higher estimates (.37, .39 and .35, respectively).

Growth rate from weaning to six months had a medium heritability estimate (.25±.08).

Mavrogenis *et al.*, (1980) reported an estimate of 0.56 from weaning to 20 weeks. The heritability estimate for six to nine months, nine to twelve months and birth to yearling were all high (.60±.13, .51±.12 and .45±.11, respectively). Stobart *et al.*, (1986), reported estimates of 0.29±.11 and .52±.12 for overall and for weaning to twelve months growth rate, respectively.

On the basis of the results of this study it appears that the most desirable selection criterion for increased growth rate in this flock would be body weight at six, nine or twelve months of age. These traits should be superior to weaning weight or preweaning growth rate, since they are much less influenced by maternal effects obscuring the genotype for growth. Although generation interval may be slightly longer, overhead costs should certainly be curtailed since the rest of the lamb crop could be disposed of at this time. In cases of low heritability, the option open is to improve environmental effects such as grazing management, nutrition and flock health, *inter alia*.

4.4 Genetic, Phenotypic and Environmental Correlations between Traits.

4.4.1 Genetic Correlations.

The genetic correlation is a measure of the extent to which the same genes, or closely linked genes, cause simultaneous variation in two different traits (Hohenboken, 1985). It describes the extent to which individuals genetically above average for one trait are genetically above, equal to or below average for a second quantitative trait. The actual genetic correlation between two traits in any population is the net effect of pleiotropy from as many segregating loci as affect both traits or linked loci as affect the traits separately. The correlation will be positive or negative depending upon whether the preponderance of pleiotropic or linkage effects results in positive or negative associations. It can be zero if none of the same or closely linked genes affect both traits or if positive effects of some loci cancel negative effects of others.

Estimates of genetic correlations between pairs of traits are presented in Table 4.9. Positive genetic correlations between weights were obtained as shown in Table 4.9. Birth weight was very highly correlated to weaning weight (.90±.18). High genetic correlation between birth and weaning weight has also been reported by Osman and Bradford (1965), Dzakuma *et al.*, (1978), Kiriro (1986), and Stobart *et al.*, (1986). Koch and Clark (1955) advanced the concept that high genetic correlation between birth and weaning weights indicates that many of the same genes affect prenatal and postnatal growth to weaning. Other workers have reported positive genetic correlations between birth weight and other weights. However, Dzakuma *et al.*, (1978) reported a genetic correlation of -.11 between birth weight and six months weight. Dzakuma *et al.*, (1978) and Stobart *et al.*, (1986) reported low values for genetic correlation between birth weight and twelve months weight (.13 and .22, respectively).

In this study, high genetic correlations were not confined to adjacent weights as reported by other workers. Stobart *et al.*, (1986) observed that genetic correlations were highest between adjacent intervals and tended to decline for gain intervals separated by more days. The correlations tended to decrease as the time interval separating the observed weights increased. A common characteristic of all correlations among weights, whether phenotypic or genetic, is that correlations between weights having closer proximity in time tend to be higher (Fitzhugh and Taylor, 1971; Ercanbrack and Price, 1972; Rae 1982). All adjacent weights were highly correlated. In addition, all weights except six month weight were highly correlated with twelve month weight. The high genetic correlations obtained in this study suggests that selection for any one weight would result in considerable positive correlated response in most other traits.

In order to minimize the effect of selection for weight on birth weight and possible increased frequency of dystocia, selection would best be directed towards weights at later ages (Thrift *et al.*, 1967; Olson *et al.*, 1976; Martin *et al.*, 1980; Mavrogenis *et al.*, 1980). However, selection for weights at later ages would be expected to lead to increased mature weights and greater maintenance requirements.

Shelton (1964) observed that birth weight is genetically correlated with the other traits and is very important from the standpoint of its relationship with lamb death losses and certain productive characters and that direct selection for this trait alone could create lambing problems due to increased size of lambs at birth. Thus, where it is desirable to select for increased growth rate in a flock, it is suggested that selection be directed at traits such as postweaning gain other than birth weight.

Genetic correlations between weights and rates of growth were mainly positive indicating the possibility of correlated response in subsequent rates of growth when selection for growth is based on body weights at specific points. Genetic correlation between birth weight and preweaning growth rate was high (.85±.27) contrary to values of .06, .06, and .09 in Rambouillet, Targhee and Columbia breeds of sheep (Ercanbrack and Price, 1972) and .16 in Chios lambs (Mavrogenis *et al*., 1980). The negative genetic correlations noted between body weights and growth rates were generally low and not significantly different from zero. Birth weight was positively correlated with growth rates preweaning, nine to twelve months and birth to yearling. Koch and Clark (1955) reported that the negative genetic correlation between preweaning gain and postweaning gain could be due to chance, a real genetic antagonism, or the automatic negative correlation between gains made in adjacent periods because of differences in fill. Apparently, different sets of genes condition the response of lambs in the preweaning and postweaning periods (Koch and Clark, 1955). Selection based on preweaning gain would be ineffectual in improving the genotypes for later gains.

There was a positive genetic correlation between weaning weight and all rates of growth except growth rate from six to nine months (-0.04±.22). Six month weight was correlated positively with all growth rates except six to nine month and nine to twelve month growth stages (-.11±.19 and -.21±.18, respectively). The genetic correlation between nine months weight and the growth rates studied was highly positive except in the case of nine to twelve months growth period (-.21±.17). In general, a majority of the negative genetic correlations between weights and rates of growth were not significantly different from zero. Most of the negative genetic correlations between pairs of traits were also lower than the corresponding phenotypic correlations, contrary to the observations reported elsewhere. Searle (1961) noted that in many instances the estimate of a phenotypic correlation was smaller in magnitude than that of the corresponding genetic correlation. Such results may seem a little surprising at first sight since phenotype includes genotype and one might anticipate the correlation between phenotypes to be larger than that between genotypes. When estimates have not followed this pattern, such as in this study, the explanation is sometimes given that a phenotypic correlation less than a genetic correlation is the result of a negative environmental correlation in the record of the two traits. Generally, the negative phenotypic correlation was noted in cases where the pairs of traits were separated by large time intervals. Apparently, these pairs of traits are conditioned by different sets of genes.

On the other hand, twelve month weight was positively correlated with all growth rates. This augurs well as far as correlated response is concerned. The breeder may base his selection on any of the growth rates except weaning to six months, which was low, and expect to obtain significant genetic progress in yearling weight. It would, therefore, be advisable to base selection on any other growth rate other than this particular one.

The genetic correlation between the rates of growth themselves are presented in Table 4.9. In general, most correlations were positive. All the negative correlations observed were not significantly different from zero except, for the correlation between GRATE2 and GRATE4 (-.53±.17). Preweaning growth rate was positively correlated with all other growth rates except the rate between six to nine months (-.03±.25). It may, therefore, be concluded that selection based on preweaning rate of growth is likely to elicit positive correlated response in most rates of growth in the subsequent growth periods.

Low genetic correlations between growth rates in different periods may be attributed to differences in genes influencing the pairs of traits, random error especially in relation to the size of the data set, or other uncontrolled factors in the data.

4.4.2 Phenotypic Correlations.

The phenotypic correlation (r_p) between two quantitative characteristics describes the extent to which individuals above average for one trait are observed to be above, below, or near average for the other trait (Hohenboken, 1985). It measures the linear association between traits; that is, it predicts the deviation from the population mean in one trait of an individual as a function of its deviation from the population mean of the other (when both are measured in their respective phenotypic standard deviation units).

Phenotypic correlations among weights, between weights and rates of growth and among growth rates themselves are presented in Table 4.9. The phenotypic correlations between birth weight and weaning weight obtained in this study are similar to those reported by Ercanbrack and Price (1972), Mavrogenis *et al.*, (1980) and Stobart *et al.*, (1986). Phenotypic correlations, like the genetic correlations between weights, were all positive ranging from .18 to 0.74.

Similarly, a trend that was clearly discernible was the generally higher correlations between adjacent weights. The phenotypic correlation between birth weight and yearling weight (.25) is not very different from that reported by Stobart *et al.*, (1986) of .37. Between weaning weight and twelve months weight Stobart *et al.*, (1986) reported a correlation of 0.59.

The phenotypic correlation between birth weight and growth rates was generally low and positive except for weaning to six months growth period which had a correlation of -.10. The correlation of weaning weight and preweaning growth rate was notably high and positive (.98). This is to be expected since the weaning weight is largely dependent on the preweaning growth rate which in turn is influenced by the dam's milk yield and indirectly through the pasture's nutritive status, *inter alia*. Vogt *et al.*, (1967) reported a phenotypic correlation of .27 between birth weight and preweaning growth rate. This was slightly higher than that obtained in this study. As would be expected, six months weight was highly correlated with the preweaning growth rate and growth rate in the interval preweaning to six months (.63 and .65, respectively).

Nine months weight was mainly positively correlated with all growth rates with the exception of nine to twelve month growth rate (-.13), whereas twelve month weight was phenotypically positively correlated with all rates of growth. A notable feature in the phenotypic correlations was the progression in magnitude of this relationship between body weight and overall growth rate (birth to yearling), as the lamb matured (.13, .35, .38, .67 and .80). This may be attributed to the fact that all the lamb weights fall in the interval birth to yearling. On the other hand, this could have resulted purely by chance. In addition, most phenotypic correlations between weights and overall growth rate were lower than their genetic counterparts. Searle (1961) stated that a phenotypic correlation less than its genetic counterpart, together with a small positive environmental correlation, will occur where the genes governing the two traits are similar but where the environments pertaining to the expression of these traits have a low correlation.

The phenotypic correlations among growth rates themselves were generally low to medium with some having negative correlations. The negative correlations (-.015 and -.05) between preweaning growth rate and growth rate in the intervals weaning to six months and six to nine months, respectively, seem to support the notion that correlations between growth rates in adjacent age intervals tend to be negative, possibly due to transient associations which appear only when the growth rate intervals have a common end point (Fitzhugh and Taylor, 1971; Stobart *et al.*, 1986). This observed relationship tends to support the hypothesis that faster growth during one interval will tend to result in slower growth in a subsequent interval. The concept of compensatory gain is illustrated by these observations; i.e. lambs that grow faster preweaning have a reduced growth rate impetus postweaning. However, the negative values obtained in this study do not seem to be so significant as to be the basis of a sound conclusion.

In addition, the phenotypic correlations between overall growth rate and all other growth rates of the lamb before yearling were consistently positive. This is to be expected since all the other growth rates are subsets of overall growth rate and are generally positively correlated. The negative correlations which appear in some growth periods such as between weaning to six months and nine to twelve months (-.07), and six to nine months and nine to twelve months (-.16) were small and insignificant statistically.

4.4.3 Environmental Correlations.

An environmental correlation (r_e) between two traits arises from the same environmental effect causing simultaneous variation in both the traits. Technically, r_e is not strictly environmental. Any correlation between traits caused by dominance effects and most of the correlation caused by epistatic effects of genes also contributes to r_e, since it is estimated as a difference function from r_g, which is caused only by average effects and a small part of epistatic genes on both traits.

It is not possible in livestock to separate true environmental from non-additive genetic portions of r_e (Hohenboken, 1985). The environmental correlation computed between two traits in a population is the effect of environmental and non-additive genetic factors causing the two traits to co-vary in positive and negative directions. The environmental correlations can equal zero if such positive and negative effects cancel one another out or if there are no environmental or non-additive genetic factors causing simultaneous variation in two traits.

Both genetic (r_g) and environmental (r_e) correlations contribute to the phenotypic correlation (r_p) between traits in a population. Their contribution is not strictly additive however, nor is r_p the numerical mean of r_g and r_e as might be expected. Rather their contribution to r_p is a function of the proportion of phenotypic variance in each trait attributable to genetic and environmental influences (Hohenboken, 1985).

Table 4.9 contains the environmental correlations estimated between pairs of traits in this study. Between body weights, all the environmental correlations were positive ranging from .10 to .77. Traits closer in time tended to have the highest environmental correlation. This is to be expected because traits adjacent to each other are more likely to be influenced by similar environmental factors than those traits that are separated by long time intervals.

The environmental correlations between birth weight and all growth rates were all quite low, although some were positive whereas others were negative. That there is a low (but positive) environmental correlation between birth weight and preweaning growth rate is not surprising. This is because birth weight is largely influenced by the uterine environment and nutrition of dam during gestation whereas preweaning growth rate is mainly affected by the nutrition of the dam post-natally, its milk production potential and mothering ability. In general, the factors operational are different in nature and occur at different physiological stages. The positive correlation, though low, may be attributed to the common influence of the dam on both the birth weight and preweaning growth rate of the lamb.

Birth weight had a negative environmental correlation with growth rates from weaning to six months and nine to twelve months. However, there was a low but positive correlation with six to nine months growth rate. These results appear to point to the fact that factors that influence the lamb's growth preweaning are different from those that are operational during the postweaning period. This observation is also corroborated by the environmental correlation estimated between weaning weight and the growth rates in the periods weaning to six, six to nine and nine to twelve months (-.28, -.06 and -.06, respectively). The high environmental correlation between weaning weight and preweaning growth rate (.98) is expected due to the similarity of factors that influence both weaning weight and preweaning growth rate. These are maternal effects such as age of dam, parity, milking and mothering ability (de Rose *et al.*, 1988). The correlations between rate of growth in the period birth to yearling and all body weights were positive ranging from .03 for birth weight and progressively increasing to 0.72 for yearling weight.

The environmental correlation between six month weight and the growth rates were all positive except for the six to nine months growth period (-.41). Nine months weight had a negative correlation only with nine to twelve months growth rate, whereas twelve months weight was positively correlated with all the growth rates studied.

As would be expected, the environmental correlations between preweaning growth rate and rate of growth in the periods weaning to six, six to nine and nine to twelve months were all negative. This is further evidence to the diversity of environmental factors influencing the lamb's growth in the preweaning and postweaning stages. In preweaning growth the lamb is protected and nourished to a large extent by the ewe, the gains of the lamb being determined largely by available milk supply. In the postweaning period foraging ability and the capacity to handle large quantities of roughage would be important factors in determining gains. Not only are these factors different in nature but also in mode of operation and severity of their effects on the lamb. Stobart *et al.*, (1986) added that the decrease in growth in the postweaning period is attributed to the stress associated with postweaning adaptation.

The negative environmental correlation between growth rate in the weaning to six months period and six to nine months , may be attributed to, *inter alia*, the seasonal variation in rainfall amount and distribution and its effect on the growth of the lamb. This being in the postweaning period, the lamb depends largely for its growth on the amount and quality of pastures. This same inference may be safely used to explain the negative correlation between six to nine and nine to twelve months growth rates. However, there were consistent positive correlations between birth to yearling growth rate and all the other growth rates. This relationship is to be expected since the growth rates in the periods birth to weaning, weaning to six months, six to nine and nine to twelve months all fall within the span birth to yearling. It follows, therefore, that any environmental (non-additive) factors influencing the growth rate of the lamb during any of these periods is most likely to influence overall growth rate.

5.0 SUMMARY AND CONCLUSION

All the environmental factors considered in this study (sex, type of birth, dam breed, season of birth, period of birth and parity) were found to influence growth at nearly all stages from birth to one year of age. Dam breed effect on growth merits special mention in that in all traits lambs born to Dorper x Red Maasai ewes were superior to their pure Dorper counterparts.

In this study, it is evident that postweaning growth generally had higher heritability estimates than preweaning growth. Environmental factors, especially high maternal influence, in relation to additive genetic factors, had more influence on early lamb gain than on gains later in the lamb's life.

The results of this study indicate that to select for lambs' own genetic merit for weights and gains, it would be best to base selection on postweaning traits such as body weight at six months as the selection criterion rather than weaning weight, as is often practised. This trait should be superior to weaning weight or preweaning growth rate since it is much less influenced by maternal effects which tend to obscure the direct additive genetic effect for growth. Although the generation interval may increase, overhead costs should certainly be curtailed when the rest of the lamb crop is disposed of at this stage.

Further, selection of ewes as dams must be based on lamb performance preweaning. In any case, the objective should be to choose a practical selection criterion which will maximize the annual rate of progress for the trait to be improved without impairing merit in important correlated traits.

Positive correlated response can be expected in other correlated traits due to the generally large and positive genetic correlations. Preliminary selection could also be conducted during the preweaning period since repeatability estimates are favourable. However the high maternal influence preweaning must not be ignored as it tends to mask the true genetic merit in the lambs.

Genetic and phenotypic correlations among weights, between weights and growth rates, and among growth rates themselves generally ranged from low to high with some estimates being negative. Genetic and phenotypic correlations between adjacent weights were higher. The correlations tended to decrease as the time interval separating the observed weights increased.

In some growth periods such as between weaning to six months and nine to twelve months (-.07), and six to nine months and nine to twelve months (-.16), small, negative and insignificant correlations were obtained. These are consequences of compensatory growth and are not antagonistic as such. There was, as would be expected, a consistent positive phenotypic correlation between overall growth rate and all other growth rates of the lamb before yearling.

In conclusion, there exist a number of indigenous sheep breeds in Kenya that could further be improved for meat, milk and fibre production. Only a handful of the most promising breeds of sheep have so far been identified and disseminated. Research observations have exposed the ill adaptability of exotic small ruminant breeds to most African ecosystems. There is therefore the need to study and characterize for productivity and utilization the available sheep breeds/strains, with a view to selection within the identified high genetic potential breeds/strains inorder to establish nucleus flocks for distribution to farmers.

It must be impressed upon everyone involved in the livestock sector to maintain accurate records on which productivity indices may be based. Success in constructing any of the indices is hinged on the availability of recorded information. It would be beneficial to this country if future studies are geared in this direction.

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