FACTORS AFFECTING FERTILITY IN A FLOCK OF DORPER SHEEP

JOYCE SEHLEPHI ETLEN GUMEDZE, B.Sc. (AGRIC.)
(LEGON).

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DECLARATION

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

J.S.E. GUMEDZE

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

J.S.E GUMEDZE

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

Dr. R.M. MZEE

Dr. R.B. DOLAN

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ABSTRACT

The present study was based on 1427 matings and lambing records of a flock of Dorper sheep kept at Ol'Magogo farm which is situated in the medium potential zone of Kenya. Genetic and non-genetic sources of variation in number of lambs born per mating were estimated.

Of all the non-genetic factors considered season, pre-mating body weight, year x season interaction and years (in order of their importance) influenced number of lambs born significantly.

Generally in all years more lambs were born when conception took place during a wet season than during a dry season. Number of lambs born per mating fluctuated greatly within seasons between years, with the largest deviations observed within the dry season. Pre-mating body weight influenced number of lambs significantly, one percent more lambs were born per kilogram increase in body weight.

Age, ram, lambing interval, year x age and age x season interactions did not have significant effects on number of lambs born per mating.

The additive genetic variation in number of lambs born per mating was estimated as 9 % using a half-sib analysis.

From the present study it was concluded that for this flock, ewes can be mated at an earlier age and that three lamb crops every two years appears feasible under proper management. If selection of ewes for fertility is anticipated, their reproductive performance should be compared within seasons and years.

1. INTRODUCTION

The sheep population of Kenya comprises of exotic and local breeds. The local breeds form 89% of the total sheep population, and are mainly kept in the marginal, semi-arid and arid areas. Most of the exotic sheep breeds except the Dorper and Merino breeds, originated from temperate areas and are therefore suited to the cool and wet areas which form only 20% of Kenya's territory.

There are about 50,000 Dorper sheep in Kenya and they are mainly kept in the following areas:- Laikipia, Machakos, Narok, Kajiado, Nakuru, Naivasha, Embu, Taita and Kilifi. The Dorper sheep breed raises special interest because of its suitability to a wide range of rainfall areas, especially the medium and low potential areas.

The Dorper breed, which was a result of breeding and selection work on a cross between Dorset Horn and Blackhead Persian, originated at Grootfontein College of Agriculture in South Africa in 1942. The establishment of the Dorper stemmed from the need to produce a young fat lamb, with good build, high quality carcass and adaptable to drier parts of South Africa. In 1950 a breed association was formed and it was agreed to name the new breed 'Dorper', suggesting its origin from the Dorset Horn and the Blackhead Persian, (Bosman, 1954).

The Blackhead Persian was a name given to the black-headed sheep in South Africa in the belief that they originated from Persia. There was one ram and three ewes on a ship en route to South Africa from Persia. In 1868 this ship wrecked near the Southern tip of Africa. These sheep were the foundation of the breed in South Africa, (Mason and Maule, 1960). Looking at the numbers involved in the parent stock one wonders what the genetic variation in subsequent generations has been.

The Dorsets are an ancient breed of sheep whose exact origin is very doubtful. They possesss many characteristics to associate them with the Down breeds. The central home of the breed at present is in Dorsetshire and Somersetshire where it has been bred for many centuries. In Australia it has an added value because the rams and ewes will mate almost at any time of the year. The breeding qualities of the breed are of the first order, the percentage of lambs born being very high and the pure bred ewes are good mothers and good milkers. They are hardy and active (Belschner, 1965).

In 1958, a small flock of Dorper sheep was brought the Government Research Station at Katumani (Machakos) the purpose of assessing the breed's suitability in low/medium potential areas of the country. In 1970, t of the progeny of this original flock was transferred the National Animal Husbandry Research Station at vasha. In 1971, 20 Dorper sheep were imported by UNDP/FAO Range Management Project and assigned to oko and Buchuma for the purpose of assessing the ed's suitability to semi-arid conditions. From the ginal area of introduction (Machakos), the Dorper ep have spread to ranching areas all over the country ich, 1973).

At the moment the flock at Naivasha Animal Husbandry earch Station forms the largest Government stud flock is the main source of rams for farmers in the country.

The Dorper breed's qualities of hardiness, fast wth rate and high prolificacy renders the breed table for the different Kenyan ecological zones. It efore seems necessary to assess the performance of breed under the diffeerent zones and to find out under h zone individual characteristics are best shown. For s where genetic improvement of each of these qualities desirable, a breeding plan can be set up.

This study was centred at analysing the reproductive performance of a flock of Dorper sheep, with the following objectives:

a) to identify the sources of variation both genetic and environmental in the reproductive capacity of the ewes.

and

b) to estimate their relative importance.

2. LITERATURE REVIEW

2.1 FERTILITY

Reproduction is the process of producing individuals of the same species. It includes, therefore, the whole sequence from the production of gametes, mating, conception, implantation, pregnancy and parturition. The increase in animal populations depends on the ability of males and females to reproduce large numbers of offsprings, rapidly and over a long period of their productive life. The result of a mating depends on the fertility of the male and female as well as on the genetic constitution of the zygote, (Johansson and Rendel, 1968). Extensive studies have been carried out into the reproductive physiology of the ewe. These studies have led to the understanding of a number of factors which can be controlled and which affect fertility.

The ovine and feral species exhibit seasonality in their breeding. Most feral species have a definite sexual seasons, which is initiated at a time that ensures the proper environment for optimum survival of the young. Even in farm animals which have no restricted sexual season, there are seasonal variations in their reproductive efficiency which correspond roughly to the restricted sexual season of their wild ancestors.

Heredity and natural selection may be responsible for much of the change from seasonal to year-long breeding under domestication. In sheep, sexual activity varies from manifestation of a few oestrus periods per year in mountain breeds to year-long breeding in tropical and sub-tropical breeds.

Among the factors of the physical environment responsible for seasonality in sheep i.e. temperature, day length, amount of green feed available, altitude, (Marshall (1952), found day length to be the most important of all. Sheep responding to decreasing day-light length are known as short-day breeders.

In East Africa none of the above factors appear to be effective stimuli. The annual day-length range only covers a difference of six minutes, the low temperatures never approach the levels thought to be effective stimuli and the critical altitude range appears to be of the order of 12,000 feet (Bishop and Walton, 1960 Cited by Carles, 1969).

Since reproduction is a complex of biological processes, it therefore has many components. Fertility and fecundity are some of the breeding efficiency components which are often confused. In this study the definitions of fertility and fecundity given by Moule (1971), will be accepted. Fertility being defined as the capacity to produce viable offsprings, and fecundity as the ability to produce offsprings rapidly and in large numbers. In mammals, fertility therefore replaces fecundity since the actual fecundities are difficult to estimate, hence observed fecundity is the same as fertility.

Reproductive efficiency depends on the proportion of ewes mated which become pregnant and the lambing rate. Lambing rate (number of lambs born of ewes lambing) in turn depends on the number of ovulations minus those ova which failed to become fertilized or embryos which died and were resorbed before birth. Ovulation rate, or number of eggs shed per heat period, through its important relationships to number of lambs weaned per ewe bred may be the most important aspect of reproduction in sheep. Ovulation rate often deduced from the number of lambs born at one time, is most commonly one, often two, occasionally three and rarely four, but has been reported as high as seven.

Numerous indices have been used to assess reproductive performance of sheep. Out of all the different figures used for expressing fertility, Goot (1951), analysing measurements of fertility, concluded that the number of multiple births per ewe lambing or put to the ram, expresses fertility best, especially for breeds with high incidence of multiple births. This sounds logical because of the number of factors influencing ovulation and conception rate. Turner and Young (1969), observed that selecting for the number of lambs born is the most profitable avenue for increasing the number of lambs weaned in both the current and future generations.

Factors affecting fertility can be categorised as hereditary and non-hereditary. Non-genetic factors tend to obscure genetic differences between individuals or groups. Identifying, evaluating and correcting for such factors is therefore necessary in making more accurate genetic comparisons, (Turner and Young, 1969).

Many workers including, Marshall and Potts, 1921; Sharafeldin, 1960; Yalcin and Bichard, 1964; De Haas and Dunlop, 1969, have shown that many non-genetic effects such as age of the ewe, weight of the ewe, time of mating, nutritional status of the flock before mating season and during gestation have an appreciable effect on multiple birth percentage.

2.2 GENETIC EFFECTS

In any selection program, it is necessary to know the extent to which the variation in different traits, is genetic in origin. The big difference between breeds in frequency of multiple births, (Terrill and Stoehr, 1938; Johansson and Hansson, 1943; Turner and Young, 1969), indicate that genetic factors have some influence. The Finnish Landrace and Romanov breeds of sheep exhibit a remarkable prolificacy. They can produce up to four (even more) lambs per birth. D'man and Blackbelly sheep breeds were reported by Mason, (1978 Personal communication) most prolific of Tropical breeds.

A few explanations have been offered as to the variation in prolificacy between breeds. The prolific genotypes may have higher ovulation rates and provide better pre-natal maternal environment. Johansson and Hansson pointed out that the differences between Cheviots and Finnish Landrace is probably genetic, since both breeds have had the same geographic distribution. Mason, (1978 Personal communication) observed that the prolific breeds are similar in their reproductive performance but differ in appearance. He also observed that these prolific sheep form islands in the middle of quite different animals, either different breeds or similar breeds which do not show the prolific characteristics, e.g. the Finnish Landrace and Romanov belong to the North European short-tailed group but the other breeds in the group (Iceland,Shetland Old Norwegian, Swedish) are not prolific. He noted a common thread that links the prolific breeds, that is they are in small flocks in farming areas. Mason supposes that the close attention given to these prolific sheep as house hold animals has enabled selection to be effective for a characteristic which a has a reputation of low heritability. Furthermore the prolificacy seemed to be part of a group of reproductive characteristics, early sexual maturity, absence of lactation anoestrus, high libido in males which appear to be due to high sensitivity to gonadotropic hormone. Therefore selection may not have been made for prolificacy alone. This implies that provided non prolific breeds are given more attention and selection is carried on for a number of generations there might be a hope of improving their fertility.

In selection we are interested in improving the production both of the current flock and the next generation. However more emphasis is placed on improving future generations. By selecting superior animals we hope that some of the mean superiority of the parents will be transferred to the offspring. We also hope to raise the production level of the selected ewes in the current flock. To be able to predict what genetic changes will be effected by selection programs, we need to know the proportion of the differences between sheep which are genetic and not environmental in origin. The statistic which measures this proportion is the heritability. Heritability measures the proportion of the variation between individuals in any given characteristics which arises from genes acting additively. It estimates, therefore, the proportion of the parents' superiority which will on the average be demonstrated in the offspring. The level of heritability indicates whether selection will be effective with or without aids, or whether other avenues of improvement should be sought.

Phenotypic variance can be partitioned into the different components, genetic, environmental, and genotype environment interactions. The variation due to all genetic causes is denoted as V_G^2. This genetic variance can be further divided into additive genetic variation, variation due to dominance and variation due to epistasis. The additive genetic variance is the important component since it is the chief cause of resemblance between relatives and therefore the chief determinant of the genetic properties of the population (Falconer, 1960).

In calculating heritability we are interested in estimating the additive genetic variation as a portion of the total phenotypic variation. The covariance between relatives provides such an estimate. The relatives most commonly used for estimating heritability in animal breeding are:-

a) Parent - offspring

b) Half or full-sibs.

For (a) regression and correlation techniques are used and for (b) correlation between sibs is estimated by the use of analysis of variance. The method to be used for estimating heritability, is usually dictated by the type of organism, the kind of data available and the magnitude of the heritability being estimated (Turner and Young 1969).

$$h^2 = \sigma_A^2 / \sigma_P^2$$

where h^2 = heritability estimate

σ_A^2 = additive genetic variance

σ_P^2 = phenotypic variance

The disadvantages of offspring-parent relationships, are that the measurements may be made in the same year, in which case the offspring and parent will be of different ages and therefore subjected to different environmental stresses. On the other hand, observations may be made in different years, so that both parents and offsprings are of the same age when measurements are made. However this introduces an error if the environment during the two years was different. The question of adjusting for known environmental effects becomes important in reducing the errors in the h^2 estimates.

Use of full sibs has a disadvantage in that the resemblance among them is not only due to genes acting additively but also to common environment, dominance and epistatic effects. Therefore the h^2 estimates obtained by using covariance between full sib groups is usually inflated. The resemblance among half-sibs is due to the common genes they have acting additively. Therefore the covariance of half-sib groups provide a better h^2 estimate.

It is common practice to attempt to raise reproduction rate, at least in the current flock by culling ewes which fail to bear or rear a lamb, sometimes at first failure and sometimes at the second. The other two avenues for increasing reproductive performance in future generations has been to increase the proportion of ewes with multiple births and by increasing the number of lambs per birth (i.e. reducing the number of barren ewes). These methods have not proved very effective because of the low h^2 estimates reported.

Various authors have published estimates of h^2 on which predictions of response to selection can be based.

The estimates have been for number of lambs born, number of lambs weaned or number of multiple births. In general the estimates are discouragingly low. See Table 2.1 for h^2 estimates for the different parameters. h^2 estimates based on three lambings or more are slightly higher than those based on single lambings. Heritability estimates for litter size based on single lambings were found to be significantly higher than that for lambs born per ewe mated and for barrenness by Purser, (1965). For failure to lamb he reported a h^2 estimate of virtually zero.

Table 2.1: Heritability estimates for reproduction rate and its components

Character	Breeds	Age of ewes (years)	Estimate	References*
Lambs weaned per ewe joined (L_{wj})	Australian Merino	{ 2	0.03-0.06	4, 12
		{ 3	0.15	12
		{2 + 3	0.09	12
	American Rambouillet	Lifetime	0.22	10
	Mountain breeds	2-4 and 2-6	0.-0.03	5
Lambs born per ewe joined (L_{bj})	Australian Merino	{ 2	0.03-0.20	4, 12
		{ 3	0.35	12
		{2 + 3	0.19	12
	American Rambouillet	Lifetime	0.21	10
	Mountain breeds	2-4 and 2-6	0-0.07	5
	Columbia and British breeds	2-4	0.07	1
	N.Z. Romney	n.s.†	0-0.15	6
	Texel	n.s.	0.03-0.17	9
Ewes failing to lamb per ewe joined (E_{dj})	Mountain breeds	2-4 and 2-6	0-0.03	5
Litter size (a) Lambs born per ewe lambing (L_{bp})	Mountain breeds	2-4 and 2-6	0.14-0.16	5
	British breeds	{ 2	0.04	2
		{Sum of 3 lambings {from 2-6	0.17-0.26	2
	Swedish Landrace	Sum of 3 lambings from 2-6	0.12	2
(b) Single or multiple birth	British breeds	2-5	0.04-0.22	8
	Swedish Landrace	2-5	0.09	8
	Rahmani	2-7	0.08	3
	Ossimi	n.s.	0.04	7
	Navajo and crosses	{ 2	0.06-0.40	11
		{Mature	0.12-0.22	11

† n.s. = not stated

1. Desai and Winters, (1951b); 2. Johansson and Hansson, (1943); 3. Karam, (1957); 4. Kennedy, (1967); 5. Purser, (1965); 6. Rae and Ch'ang, (1955); 7. Ragab and Asker, (1954); 8. Rendel, (1956); 9. Sharafeldin, (1960); 10. Shelton and Menzies, (1968); 11. Sidwell, (1956); 12. Young, Turner and Dolling (1963).

2.3 NON-GENETIC EFFECTS

2.3.1 Age of the ewe

Under tropical conditions, ewes are usually mated for the first time at one and a half years of age and annually thereafter, (Moule, 1971). Sheep reach sexual maturity at four to ten months of age, however mating is delayed in order to avoid a check in growth. Sharafeldin (1960), observed that ewes first bred at a younger age of seven to nine months produce fewer lambs at their first lambing than ewes first mated at 19 to 20 months of age.

The influence of age of ewe on the incidence of multiple births is very pronounced. An increase in litter size with advance in age has been reported by several workers (Marshall, and Potts, 1921; Johansson and Hansson, 1943; Ragab and Asker, 1956; Sharafeldin, 1960; Yalcin and Bichard, 1964; De Haas and Dunlop, 1964; and others). They have shown a steady rise in number of lambs per birth up to four to eight years of age with a drop thereafter. The highest rate of increase in litter size has been observed to be between the first and second crop when ewes are first bred at seven to nine months of age. Yalcin and Bichard (1964) working with Border Leicester, Cheviot cross ewes reported a 0.58 increase, whilst Sharafeldin (1960) reported a 0.4

increase for Texel ewes. There is then a gradual in the proportion of twins born until ewes reach their production (Marshall and Potts, 1921). Nikoljskill, 3) reported a twinning rate of 17 percent for Karakul -year-old ewes compared to three to seven percent for ger ewes. Different breeds have their peak production lifferent ages, thus the wide range four to eight s quoted above. Early maturing breeds such as the rddown, have been reported as reaching their maximum luction as early as three years of age and late maturing eds, such as Egyptian Ossimi sheep, as late as seven to it years of age (Johansson and Hansson, 1943; Ragab Asker, 1956). Turner (1968) observed that in flocks with igh average level of reproduction rate ewes reach their and start declining earlier than in lower producing cks.

There are a number of reasons for this relationship ween fertility and age of the ewe. A contributory factor some studies is the culling of less fertile ewes which be responsible for the increase in lambing percentage the increase in age than where no selection has been ctised. In the flock studied culling was done for cific reasons as explained in the Materials and Methods. biological explanation for the age fertility curve, is that in normal polytocous animals, such as sheep, the litter size is determined by the level of the gonadotrophic hormones and the response of the target organ (the ovaries). Young females do not secrete as much follicle stimulating hormone as mature ones (Robinson, 1951a). This is because the female undergoes a certain gradual transition from an inactive to a fully active ovarian state with advance in age from puberty to the level of maximum reproductivity. Hafez (1952) reported a shorter breeding season for ewe lambs than adult ewes. He recorded the mean number of heats per sheep per season as 1.5 and 3.5 for Blackface and Suffolk respectively as compared to 6.9 and 10.2 for corresponding adults. Yearling ewes had a shorter breeding season and somehow later onset than older ewes. However, since tropical breeds do not show any seasonality in their breeding, the difference between lengths of the heat period for young and older ewes remains to be verified though the case might be true in situations where mating is controlled.

Ewe lambs of many breeds reach their first oestrus at the 40-70% of adult body weight (Dy'rmundson, 1973; Hafez, 1952). They show a number of silent heats and generally low level of efficiency in most aspects of reproductive performance. Thus ewe lambs and to a lesser extent ewes in their second year of life, have lower ovulation and conception rates than more mature ewes. Oestrus is generally shortest for ewe lambs with that of yearling being intermediate (Mackenzie and Terrill, 1937).

2.3.2 Live weight of the ewe

There seems to be general agreement in the literature that body weight is important in relation to reproduction rate, although there is controversy over whether weight should be maintained or increased quickly over a certain period of time. Purser (1965) estimating heritability and repeatability of fertility in Blackface and Welsh ewes, found a positive genetic and phenotypic correlation between live weight and fertility within breeds. (Genotypic and phenotypic correlations for Blackface ewes were 0.44 and 0.23 respectively and 0.78 and 0.25 for Welsh ewes). He concluded that any genetic improvement in litter size at birth, would bring about correlated changes in body weight. De Haas and Dunlop (1962) reported a 0.37% increase of multiple births per pound increase in body weight.

Between breeds, there is much variation in the relationship between body weight and ovulation rates. Some of the most prolific breeds are of relatively small size such as the Finnish sheep and the Romanov. No positive correlation was found between body size and fertility when different breed were compared by Johansson and Hansson, (1943). However a positive correlation was found by Terrill and Stoehr (1942), between breeds when comparisons were made between yearling groups. Young, Turner and Dolling (1963) reported a positive but non-significant genetic correlation (0.47), between liveweight and number of lambs born between breeds.

2.3.3. Flushing of ewes

In spite of the frequently quoted effects of a high plane of nutrition in the few weeks prior to mating on ovulation rates, there is little evidence provided for the belief in the many trials that have been carried out. The increase in lambing percentage after flushing has been accredited to the increase in twinning rates and decline in number of barren ewes rather than the flushing effect on fertility *per se*, (Marshall and Potts, 1921; Tribe and Seebeck, 1962). Clark (1934) reported an increase in the number of eggs shed on flushing only if ewes were thin. He then concluded that the efficacy of flushing in increasing ovulation rate depends on the condition of the ewe at the time of flushing. Kelley (1939) reported a positive correlation between the incidence of twinning in a stud Merino flock and the average rainfall during and immediately before the mating season, the high rainfall improving the feeding conditions. Radford (1959) did not agree with this previous investigation. He observed that incidences of twin ovulation in Merino ewes occurred equally among animals in which there were little or no changes in body weight and among those in which there were more pronounced changes in weight. He further stated that the variation in the incidence of twin ovulation was not associated in any way with the change in the plane of nutrition of the animal.

2.3.4 Year and Season

Yearly differences in fertility have been observed by Goot, (1951); Sharafeldin, (1960) and De Haas and Dunlop (1969). Yearly fertility changes are due to changes in management, and rainfall which results in improved pasture quality and quantity. Under tropical conditions seasonal influence on fertility is due to the amount of rainfall during and immediately before mating which also result in improved pastures (Kelley, 1939).

2.3.5 Lambing to conception interval

Depending on management systems, ewes are normally bred once a year. Cases of three lambings in two years have been reported. In temperate countries ewes breeding is mainly controlled by season. It has been observed, (Owen, 1976), that even in ewes with a long breeding season, mated early enough to allow a long period of potential breeding activity after lambing, there is a period during which successful mating cannot be achieved.This includes the puerperal period and occurs in many species that are not seasonal breeders. Hunter (1968 a), reviewed observations recorded at that time and concluded that the post partum anoestrus is a phenomenon distinct from the seasonal anoestrus and controlled by different factors. 70-120 days has been reported as the period it takes a normal proportion of ewes to return to oestrus after lambing.

There is very limited evidence of the true interval between lambing and conception when breeding season effects are removed. For a small number of Clun Forest ewes the period was reported as 42 days by Lees, (1969). Therefore the frequency of lambing over a defined interval can be limited by length of both the puerperal and mating period.

2.3.6 Rams as mates

Rams libido has been shown to improve with age. During their first breeding season, rams show a distinct lack of libido. Therefore young rams are usually joined to old ewes which have long heat periods and have the experience of seeking the rams when on heat.

The differences in fertility of different rams have been reported as not being significant (Marshall and Potts, 1921, Forrest and Bichards, 1974). The non-significant differences, might be due to the fact that ram lambs which are eventually used for matings are highly selected. Selection is mainly based on the condition of the reproductive organs and the general body condition.

Since in animal breeding we wish to understand the relative influence of the environment and genotype on various characters, it is important to estimate the size of the effects of the environmental factors. Such estimates can then be used as correction terms so that genetic comparisons can be made with greater accuracy.

3. MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Location and rainfall

Data came from a Dorper flock of the Sheep and Goats Development Project. These sheep are kept at Ol'Magogo, a substation of the Animal Husbandry Research Station, Naivasha. The farm is situated in the Medium potential areas, (ecological zone IV) at an altitude of 1,952 metres (Pratt, Greenway and Gwyne, 1966). The average rainfall of the nearest meteorological station (Naivasha Veterinary Experimental Station)over the 8 years period of study was 653.7 mm per year. Most of the rain fell between March and August. Monthly rainfall was less reliable than annual rainfall, and complete absence of rain or vast excesses was often experienced. There was great variation between years ranging from 405 mm in 1976 to 964 mm in 1977, (Table 3.1).

3.1.2 Vegetation

The land is of marginal agricultural potential, carrying as natural vegetation dry forms of woodland and savanna, (often an acacia-themeda association) with semi-evergreen or decidious bushland. The most common grasses are *Pennesitum purpureum*, *Eriochloa nubica* and *Lintonia nutans*.

Table 3.1: Distribution of monthly rainfall from 1971 to 1978 at Naivasha Veterinary Experimental Station in millimetres

	Years							
Months	1971	1972	1973	1974	1975	1976	1977	1978
Jan.	27.0	28.8	56.6	2.8	4.5	0.0	28.6	85.2
Feb.	1.1	145.3	61.1	16.7	12.5	0.0	37.6	46.7
Mar.	7.5	21.2	3.0	48.7	33.7	32.3	37.7	155.6
April	73.5	26.6	94.8	120.9	13.7	68.2	291.7	94.5
May	106.8	116.7	31.8	51.9	84.3	11.4	90.8	57.5
June	20.6	124.8	36.6	103.6	2.6	86.6	15.0	46.5
July	55.7	25.6	22.2	74.1	64.2	23.7	100.3	13.3
Aug.	104.3	46.6	59.2	67.5	135.7	65.5	52.7	69.5
Sept.	15.7	45.8	64.6	63.9	42.9	38.4	55.6	55.6
Oct.	17.8	98.0	40.6	60.0	55.0	10.1	52.6	64.5
Nov.	49.2	74.7	72.8	76.5	0.0	25.6	146.0	43.0
Dec.	60.6	12.8	2.8	28.7	43.6	43.0	55.0	68.3
Totals	539.8	766.9	546.1	715.3	492.7	404.8	963.6	800.2

3.1.3 Stock and its management

The Dorper breed of sheep was introduced to the Station in 1970. The station also rears Merino, Red Maasai, a few Blackheaded sheep and crossbreds.

All sheep were herded in the following flocks.

(i) Breeding ewes flock

(ii) Weaners and Hoggets flock

(iii) Cull sheep flock

(iv) Rams flock.

It was common practice to breed maiden ewes when they were over 12 months of age, however, it was not uncommon to find cases where they were bred much earlier than this, the majority were mated between 12 and 18 months of age. Prior to mating, depending on the natural grazing conditions, ewes were or were not flushed. At mating time the breeding flock of ewes was split to ram-groups at a ratio of ram to ewes as one is to fifty. Before joining rams to ewes, pre-mating body weights of the ewes were recorded. Each ram was fitted with a sire harness with a crayon to enable identification of matings. Records of matings were taken every week from the beginning of the mating period. Six weeks later when the mating period ended, ewes were put to one flock and herded rotationally in different paddocks.

Except in 1973 and 1974, mating took place once a year. It was planned such that lambing occurred during a period that coincided with the wet season, which was suitable for ewes in milk as well as lambs. During 1973 and 1974, frequent mating was practised with an objective of getting three lamb crops in two years. In 1975, due to management problems, this practice was abandoned.

Two months before lambing, pregnant ewes were herded in paddocks with plenty of pasture. They were crutched and the feet trimmed in preparation for lambing. One month to lambing, ewes were vaccinated against enterotoxaemia, tetanus and lamb dysentry to give a stronger pre-immunity to the lambs when they were born. They were dosed against internal parasites at two weeks to lambing. At lambing, ewes lambing first were moved to adjacent paddocks, any ewes having twin or triplets to their own paddock. Lambs were eartagged for identification purposes within 24 hours of birth. The following information was recorded.

(i) Dam's identity

(ii) Sire's identity

(iii) Date of birth

(iv) Type of birth (single, twin, or triplets)

(v) Sex

(vi) Birth weight

(vii) Breed

For Dorper lambs, weaning took place at the age of 103 days. Lambs were weaned at two week intervals, until the lambs born last in the lambing season reached weaning age. They were drenched against internal parasites immediately after weaning and put to clean pastures.

Culling among ewes was done on specific abnormalities (e.g. deformed udders), condition of the ewe, disease susceptibility and infertility problems over two successive breeding seasons. Besides that, ewes were kept up to an age of 11 years. Selection of rams was based on body weight at weaning together with dam's reproductive performance over the years. After fattening, excess ram lambs were disposed of by selling to local farmers for breeding.

3.2 Source of experimental animals and data

3.2.1 Stock

Mating and lambing record forms and ewes register books provided the data for this study. Life-time records of 421 ewes from 1971 to 1978, with a total of 1427 matings were used. The ewes were initially of three origins. The initial stock comprised of 53 ewes brought in from the Agricultural Research Station at Katumani. Their age ranged from one to five years. Their previous lambing records were not known. In 1973 a further 58 ewes were introduced to the farm. This latter group was freshly imported into the country and brought to Ol'Magogo in 1972. The oldest of these ewes was three years of age whilst the youngest was one year. There were no previous records on these animals. The remaining 310 ewes were progeny of the above ewes on the farm. Most of these had complete records. Rams were identified as to whether they were mates or sires of the lambing ewes.

3.2.2 Records

From the sources stated under section 3.2.1 the following information was obtained.

(i) Ewe's identification

(ii) Date of birth of ewe

(iii) Sire of ewe

(iv) Pre-mating body weight of ewe

(v) Mate's identification

(vi) Lambing date

(vii) Identification of lamb born.

Data included all ewes from first lambers to last lambers (maximum number of lambings being ten). There were 213 first lambers. The values as expressed in terms of ewes lambing, estimate the reproductive capacity of ewes which conceived and completed pregnancy. Ewes which did not produce lambs included ewes which did not conceive, ewes which died before lambing and ewes which conceived but aborted during pregnancy. Lambs born included lambs born dead or alive.

3.3 Methods

3.3.1 Variables used

From sources mentioned earlier (3.2.1), data was compiled into a complete form together with all variables considered to influence mating results.

The dependent variable, which was the result of each mating, in which all necessary details were known was coded as (1) for no birth, (2) for the birth of a lamb, (3) for twin births and (4) for tripplet births. Date of conception was obtained by subtracting five months (gestation period) from the lambing date. If there was no lambing, the date when the ewe was put to the ram was used. If both dates were unknown, the record was omitted.

The effect of season was based on rainfall figures a month before conception. Season was classified into three levels with 30 millimetres as a cut off point for dry and intermediate, 50 millimetres for intermediate and wet. Having found no significant difference between the effect of the intermediate and wet seasons, these two were then grouped together in further analysis.

Age at conception was calculated for each record. Ewes were grouped into two classes i.e. ewes less or equal to 18 months of age and these 19 months and above.

In view of the frequent mating practised in 1973 and 1974, lambing interval was considered to influence mating results of 1973 and 1974. Lambing interval was calculated from the last successful conception to the mating under consideration. First lambers and those whose previous lambing records were not known were given seperate classes, otherwise, lambing interval was divided into three classes.

Pre-mating body weight was included in the analysis as a covariable. Out of 1427 matings, 155 pre-mating body weights of ewes were missing. These records were excluded in the model where pre-mating body weights were taken into account.

Other factors considered to influence the mating result were the year of conception, the ram as a mate and the ram as a sire through the genes he transmits to his offsprings. The latter was a genetic effect.

3.3.2 Statistical analyses

The data was analysed by the least-squares method of fitting constants for non-orthogonal data, described by

Harvey (1960). The Sysnova computer program version 7.1 by Seebeck, (1976) was used with the aid of an ICL 1902 Computer belonging to the Institute of Computer Science of the University of Nairobi.

A set of regression coefficients or constants for each level of an independent variable were computed, together with their standard errors. In some cases, when the mean square for the treatment was significant, the differences between the levels were divided by the appropriate standard error of contrast to give values of "t" for the residual degrees of freedom. This test, however, is exact in cases of treatments with two levels, but tends to give too high a level of significance for more than two levels. Therefore borderline significant results in such cases had to be interpreted with caution.

Several mathematical models were set up for determining the effect due to individual factors. A single mathematical model with all factors considered at once would have given a better estimate of the extent to which individual factors affect the number of lambs born, since in reality these act at the same time. However, this was not possible because of the restriction on number of variables the program could handle at one time, a number of models were therefore necessary.

For each model an analysis of variance and covariance was obtained in which each mean square was tested against that of the residual. An F-test to check if some significant interactions were left out of the models was given.

In view of the difficulty of estimating variance components in a fixed model, F-values were used to estimate the relative importance of individual effects.

<u>Model 1</u>

The main aim of setting up this model was to find out if environmental factors like season and year had any effect on mating results. Age was included, as many workers have reported significant effect of age on fertility. Interactions between these main effects were also of interest.

$$Y_{ijkl} = \mu + B_i + A_j + S_k + (BA)_{ij} + (AS)_{jk} + e_{ijkl}$$

Where Y_{ijkl} = the result of a mating

μ = constants

B_i = the effect of the ith year (i = 1.....8),

A_j = the effect of the jth age (j = 1 .....2),

S_k = the effect of the kth season (k = 1 .....3),

$(BA)_{ij}$ = the interaction effect of the ith year and jth age,

$(AS)_{jk}$ = the interaction effect of the jth age and kth season

e_{ijkl} = random effects, characteristic of the ijklth ewe, independent of other effects and assumed to be NID (0, σ_e^2); all other effects assumed to be fixed.

Other restrictions imposed were:-

$$\sum_i (B_i = \sum_j A_j = \sum_k S_k = \sum_{ij} (BA)_{ij} + \sum_{jk} (AS)_{jk} = 0$$

Since the program does not permit missing cells in the first level of the main effects, year x season interaction could not be computed. However, when seasons were subsequently classified into two levels, this limitation was overcome. See Table 3.2 for observations within each classification.

Model 2

The main objective of setting up this model was to test the addivitity of year and season effects and to investigate the effects of rams as mates and the lambing interval on number of lambs born.

$$Y_{iklmn} = \mu + B_i + S_k + C_l + M_m + (BS)_{ik} + e_{iklmn}$$

Where Y_{iklmn} = the result of a mating

C_l = the effect of the lth lambing interval (l = 1 ... 5),

M_m = the effect of the mth mate (M = 1 ....10)

Table 3.2 Distribution of number of ewes mated in different years, seasons and at different ages

Season	Age	1971	1972	1973	1974	1975	1976	1977	1978	Totals
1	1	13	2	2	19	20	12	24	0	92
	2	23	1	60	36	149	68	104	0	441
2	1	0	0	14	0	0	8	11	0	33
	2	48	0	9	27	0	127	40	0	251
3	1	1	21	5	45	16	0	26	14	128
	2	2	6	63	192	16	8	16	179	482
Totals		87	30	153	319	201	223	221	193	1427

$(BS)_{ik}$ = the interaction effect of the ith year and the kth season

e_{iklmn} = random effects

Except for mate which was random, all other terms and restrictions were the same as in model 1. Nine mates with not less than 53 matings were given seperate classes. The rest together with unkown mates were considered a random group and put to one class.

Model 3

This model was set up to find out the effect of rams as sires on the performance of their daughters and therefore to estimate heritability of number of lambs born. Age, other significant factors from models 1 and 2 and pre-mating body weights were included in this model, in order to estimate the component of variance due to sires with these factors corrected for.

$$Y_{ijklm} = \mu + B_i + A_j + S_k + D_l + (BS)_{ik} + \beta(X_{ijklm} - \bar{X}) + e_{ijklm}$$

where Y_{ijklm} = the result of a mating,

D_l = the effect of the lth sire (l = 1.....15)

β = partial regression coefficient of number of lambs born per mating on pre-mating body weight,

X_{ijklm} = an independent continuous variable, pre-mating body weight,

$\bar{X}$ = the mean pre-mating body weight,

e_{ijklm} = random effects

Except for sire which was random, all other terms and restrictions were the same as in Model 1. Sires had to be classified into 15 for ease of computation 14 of these had at least four daughters and the rest were put into a 15th group which was taken to be random.

Estimation of heritability

Heritability of number of lambs born per mating was estimated by using intra-class correlation between half-sibs. Using the analysis of variance obtained from model 3, variance component due to sires was estimated after correcting for effects due to year, age, season, pre-mating body weight and year x season interaction. Heritability was then estimated by using the formula:-

$$\hat{h}^2 = 4\,\hat{t}$$

where $\hat{h}^2$ = heritability estimate

$\hat{t}$ = intra-class correlation between members of half-sib families

t was estimated by finding the proportion of variance between means of half-sib families.

$$\hat{t} = \frac{\sigma^2{}_s}{\sigma_s^2 + \sigma_r^2}$$

where $\sigma^2{}_s$ = variance component due to sires

σ_r^2 = variance component due to random effects

Table 3.3 Form of analysis of half-sib families

Source of variation	DF	MS	Composition of MS
Between sires	s - 1	MS_s	$\sigma^2{}_r + k\sigma^2{}_s$
Within Progenies	s(k - 1)	MS_r	$\sigma^2{}_r$

where DF = degrees of freedom

MS = Mean square

s = number of sires

k = number of offsprings within a sire group (for a balanced design).

Estimation of the standard error of heritability estimate

The estandard error of the heritability was estimated by using the formula given by Robertson, (1959b).

$$SE(h^2) = \sqrt{\sigma^2 (h^2)}$$

where $(h^2) = 16\ (\sigma_t^2)$

$$\sigma_t^2 = \frac{2(1 + (k - 1)\ t)^2\ (1 - t)^2}{k\ (k - 1)\ (s - 1)}$$

σ_t^2 = variance of the intra-class correlation coefficient

k = average number of individuals per sire group

s = number of sires

4. RESULTS

The results will be presented for the different models as discussed in Materials and Methods. Table 4.1 shows the analysis of variance and the F values. The model was based on the main fixed effects due to year, age, season and two-way interactions between year x age and age x season.

Model 1

Table 4.1 Mean squares and F-values of individual effects

Source of variation	D.F.	Mean Square	F
Year	7	0.6124	2.13*
Age	1	0.0635	0.02
Season	2	5.7743	20.13***
Year x Age	7	0.4861	1.69
Age x Season	2	0.2310	0.81
Residual	1407	0.2869	0
Remaining interactions	17	1.2886	4.69**
Within-Cell Residual	1390	0.2747	

* $p \leq 0.05$, ** $p < 0.01$, *** $p < 0.001$

$R^2 = 9.28\%$

The results in Table 4.1 indicate that year and season had significant effects on the result of a mating. The model accounted for 9.28 % of the total variation.

The mean square for the remaining interactions was significant, implying that even after the removal of year x age, age x season interactions, other interactions not included in the model contributed significantly to the total variation. The only remaining two-way interaction between year x season might be an important contributor to the high mean square of remaining interactions. Higher order interactions between main effects may also be contributing.

Figure 4.1.A shows the LSQ - constants for the individual years. 1977 had the highest number of lambs born per mating, (1.09) whilst 1978 had the lowest (0.86).

Seasons had a very large F-value ($p < 0.001$) (Table 4.1) and therefore must be considered as an important environmental source of variation. LSQ-constants are depicted in figure 4.1.B.

Model 2

Table 4.2 shows the analysis of variance of the model based on year, season, lambing interval, mate and year x season interaction.

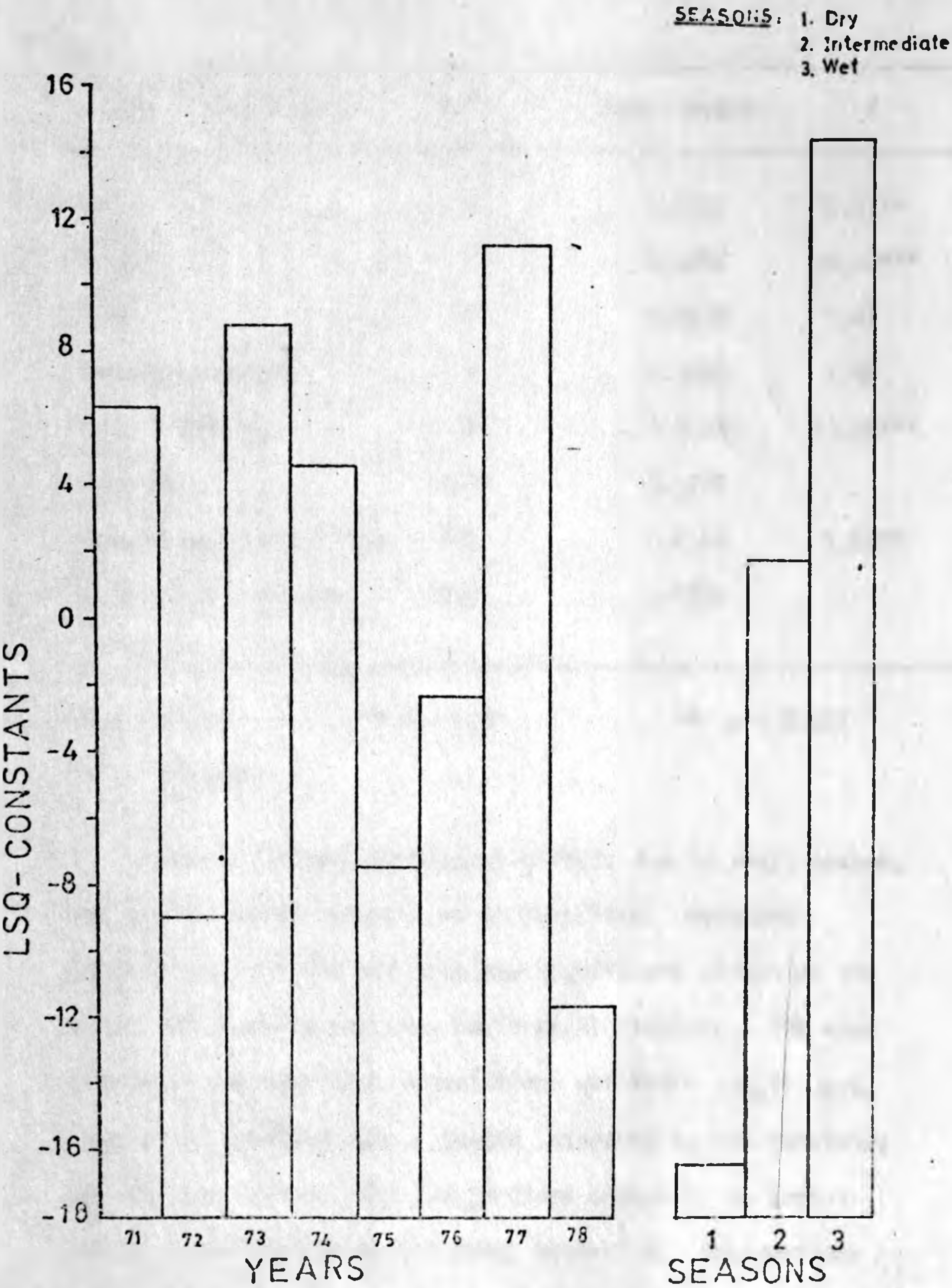

FIGURE 4.1 THE INFLUENCE OF YEAR AND SEASON ON THE RESULT OF A MATING.

Table 4.2 Mean squares and F-values of individual effects

Sources of variation	D.F.	Mean square	F
Year	7	1.4382	5.27**
Season	1	5.0642	18.55***
Mate	9	0.4032	1.47
Lambing interval	4	0.3960	1.45
Year x Season	6	3.7036	13.56***
Residual	1399	0.2731	
Remaining interactions	180	0.4060	1.60**
Within-Cell Residual	1290	0.2535	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

$R^2 = 14.14\%$.

Table 4.2 shows significant effects due to year, season, and year x season interaction on fertility. Mate and lambing interval did not have any significant effect on the result of a mating and thus their small F-values. The mean square of the remaining interactions was again significant. Even after removing year x season interaction, the remaining two-way and higher order interactions appear to be contributing significantly to the total variation. Interactions like season x lambing interval, mate x year and mate x season may be some of the important remaining interactions.

The model accounted for 14.14 % of the total variation, higher than that accounted for by Model 1 (9.28%). With the inclusion of year x season interaction, mate and lambing interval, the F-values of year and season, increased and decreased respectively as compared to their respective F-values in Model 1.

Year x Season interaction appears to be an important source of variation, giving the second highest F- value after seasons. The year effect computed within seasons gave a picture shown on Figure 4.2. Generally in all years ewes conceiving during the dry season produced less lambs than ewes conceiving during the wet season. The greatest deviation from additivity was observed in 1974 followed by 1972. In 1973 and 1976 ewes conceiving during the dry season had 0.031 and 0.56 more lambs respectively, than ewes conceiving during the wet season. The effect of the wet season was more repeatable over the years than that of the dry season. The significant year x season interaction implies that year and season effects are not additive.

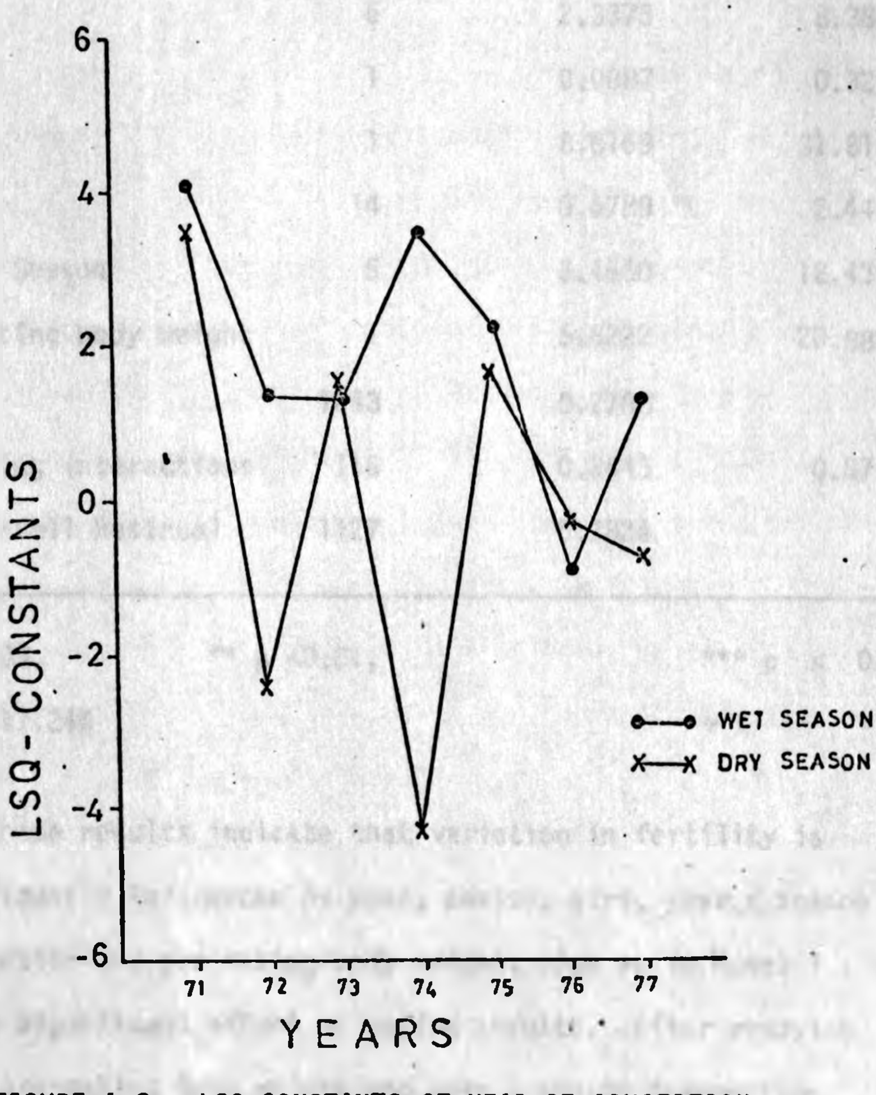

FIGURE 4.2: LSQ-CONSTANTS OF YEAR OF CONCEPTION BETWEEN SEASONS.

Model 3

Table 4.3 Mean squares and F-values of individual effects

Sources of variation	D.F.	Mean squares	F
Years	6	2.3375	8.38**
Age	1	0.0887	0.32
Season	1	8.8169	31.81***
Sire	14	0.6789	2.44**
Year x Season	5	3.4660	12.43***
Pre-mating body weight	1	5.8222	20.88***
Error	1243	0.2788	
Remaining interactions	116	0.2443	0.87
Within-Cell Residual	1127	0.2824	

*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

R^2 = 17.24%

These results indicate that variation in fertility is significantly influenced by year, season, sire, year x season interaction and pre-mating body weight. Age as in Model 1 had no significant effect on mating results. After removing sire, pre-mating body weight and year x season interaction effects, remaining interactions did not have significant effects on fertility.

The model accounted for 17.24 % of the total variation, Sire effect resulted in a significant mean square. The individual sire group LSQ-constants are shown in Figure 4.3. The ewes belonging to sire number 9 had significantly more lambs per mating than ewes belonging to the rest of the sire groups except for sire number 11.

Interaction of year x season of conception had significant effect on fertility. This interaction effect is depicted in Figure 4.4. Generally in all years, ewes conceiving in the wet season had more lambs than ewes conceiving in the dry season except in 1973, when the reverse was true. Comparing the interaction effect in this model and that in model 2, it can be observed that in this model the interaction effect was more marked in 1975 dry season and 1976 both seasons. In 1973 and 1974 the interaction effect was not affected by the inclusion of sire, age, pre-mating body weight and exclusion of the mate and lambing interval.

Age did not have a significant effect on the result of mating, however it was included since an estimate of heritability was to be obtained with age corrected for.

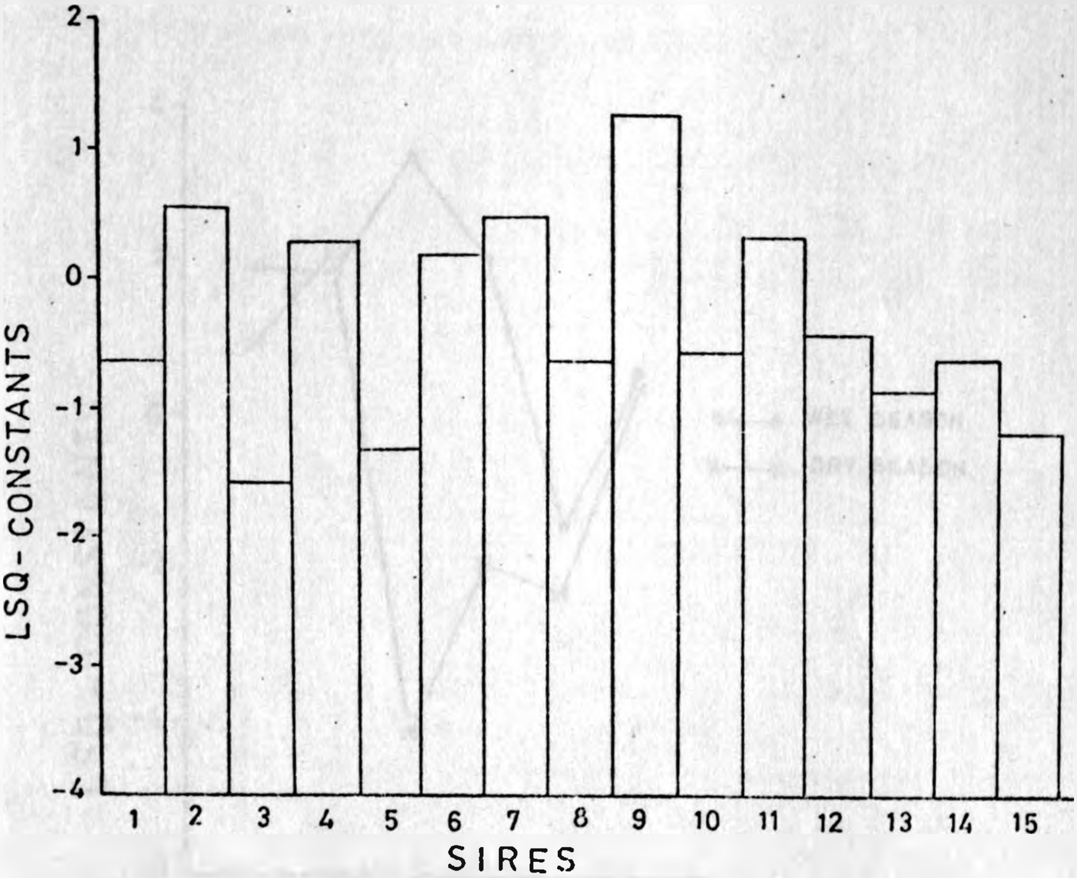

FIGURE 4.3: LSQ-CONSTANTS FOR INDIVIDUAL SIRE GROUPS.

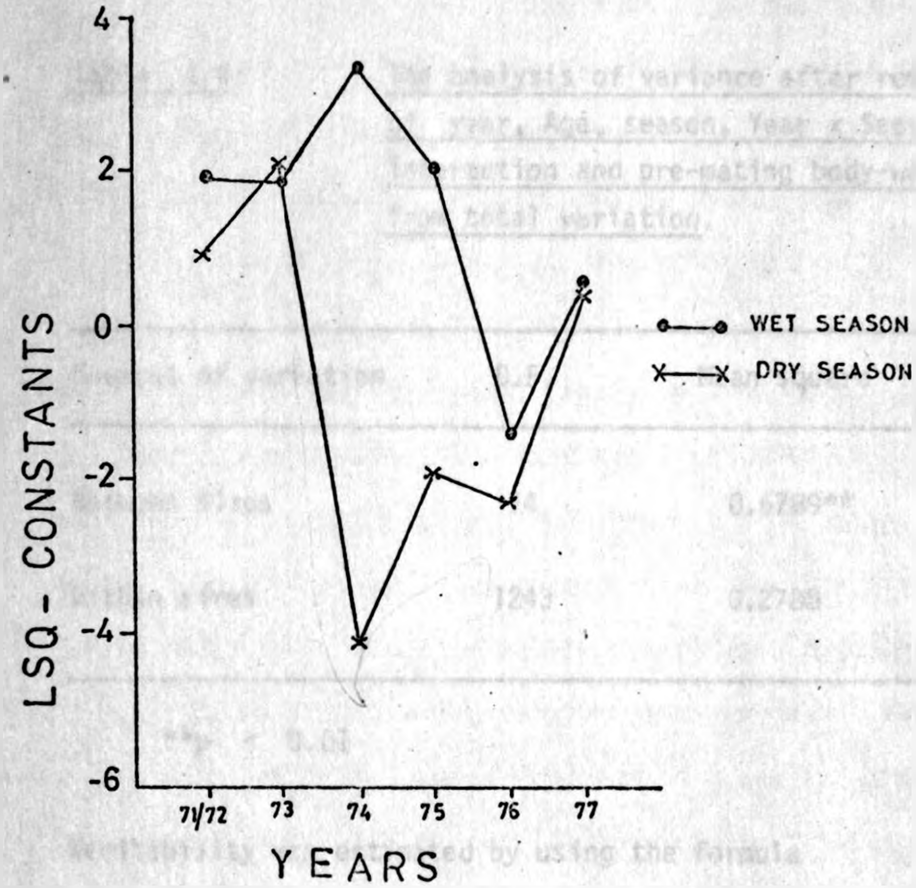

FIGURE 4.4: LSQ-CONSTANTS OF YEAR OF CONCEPTION BETWEEN SEASONS.

ESTIMATION OF HERITABILITY

Heritability of number of lambs born per mating was based on intra-class correlation of half-sib families. The form of analysis is shown in Table 4.4.

Table 4.4: The analysis of variance after removal of year, Age, season, Year x Season interaction and pre-mating body-weight from total variation.

Sources of variation	D.F.	Mean square	Variance component
Between sires	14	0.6789**	0.0065
Within sires	1243	0.2788	0.2788

**p < 0.01

Heritability was estimated by using the formula

$$h^2 = \frac{4\sigma^2_s}{\sigma^2_s + \sigma^2_r}$$

where h^2 = heritability estimate

σ^2_s = variance component due to sires

h^2 = 0.0911

The heritability estimate obtained after removing variation due to year, age, season, year x season interaction and pre-mating body weight was 0.0911, with a standard error of 0.0009.

5. 5. DISCUSSSION AND CONCLUSIONS

5.1 Age

Most of the cited literature indicates that fertility increases with age up to a peak after which it begins to decline. The highest rate of increase in litter size has been observed to be between the first and second crop when ewes are first bred at seven to nine months of age, (Sharafeldin, 1960; Yalcin and Bichard, 1964). Contrary to these studies, age of the ewe at conception had no significant influence on fertility in the present study. The explanation for this most likely is associated with the rather high age at which ewes are first bred at Naivasha. The policy is that ewes are not bred before they reach 12 months of age. The threshold age for the division of the first lambers versus mature ewes was 18 months. Therefore maiden ewes are possibly mature enough to have a comparable reproductive performance to the older group. The work of Fahmy and Bernard (1973) provides a better comparison. They considered ewes first lambing at two years of age as compared to mature ewes and in agreement with the results of the present study found no significant difference in fertility.

The comparable reproductive performance between first lambers and mature ewes could be due to the fact that the physiological strain of growth for maiden ewes had diminished i.e. feed nutrients not needed for growth were being directed to reproduction. The reproductive system of the young ewes might have been fully developed implying that maiden ewes could be mated at an earlier age. Performance of maiden ewes first mated at an earlier age than is the case at present would be poorer than for older ewes. However, if subsequent reproductive performance and the length of their reproductive life are not adversely affected, breeding ewes at an earlier age would increase the life-time performance of the ewe.

Under temperate conditions where sheep are reared in fertile lowland areas, age has been reported to be one of the most important sources of variation in fertility. Under these conditions, management practices are up to the standards required for sheep production i.e. among other things ewes are well fed through out the year. Under tropical conditions adequate feeds are wanting during certain times of the year. During such times, if there is no supplementary feeding, animals lose body condition, the effect of which is likely to be carried over to the mating season resulting in year and season being more important sources of variation, as was the case in the present study.

5.2 Year, Season and the interaction between the two

Goot, (1951) in New Zealand, Sharafeldin, (1960) in the Netherlands and De Haas and Dunlop, (1969) in Australia, found years to have a significant effect on fertility. No studies to this effect have been done in Kenya before. The results of the present study agree with those of the above workers.

Fertility fluctuated over the years and does not show any trend. The results generally show higher fertility during a wet season than during a dry season in all years except in 1973 for model 1 and in 1973 and 1976 for model 2, when the reverse was true. The effect of individual seasons changed over the years, showing great departures in both seasons of 1971, in the dry season of 1972, both seasons of 1974 and the wet season of 1976 for model 1. In model 2 large deviations were observed in both seasons of 1974 and in the dry season of 1975.

Yearly fertility changes might be due to differences in rainfall, changes in physical environment (besides pasture), grazing regimes, disease control and changes in the genetic composition of the flock. Fluctuations in yearly fertility might be due to differences in rainfall (see Table 3.1 for rainfall figures). For example in 1977 ewes were put to the ram in January to February, 1977 and lambed in June to

July, 1977 producing the highest number of lambs born per mating. 1977 was also the year of highest total rainfall. Rainfall was also well spread through out this year.

Yearly changes might also have been as a result of changes in management personnel. Such changes might have resulted in changes in grazing regimes and disease control. Goot, (1951) believed that yearly differences in fertility within studs were due to fluctuating management standards. Depending on the efficiency of the manager in charge in one particular year reproductive performance of ewes was either improved or lowered.

Yearly fertility changes could also be confounded with the changes in the genetic composition of the flock. In 1973 imported rams and ewes were added to the flock after having several other stations as temporary homes. Their first reproductive performance in 1974 was very poor as compared to the old stock. The physiological stress these imported sheep underwent in being moved from one country to another and from station to station in the new country might be responsible for their poor performance, contributing to the low mating results for the whole flock in 1974.

Little literature is available on the influence of seasons as classified in this study. Some workers have discussed the effect of seasons as related to the distribution of lambs throughout the year, yet others have investigated differences in different locations which are mainly characterized by differences in the rainfall pattern. The classification of seasonal influence in the present study can be likened to the latter. Kelley, (1939) reported a positive correlation between the incidence of twinning in a Merino stud flock and the average rainfall during and immediately before mating and the results of the present study are in agreement with this. High rainfall immediately before mating resulted in improved pasture quality and quantity resulting in improved body condition at mating.

Ovulation rate is influenced by the body condition of the ewe and the plane of nutrition during the breeding season. It has been reported to be higher in fat ewes than in thin ewes. It appears to be a function of the level of available nutrients and body reserves of stored energy, (Allen and Lamming, 1961). Nutrition is believed to affect ovarian activity by increasing (a) the rate of secretion and/or release of gonadotrophins from the pituitary gland, (b) tissue reactivity to the action of these hormones and (c) the metabolism of reproductive hormones. Therefore the improved body condition after high rainfall is likely to be associated with high ovulation rate which is highly correlated to large litter size.

The F-value due to seasonal effects in the present study only altered a little after inclusion of pre-mating body weight in model 3, implying that though pre-mating body weight accounts for some of the variation due to seasons, it does not fully explain seasonal effects. Environmental stress during a dry season might have resulted in sub fertility, which might be a normal adaptation syndrome to protect against further stress.

Deviations from additivity within the same season might be due to the amount of available pastures coupled with other systematic effects e.g. disease incidence. The largest departure during the dry season was observed in 1974. This was the second and last year during which frequent mating was practised. At the end of 1973 and beginning of 1974, very low rainfall figures were recorded. Ewes that lambed during the last two months of 1973, must have undergone a great physiological stress from pregnancy, lambing and remating during a dry season, so that the second lambing results were drastically reduced.

From these results it can be concluded that reproduction of different ewes can only be compared within the same season in the same year. For any selection program, ewes should be selected on their reproductive performance within seasons.

5.3 Pre-mating body weight

Tribe and Seebeck, (1962) found high body weight at joining to be associated with the highest twinning percentage. Kozdrecev, (1951) reported a positive correlation between body weight and fertility in Merino, but the regression was not linear. In the present study body weight at joining was found to influence number of lambs born significantly. Body weight within ewe ages did not have a significant effect on fertility, contrary to the findings of Johansson and Hansson, (1943). The high age limit at first breeding might mean that the average body weight of first lambers and therefore their reproductive performance was not sufficiently different from that of the older group.

Coop and Hayman, (1962) reported an increase of 0.46% in number of lambs born per pound increase in the body weight, whilst Fahmy and Bernard, (1973) reported an increase of 0.8% in multiple births per kilogram increase in body weight. In the present study a kilogram increase in body weight resulted in 0.97 % increase in number of lambs born per mating. This result was not very different from the results of the above workers. It is interesting to note that changes in reproduction associated with body weight changes for Dorper sheep, reared under range conditions, is similar to that of other genotypes reared under better conditions.

5.4 Lambing interval

Lambing interval did not have a significant effect on the number of lambs born per mating. During 1973 and 1974, ewes were joined to the ram when the lamb born earliest in the previous lambing season was 42 days of age. There was no significant difference in number of lambs born to ewes which had long resting periods and to ewes which had short resting periods. Provided body weights and seasons are favourable a long lambing interval will not necessarily result in more lambs than a short interval. A short interval would undoubtedly be economically viable provided pasture is not limiting.

However, there is a limit as to how far the lambing interval can be reduced. For one thing it cannot be reduced beyond the puerperal period which was reported as 42 days by Lees, (1969). From this study remating ewes 42 days after lambing appears to have no significant detrimental effects on lambing performances.

5.5 Rams as Mates

Marshall and Potts (1921), Forrest and Bichard, (1974) reported no significant influence of rams on the number of lambs born by their mates. Results of the present study agree with the findings of these earlier workers.

Differences in mating results of rams could be due to differences in sperm traits, libido and working performance which may outway other differences particularly where maiden ewes are concerned. Differences in the mating results of different rams besides being due to behavioural differences are not likely to be significant because large differences exist between different ejaculates of the same ram.

5.7 The heritability estimate of number of lambs born per mating

Many workers have made heritability estimates of different fertility measurements. Because of the association of fertility with fitness, natural selection has reduced the genetic variation of this trait resulting in small heritability estimates. Reported heritability estimates for lambs born per ewe joined (see Table 2.1) range from 0.03 to 0.35. Estimates for younger ewes being generally lower than those for older ewes. This is to be expected since immature ewes are not able to express their inherent capabilities of producing large litters. In the present study the heritability estimate for the number of lambs born per ewe joined (including the life-time peformance of all ewes) was 0.09. Though this estimate lies within the range reported above it is likely to be inflated because of the nature of data used in the estimation.

There were 14 half-sib families, whose sizes ranged from 4 to 35 daughters. The last (15th) group was composed of the initial stock whose sires were unknown and half-sib families with less than four daughters.

As the life performance of each ewe was considered, these half-sib families included lambing records repeated for the same individual. Thus each sire group i.e. half-sib family was partitioned into a number of ewes each having a number of lambing records which varied from one to ten. Due to restrictions imposed by the capacity of the program it was not possible to further partition the variance due to sires into the variance due to ewes within sires. All records within a sire group were therefore regarded as observations on different half-sibs and the covariance of these records was regarded as an estimate of $\frac{1}{4}\ V_A$. Included within the group of individuals with $\frac{1}{4}$ of their genes in common are records from individuals with all genes in common i.e. repeated observations on the same individual.

Combining the records from a number of different sires into one group, group 15, would on the other hand have resulted in a reduced estimate of the variance between sires. Again the capacity of the program restricted the number of sire groups to 15.

Conclusions and Recommendations

Fertility expressed as number of lambs born per ewe mated is affected by both genetic and non-genetic factors. Non-genetic effects being, year, season, the interaction between year and season and pre-mating body weights. Fertility is higher when the season of conception is wet and when pre-mating body weights are high. Seasons play an important part in yearly fertility fluctuations. If mating takes place during a dry season adequate supplementary feeding should be ensured.

When maiden ewes are mated to lamb when they are two-years of age, their reproductive performance is not different from that of mature ewes. Mating ewes at an earlier age would give perhaps a lower number of lambs at 1st lambing but higher profits per year over their life-time.

Frequent mating does not have adverse effects on number of lambs born. Efforts should be made to ensure that mating takes place where possible in the wet season, otherwise supplementation might be considered.

The heritability estimated of 9% should be regarded as an indication of the presence of additive genetic variation rather than an exact estimate. Further analysis is required to enable recommendations on the type of selection most appropriate. A more reliable estimate would also enable predictions to be made of genetic gain over subsequent generations and the profitability of a selection program.

Similar studies in the low potential or semi-arid areas should be undertaken. Results from such studies would widen the understanding of what factors are of importance in the reproductive levels of Dorper sheep under dry conditions.

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7. APPENDICES

Appendix A1. Least square coefficients ± standard error for treatments in Model 1.

Corrected Mean	0.9759	± 0.5356*
Main effects:		
Year:		
1971	0.0625	
1972	- 0.0936	± 0.1053
1973	0.0891	± 0.0678
1974	0.0470	± 0.0431
1975	- 0.0754	± 0.0515
1976	- 0.0244	± 0.0646
1977	0.1116	± 0.0434
1978	- 0.1169	± 0.0736
Age (months):		
≤ 18	- 0.0040	
≥ 19	0.0040	± 0.0272
Season:		
Dry	- 0.1643	
Intermediate	0.0189	± 0.0447
Wet	0.1454	± 0.0346
Interactions:		
Year x Age		
$Yr_1 \times Ag_2$	- 0.0445	
$Yr_2 \times Ag_2$	- 0.0910	± 0.1053

* = *Standard deviation.*

$Yr_3 \times Ag_2$	0.0953	± 0.0678
$Yr_4 \times Ag_2$	0.1023	± 0.0431
$Yr_5 \times Ag_2$	0.0231	± 0.0515
$Yr_6 \times Ag_2$	- 0.0555	± 0.0646
$Yr_7 \times Ag_2$	0.0649	± 0.0434
$Yr_8 \times Ag_2$	- 0.0946	± 0.0736
Age x Season		
$Se_1 \times Ag_2$	0.0206	
$Se_2 \times Ag_2$	0.0193	± 0.0447
$Se_3 \times Ag_2$	- 0.0399	± 0.0346

Appendix A2. Least square coefficients ± standard error for treatments in Model 2.

Corrected Mean	0.9838	± 0.5226*
Main effects:		
Year:		
1971	0.0608	
1972	- 0.0494	± 0.1407
1973	0.1516	± 0.0574
1974	- 0.0426	± 0.0442
1975	0.0273	± 0.0549
1976	- 0.0662	± 0.0459
1977	0.1162	± 0.0453
1978	- 0.1976	± 0.0483

* = *Standard deviation.*

Season		
Dry	- 0.1210	
Wet	0.1210	± 0.0281
Rams (as mates)		
1	- 0.0083	
2	0.0966	± 0.0854
3	- 0.0373	± 0.0701
4	0.0544	+ 0.0701
5	- 0.0300	± 0.0506
6	- 0.0745	± 0.0461
7	- 0.0541	± 0.0667
8	0.0763	± 0.0486
9	0.0438	± 0.0706
10	- 0.0669	± 0.0283
Lambing interval:		
First lambers	- 0.0304	
Unknown	- 0.0363	± 0.0425
≤9 months	- 0.0105	± 0.0296
10-14 months	- 0.0222	± 0.0312
≥14 months	0.0994	± 0.0417
Interaction:		
Year x Season		
$Yr_1 \times Se_1$	0.0557	
$Yr_2 \times Se_1$	- 0.0757	± 0.1386
$Yr_3 \times Se_1$	0.1356	± 0.0472
$Yr_4 \times Se_1$	- 0.2725	± 0.0439
$Yr_5 \times Se_1$	- 0.0844	± 0.0517

$Yr_6 \times Se_1$	0.1479	± 0.0420
$Yr_7 \times Se_1$	0.0934	± 0.0427

Appendix A3: Least square coefficients ± standard error for treatments in Model 3

Corrected Mean	0.9889	± 0.5280*
Main effects:		
Year:		
1971/72	0.1463	
1973	0.2076	± 0.0453
1974	- 0.0410	± 0.0399
1975	. 0.0035	± 0.0495
1976	- 0.1854	± 0.0452
1977	0.0537	± 0.0422
1978	- 0.1847	± 0.0437
Age (months)		
≤ 18	- 0.0124	
≥ 19	0.0124	± 0.0219
Season:		
Dry	- 0.1108	
Wet	0.1108	± 0.0196
Rams (as sires):		
1	- 0.0706	
2	0.0606	± 0.0596

* = *Standard deviation.*

3	- 0.0592	± 0.0667
4	0.0318	± 0.0746
5	- 0.1292	± 0.1173
6	0.0216	± 0.1006
7	0.0544	± 0.1296
8	- 0.0663	± 0.0641
9	0.1252	± 0.0664
10	- 0.0599	± 0.1043
11	0.3790	± 0.1276
12	- 0.0473	± 0.0761
13	- 0.0895	± 0.1010
14	- 0.0294	± 0.2516
15	- 0.1210	± 0.0406
Covariate:		
Pre-mating weight	0.0096	± 0.0021
Interaction:		
Year x Season:		
$Yr_{1/2} \times Se_1$	0.0578	
$Yr_3 \times Se_1$	0.1297	± 0.0441
$Yr_4 \times Se_1$	- 0.2699	± 0.0476
$Yr_5 \times Se_1$	- 0.0908	± 0.0476
$Yr_6 \times Se_1$	0.0683	± 0.0446
$Yr_7 \times Se_1$	0.1050	± 0.0395