GENETIC AND PHENOTYPIC PARAMETER ESTIMATES FOR GROWTH, SURVIVAL AND REPRODUCTIVE TRAITS IN MORADA NOVA HAIR SHEEP

By

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DEDICATION

This dissertation is dedicated to those

who have made me what I am:

My marvelous parents,

Francisco Antonio and Maria Nila,

my lovely wife

Edla,

and my dear children

Daniel, Debora and Diego.

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CHAPTER I

INTRODUCTION

Hair sheep comprise 7 to 10% of the world's 1.1 billion sheep population (Bradford and Fitzhugh, 1983). In relation to wool sheep in temperate environments, hair sheep in tropical and subtropical areas are smaller (adult weight of about 20 to 40 kg for females and 30 to 60 kg for males), slower growing, and earlier maturing. Hair sheep have adapted to the extremely adverse conditions of tropical semiarid and humid regions.

Brazil has a large sheep population, mostly distributed over the South (56.28%) and Northeast (38.46%) (IBGE, 1992) (Figure 1). It is important to mention that sheep in the South region are only wool sheep. In the "drought polygon" of Northeast Brazil (NEB), a hot tropical semi-arid region, sheep and goats are among the most viable sources of animal production and play very important socio-economic roles for the small farmers of this area. The sheep of the NEB are mostly of the woolless type (hair sheep) and are more concentrated in the states of Bahia, Ceara and Piaui (IBGE, 1992) (Figure, 2). There are several distinct types of sheep in the NEB, but the four major strains of hair sheep are: Morada Nova, Santa Ines, Brazilian Somalis, and Crioulo. The Morada Nova comes closest to being a native type unique to Brazil and has the potential to serve as a base for commercial exploitation.

On a world basis, the major products obtained from sheep are meat, fiber (included hides or skins) and milk. It has been estimated that 43.4% of the total value of products

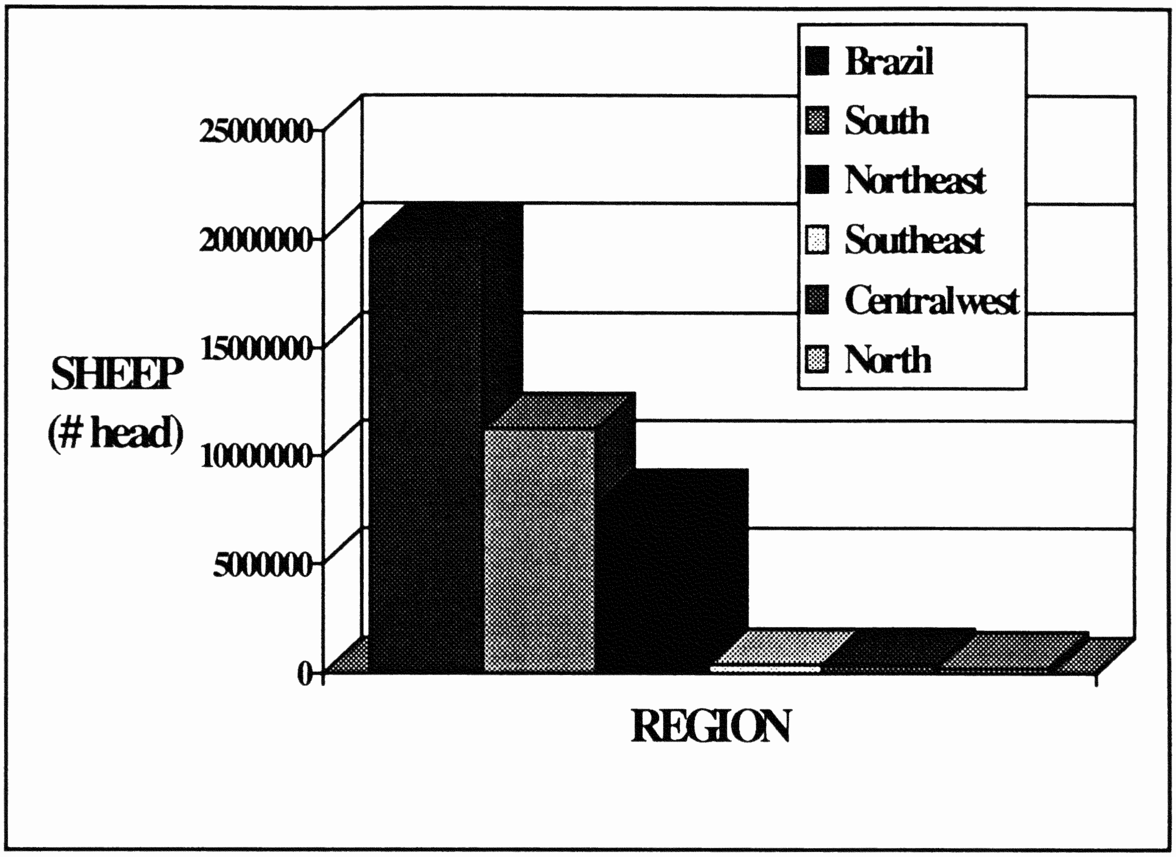

FIGURE 1. BRAZILIAN SHEEP POPULATION BY REGION

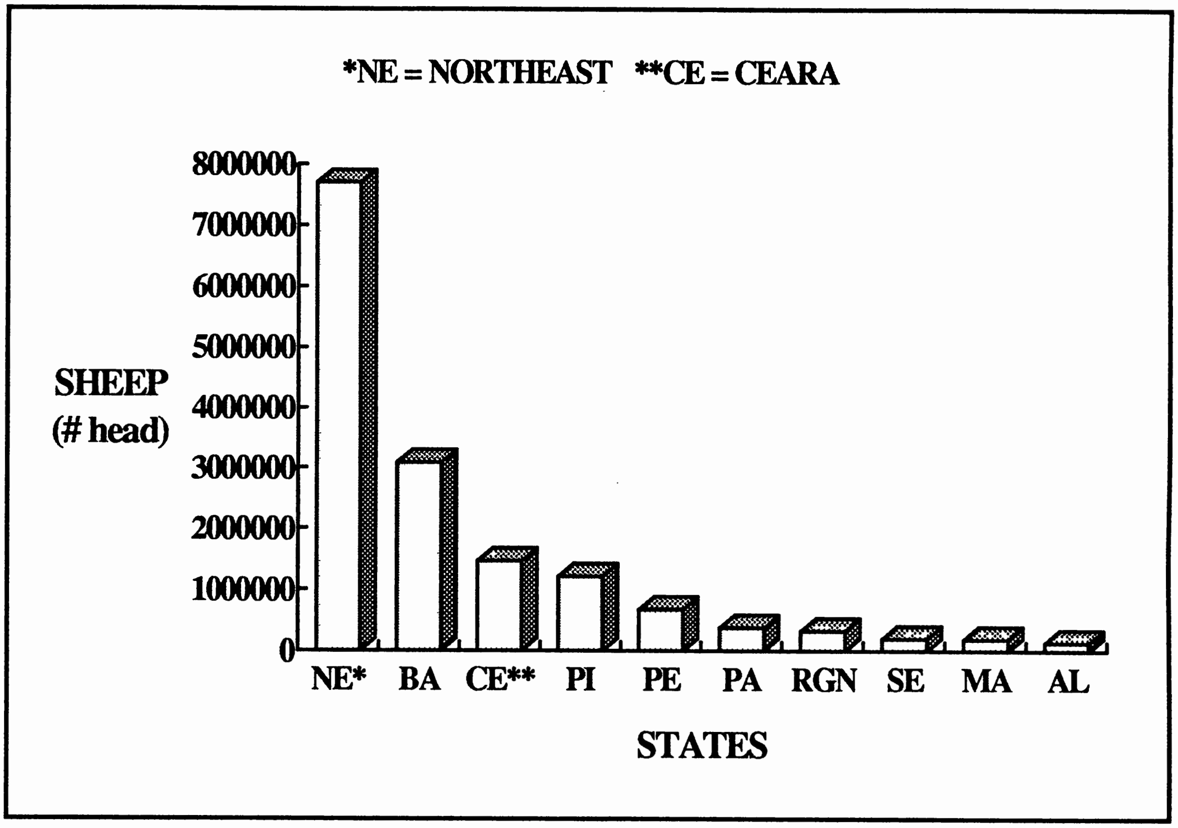

FIGURE 2. SHEEP POPULATION IN THE NORTHEAST BRAZIL BY STATE

generated by sheep is from meat, 39.3% from fiber and 15.0% from milk (Ensminger and Parker, 1986). Sheep production in tropical areas, such as NEB, is based largely on meat, with skins or hides as a secondary product. So, it is imperative that they be efficient meat producers. This potential exists, but for the most part, has not been accomplished.

Despite the overwhelming social and economic importance of sheep production in NEB, it is practiced through a very extensive and traditional system without the application of new technologies of animal production. It has also been noted that sheep performance should be classified as poor in this area. This may be due to the fact that small producers in developing countries are more difficult to reach and influence with new development programs and technologies. The unpredictable and unstable economic situation of many developing countries, such as Brazil, also has a very strong negative impact on production systems of agriculture. This fact definitely has a stronger effect, principally, in those systems run by small farmers, such as the NEB sheep producers. Measurements of productivity on a flock basis are highly variable. These may be lamb-crop raised and marketed as a percentage of the breeding ewes present in the flock. Other productivity measurements are offtake, extraction rate, or simply the number of animals sold expressed as a function of the total number of adult animals in the flock. Souza Neto (1987) observed that the offtake rate of 1980 in the NEB was 13.9% which represented the slaughter of 864,000 head out of a total population of more than six million. It has been estimated that with significant inputs, values as high as 40 to 66% should be realized (EMBRAPA, 1980; EPACE, 1980). On a theoretical basis, figures much higher than this may be postulated.

Animal productivity is the result of the genotype, the environment and possible interactions between them. Meat production can be expressed as a function of reproductive efficiency, survival rate, growth rate and carcass characteristics of any genotype in a given environment. Improvements in efficiency should be made by improving the environment conditions (nutrition, sanitary practices, etc.), or permanently and cumulatively through improvement in the genetic potential of the herd. Over a long period of time, genetic improvement often makes the most valuable contributions. Thus, genetic and phenotypic parameters (heritability, repeatability, genetic and phenotypic correlations) estimates for growth and reproduction traits are necessary in order to evaluate sheep breeds and consequently to design selection schemes and(or) mating systems as a consistent way to increase the performance of sheep production in the NEB.

Considering this background, the purposes of this study are (1) to investigate the relative importance of genetic and environmental sources of variations in growth and reproduction characters of Morada Nova sheep; (2) to obtain estimates of genetic and phenotypic parameters for growth traits and for the various components of reproductive performance in Morada Nova sheep; (3) to estimate additive and multiplicative correction factors for adjusting preweaning and postweaning weights of Morada Nova lambs to a common age of dam, sex, and type of birth-rearing class; and (4) to define possible potential breeding plans to improve sheep productivity in the NEB, considering results associated with the previous objectives.

CHAPTER II

LITERATURE REVIEW

Sheep performance is a function of genetic and environmental effects and associated interactions.

This chapter will be a review some of the major environmental sources of variation affecting growth, reproduction, and survival rate on sheep, and the genetic factors influencing those productive traits. It will also consider the adjustment factors available for adjusting lambing preweaning and weaning growth and for adjusting ewe productivity performance.

ENVIRONMENTAL FACTORS

The non-genetic (environmental and physiological) causes of variation affecting growth and reproductive performance in sheep will be reviewed under the following topics: year, age of ewe, weight of ewe, body condition of ewe, sex of lamb, type of birth and(or) rearing.

YEAR

The modifications in ambient temperature and rainfall (amount and distribution), and also, their effects on availability (quantity and quality) of pastures for grazing by sheep are the principal sources of yearly effects on sheep production. Thus, year affects animal performance only through environmental factors associated with it.

Year has been reported to have a significant influence by several researchers on growth traits (Sidwell et al., 1970; Vesely and Robinson, 1970; Dickerson et al., 1975; Walstrom et al., 1976; Magid et al., 1981b; Alrawi et al., 1982; Singh et al., 1982; Fogarty et al., 1984; Kaushish et al., 1990; Kabuga and Akowuak, 1991; Buvanendran et al., 1992; Nawaz and Meyer, 1992); on lamb survival (Sidwell et al., 1962; Mullaney and Brown, 1969; Dickerson and Glimp, 1975; Fogarty et al., 1984; Younis et al., 1990; Iniguez et al., 1991; Kleemann et al., 1991; Nawaz and Meyer, 1992); and on reproductive characters (Vakil et al., 1968; Basuthakur et al., 1973; Levine and Hohenboken, 1978; Fogarty et al., 1984; Fernandes, 1985; Younis et al., 1990; Kabuga and Akowuak, 1991; Kleemann et al., 1991; Bedier et al., 1992; Nawaz and Meyer, 1992). However, some studies reported no significant effect of year on survival rate (Vesely et al., 1977; Fernandes, 1985), on growth (Hohenboken et al., 1976b; Galal and Awgichew, 1981; Iniguez et al., 1991), and on reproductive traits (Mavrogenis, 1982; Iniguez et al., 1991).

AGE OF DAM

The influence of age of ewe on her reproductive performance has been investigated by many researchers (Coop, 1962; Shelton. 1963; Turner and Dolling, 1965; Maijala, 1967; Mullaney and Brown, 1969; Turner, 1969a; Ch'ang and Rae, 1970; Laster et al., 1972; Vesely and Peters, 1974; Dickerson and Glimp, 1975; More O'Ferrall, 1976;Maijala and Osterberg, 1977; Valls, 1979; Martin et al., 1980; Haughey, 1983; Fernandes, 1985; Atkins, 1986; Long et al., 1989; Gates, 1990; Younis et al., 1990; Bedier et al., 1992).

These references cover a wide number of breeds and countries and in general they presented a similar pattern of an increase in reproductive performance with age of ewe to a maximum (5 to 6 yr), followed by a decrease (≥7 yr and older).

In a report by Turner and Dolling (1965), the number of lambs born per ewe mated increased from a minimum of 0.84 for 2-year-old ewes to a maximum of 1.11 for 7-year-old, then decreased to 1.04 for 10-year old ewes. Also, they found that the number of lambs weaned per ewe joined rose from 0.62 for 2-year-old ewes to 0.89 for 6-year-old ewes. Similar results were described by Vakil et al. (1968), Iwan et al. (1971), and Glimp (1971). Dickerson and Glimp (1975) reported that fertility in nine different type ewe breeds (Suffolk, Dorset, Targhee, Hampshire, Rambouillet, Coarse Wool, Navajo, Fine Wool, and Correidale) modified curvilinearly with age at lambing from 45 to 75% at 1 year, to 85 to 95% at 4-6 years, and 60 to 80% at 9 years. Also, prolificacy increased curvilinearly with age of dam, from 100% for 1-year to 160% for 6-years and declined to 135% for 9-year-old ewes. According to Martin et al. (1980), reproductive traits in a synthetic line of sheep was influenced ($P<.01$) by age of ewe. Fertility increased with age, from .78 for 1-year-old dams to .89 for 2- and 3-year-old dams. Prolificacy was greatest (2.08) for 3-year-old ewes, intermediate (1.83) for 2-year-old ewes, and least (1.17) for yearling ewes. Also weaning rate (number of lambs weaned per ewe lambing) was 0.84, 1.49, and 1.77 for 1-, 2-, and 3-year-old ewes, respectively. However, Bedier et al. (1992) studying Barki sheep found that age of ewe did not affect litter size, weaning rate, and total kg of lamb weaned per ewe lambing.

Age of ewe has been reported to have a significant effect on lamb survival (Purser and Young, 1964; Vesely et al., 1966; Smith, 1977; Dalton and Rae, 1978; Oltenacu and Boylan, 1981; Valencia and Gonzalez, 1983; Owens et al., 1985; Peterson and Danell, 1985; Atkins, 1986; Long et al., 1989). In studies by Dalton et al. (1980) and Hinch et al. (1985b) differences due to age explained variation in birth weight of lambs from young and older ewes. Vesely et al. (1966) reported that lambs from young ewes and from 9-year-old ewes had a survival rate of 11% and 15% lower than lambs born to 2- to 8-year-old ewes, respectively. Also, Gonzalez (1983) studying Red African sheep in Venezuela found that lamb mortality decreased with age of dam: 36.8% for lambs from yearling ewes, 28.0% for lambs from 2-3 years old, and 17.6% for lambs from mature ewes. In addition, Boujename et al. (1991), studying crossbred sheep from D'Man x Sardi breeds, found that lambs born from yearling ewes had lower survival rate (84%) than those from mature ewes (94%). However, results from Walker et al. (1979), Atkins, (1980), Fernandes (1985), Hinch et al., (1986), Long et al. (1989), Kleemann et al. (1990), and Gama et al. (1991a) reported no significant variation in lamb survival due to age of dam.

The effects of age of ewe on lamb weight have been described by several researchers. A study done by Nelson and Venkatachalam (1949) found that significant proportion of the variation in birth weight was due to differences in age of dam. They found that lambs from mature ewes were 10% heavier than those from two-year-old ewes. Similar findings were reported by Bodisco et al. (1973), Walstrom et al. (1976), Vesely et al. (1977), Martin et al. (1980), Galal and Awgichew (1981), Alrawi et al. (1982), Fernandes (1985), and Boujenane et al. (1991). Also, Kleemann et al. (1990) stated that birth weight increased with an increase in age of dam within litter size categories, but the size of the increase was lower as litter size increased. In addition, Nawaz and Meyer (1992) studying growth performance of Polypay, Coopworth, and crossbred lambs concluded that the effect of ewe age on birth weights was curvilinear as previously reported by Dickerson et al. (1975) and Lewis and Burfening (1988). In contrast, Olthoff and Boylan (1991) found that age of ewe did not affect (P>.05) birth weight of purebred Finn, Suffolk, Targhee, and Dorset lambs. Also Juma and Faraj (1966) and Mavrogenis (1982) found no significant influence of age of ewe on birth weight.

Weaning weight was significantly affected by age of ewe (Sidwell et al., 1970). They found that two-year-old dams weaned the smallest lambs; four- to eight-year-old ewes weaned the heaviest and three-year-old and eight- to eleven old ewes weaned lambs of intermediate weight. Martin et al. (1980) reported weaning weight of lambs from 3-year-old ewes exceeded those of 2-year-old ewes by 2.5 kg. In addition, Buvanendran et al. (1992) studying Dorper sheep, described that age of dam had a significant curvilinear relation with weaning weight; peak weaning weight was attained by lambs out of ewes 33 to 44 months of age. Also similar results were mentioned by Veseley and Robinson (1970), Dickerson and Laster (1975), Alrawi et al. (1982), Mavrogenis (1982), Fernandes

(1985), Cloeste and de Villiers (1987), Long et al. (1989), and Boujenane et al. (1991). Conversely, Sidwell and Miller (1971), Galal and Awgichew (1981), and Olthoff and Boylan (1991) reported that weaning weight was not affected by variation in age of dam. The effect of age of ewe on weaning weight of her lamb is mainly due to the differential milk production as the ewe ages (Barnicoat et al., 1956; Boyazoghu, 1963). It is generally accepted that a maximum yield is found in the third to sixth lactation (Boyazoghu, 1963). This agrees with the most typical effect of age of ewe on these weights, which has been a quadratic effect; that is, young ewes (mainly 2-year old and younger), produce lighter lambs at the mentioned weights than mature ewes (3- to 7-year-old), and old ewes (older than seven years) produce lambs of intermediate weights.

Price et al. (1962) found that ewe lambs from mature dams were 3 pounds heavier at yearling age than were ewe lambs from 2-year-old dams. Also, Fernandes (1985) reported that Morada Nova lambs born from two-year to less than three-year-old ewes were 7.6% heavier than those from one-year to less than two-year-old ewes. Sidwell et al. (1970), Eltawil et al. (1970), Dickerson and Laster (1975), and Alrawi et al. (1982) reported similar results. In contrast, Terrill et al. (1947), Galal and Awgichew (1981), and Boujenane et al. (1991) reported that age of dam did not significantly affect yearling weights in Columbia and Targhee, Adal, and crossbred D'Man x Sardi sheep, respectively.

WEIGHT OF EWE

Body weight is largely determined by skeletal size and by body condition or fatness. The former is determined by genetic factors, age and permanent environmental factors; the latter, conversely, is largely determined by temporary or short-term environmental effects.

The importance of weight of ewe at mating and(or) lambing as affecting her productive performance has not been consistent (Coop, 1962; Coop, 1966; Bowman, 1966; Killeen, 1967; Younis and Galal, 1973; Bichard et al., 1974; Cumming et al., 1975;

Jonmundsson, 1977; Dymundsson, 1971; Cochran et al., 1984; Iniguez et al., 1991; Reyna et al., 1991; Bedier et al., 1992). For instance, Coop (1966) showed that an increase of 5 kg in weight at mating of Merino and Rambouillet ewes was followed by a 6% increase in number of lambs born. Similarly, Bichard et al. (1974) reported that for each 4.5 kg increase in pre-breeding weight of Clun Forest ewe lambs, lambing rate increased by approximately 7%. Also, in a report by Cochran et al. (1984), significant within ewe correlations were obtained between ewe weight and lamb production traits. Thus, individual ewes tended to be more productive when they were above their expected weight at a given age. In addition, Bedier et al. (1992) concluded that a reduction in ewe's weight at mating by 25% below the average mature weight of Barki ewes resulted in a reduction of 51%, 21%, and 46% in litter size at birth, weaning rate, and total kg of lamb weaned per ewe lambing, respectively. Iniguez et al. (1991) found a suprising negative relationship (P<.01) between ewe body weight at lambing and litter size, implying a reduction of 0.025 lambs per parturition per kg of dam, suggesting that smaller Sumatran ewes could be more prolific than heavier ewes. However, some reports are available where weight of ewe has not influenced significantly her reproductive performance (Laster et al., 1972; Keane, 1974; Dyrmundsson, 1976; Hohenboken et al., 1976a; Geisler and Fenlon, 1979).

In general, productivity (reproductive performance) of ewe is positively influenced by ewe weight at breeding and(or) lambing. Too high or too low weights tend to present a lower productivity with a nearly linear relationship between productivity and ewe body weight in the middle of the range.

Ewe lambing weight has also been reported to influence birth and weaning weights of the lambs (Bhasin and Desai, 1967; Chopra and Acharya, 1971; Arora and Acharya, 1972; Singh et al., 1982; Iniguez et al., 1991). For instance, Iniguez et al. (1991) reported a significant linear relationship between weights of dams and weights of their offspring. Heavier lambs were born and weaned by heavier ewes at a rate of b=.038 and b=.291 kg of lamb per kg of ewe in lamb weights at birth and weaning, respectively. However, there are also two reports available, in which such weight did not affect significantly lamb birth weight, lamb survival up to weaning, the percentage of lambs born, or weaning rate (Laster et al., 1972; Kleemann et al., 1990).

EWE BODY CONDITION

Body condition is highly dependent on environmental factors, mainly nutrition and physiological status. In general, ewe body condition at breeding has been reported to positively influence reproductive performance (Allen and Lamming, 1961; Gunn et al., 1969; Bastiman, 1972; Ducker and Boyd, 1977; Whiteman, 1984) by increasing the reproductive performance as the breeding body condition score increases. Gunn et al. (1969) described a significant and positive correlation between body condition score of ewes at breeding and their reproductive performance. They reported that a significant ($P<.001$) difference between the condition scores 3 and 1.5 where ewes with score 3 had a lambing rate of 169% versus 79% for the ewes with score 1.5. However, Laster et al. (1972) reported no significant effect of body condition on ewe lambing rate.

Molina et al. (1991) studying growth traits in Manchega sheep, found that ewe body condition had a highly significant ($P<.01$) effect on birth and weaning weight of its lambs.

SEX OF LAMB

Sex of individuals is genetically determined, but is considered an environmental effect to study the inheritance of production characters. The effect of sex on growth should be due to the influence of sex hormones. In most animals, males tend to grow faster and reach a greater mature weight than females. Usually, male lambs have been reported to be heavier than female lambs at birth and weaning (Hazel and Terrill, 1945a; Brown et al., 1961; Juma and Faraj, 1966; Vesely and Robinson, 1970; Eikje, 1971;

Dickerson et al., 1972; Hohenboken et al., 1976b; Dickerson et al., 1975; Magid et al., 1981a; Martinez, 1983; Bennett et al., 1991a; Iniguez et al., 1991; Kabuga and Akowuah, 1991; Kleemann et al., 1991; Molina et al., 1991; Buvanendran et al., 1992; Nawaz and Meyer, 1992). Kaushish et al. (1990) studying growth performance of Malpura and Avikaline lambs, found that sex of lamb had a significant effect on birth, weaning, and 6-month weights. On average, males were heavier than females by 0.14, 0.10. and 0.90 kg at birth, weaning, and six-months of age, respectively, than female lambs. Conversely some authors reported that sex of lamb had no significant effect on birth (Bodisco et al., 1973; Fuenmayor et al., 1978), and on weaning and six-month weights (Amble and Malhotra, 1968; Malik and Acharya, 1972; Bodisco et al., 1973; Gour et al., 1977; Figueiredo et al., 1982; Singh et al., 1982; Eltawil and Narendran, 1990). In addition, Olthoff and Boylan (1991) described a non-significant effect on birth and weaning weights due to sex differences on Finn, Dorset, Suffolk, Targhee, and F_1 crossbred lambs.

Galal and Awgichew (1981), Alrawi et al. (1982) and Fernandes (1985), also reported significant effects of sex on yearling weight. As reported by Galal and Awgichew (1981), lamb sex had a significant effect on yearling weight in Adal sheep. Sex of lamb accounted for 46.2% of the total variability on this growth trait.

Sex has also been reported to influence lamb survival. For instance, Turner and Dolling (1965) found that single females had better survival rate than single males. Some other researchers reported better survival rate for females than males (Vetter et al., 1960; Lax and Turner, 1965; Hight and Jury, 1970; Dickerson et al., 1975; Smith, 1977; Oltenacu and Boyland, 1981; Gonzalez, 1983; Fernandes, 1985; Kleemann et al., 1991). Gonzalez (1983) found that mortality was higher (P>.05) for males (27.1%) than for females (21.3%) in Red African lambs. However, Vesely et al. (1977), Magid et al. (1981a), and Ercanbrack and Knight (1985) did not find significant influences on lamb survival rate due to sex of lamb. Different results were obtained by Vall (1979) and Nawaz and Meyer (1992) where male lambs had higher survival rate than female lambs.

Nawaz and Meyer (1992) found that single male lambs had 5% smaller death rate than single female lambs.

TYPE OF BIRTH AND(OR) REARING

In general, it has been shown that single born lambs are heavier than twin born lambs at birth (Chapman and Lush, 1932; Blackwell and Henderson, 1955; Brown et al., 1961; Bowman and Broadbent, 1966; Juma and Faraj, 1966; Vesely and Robinson, 1970; Walstrom et al., 1976; Magid et al., 1981a; Galal and Awgichew, 1981; Figueiredo et al., 1982; Martinez, 1983; Fernandes, 1985; Hinch et al., 1985a; Eltawil and Narendran, 1990; Bennett et al., 1991a; Kabuga and Akowuah, 1991; Kleemann et al., 1991; Molina et al., 1991), at weaning (Sidwell et al., 1970; Eikje, 1971; Dickerson and Laster, 1975; Walstrom et al., 1976; Vesely et al., 1977; Magid et al., 1981a; Alwari et al., 1982; Martinez, 1983; Fernandes, 1985; Cloeste and de Villiers, 1987; Benett et al., 1991a; Kleemann et al., 1991; Molina et al., 1991; Olthoff and Boylan, 1991), and at yearling (Karam, 1959; Sidwell et al., 1970; Galal and Awgichew, 1981; Fernandes, 1985).

Martinez (1983), studying tropical sheep in Venezuela, found that type of birth (single vs multiple) consistently affected birth and weaning weights. Twins weighed 86.7% and 86.0% of the weight of singles at birth and weaning, respectively. However, the significant effect of type of birth disappeared by the age of six-months, although there was a tendency for twins to be litter than singles. Iniguez et al. (1991) reported that twins were 80% of single weights at birth. They also found that at weaning, twins raised as twins, and twins raised as singles were 72 and 79%, respectively, of the weight of singles raised as singles. Similarly, Buvanendran et al. (1992) found that birth-rearing class was the most importance source of variation influencing weaning weight of Dorper sheep. They reported that lambs born and reared as singles were about 20% heavier at weaning than lambs born and reared as twins.

It has been reported that single born lambs presented lower mortality rate than twin born lambs (Vetter et al., 1960; Sidwell et al., 1962; Donald et al., 1963; Shelton, 1963; Asker, 1964; Turner and Dolling, 1965; Mullaney and Brown, 1969; Vesely et al., 1977; Vesely and Peters, 1981; Magid et al., 1981a; Gonzalez, 1983; Alexander, 1984; Fernandes, 1985; Iniguez et al., 1991; Kleemann et al., 1991). Purser and Young (1959) and Purser (1965) showed that mortality was higher among twins than among singles of Scottish Blackface and Welsh Mountain sheep; however, the higher mortality was attributed to lighter birth weight of twins, and at the same weight, mortality was similar for single and twins. Sidwell (1956) found superior survivability of crossbred single over crossbred twin Navajo lambs. Shelton and Carpenter (1957) reported that the death loss to weaning for twins was 15.3% and for singles was 9.9%. Also, Nawaz et al. (1992) found that survival rate for single lambs was 10% higher than among twin born lambs. Similar findings were described by Donald et al. (1963) and Gunn and Robinson (1963). In addition, Bodisco et al. (1973), studying Criollo and West African sheep reported that twins had higher mortality rate (26.5 and 32.1%) than single lambs (18.9 and 16.3%) for the two breeds, respectively. Conversely, they also found that mortality of Barbados Backbelly lambs did not differ (P>.05) between singles (33.6%) and twins (35.2%).

It has been a matter of some controversy, however, whether twin born ewes will be more productive than single born ewes. In environments where twins are tolerated or desired it is very important to know how multiple born lambs perform in comparison with single born lambs. In a study of some aspects of lifetime production in Targhee and Columbia sheep, Basuthakur et al.(1973) reported that, in Columbia, the type of birth of ewes significantly affected (P<.05) the number of lambs born as a total lifetime production. Ewes born as singles or sired by single rams tended to produce less lamb in lifetime than did ewes born twin or sired by twin rams. Dunn and Grewal (1963) and Piper and McGuirk (1967) concluded that twin born ewes were productively superior to singles because of their higher fertility. In addition, Vakil et al. (1968) reported that ewes and rams born as twins tended to produce more lambs than those born as singles, in Rambouillet, Hampshire, Suffolk, Columbia and Corriedale sheep. The authors also concluded that type of birth of ewe and type of birth of her sire affected significantly the number of multiple births, number of lambs weaned, and total lamb weight weaned in Targhee ewes. In Columbia ewes it affected only the number of lambs born.

Individual growth performance of twin lambs was found by Baharin and Beilharz (1977) for Corriedales and by Fernandes (1985) for Morada Novas to be lower than singles; however the latter study found that when the character measured was total kg of lamb weaned per ewe lambing, ewes that produced twins weaned 27% more kg of lamb than ewes dropping single lambs. Iniguez et al. (1991) reported that type of lambing had a significant effect on total litter weight at birth and weaning of Sumatran sheep. Ewes having twins produced 59 and 34% more kg of lamb at birth and weaning, respectively, than ewes lambed singles. Similar findings also were described by Sidwell (1956), Campbell (1962), More O'Ferrall (1976), Black (1982), Eltawil and Narendran (1990), and Nawaz and Meyer (1992).

Controversies can arise from the comparison of results from research conducted under different experimental conditions. In general, it has been true that twins and(or) multiple born lambs suffer more stress from competition than singles. If, however, there is a way of eliminating or reducing such competition, by providing better feed supply to the mother and(or) to the lambs, the differential performance tends to disappear. Ewes dropping multiple lambs per lambing would be more productive and multiple lambs could perform similarly to single lambs.

GENETIC FACTORS

Improving the level of expression of economic traits in sheep through breeding requires an effective use of genetic variation. Pertinent to the effective use of this genetic variability is a knowledge of its magnitude as reflected by heritability of characters.

Genetic and phenotypic correlations among various traits also are important in planning selection procedures. The first step essential to the successful application of genetic principles in improvement of sheep is the estimation of the heritabilities of characters which the breeder wants to improve.

Traits are often described as being highly (e.g., carcass traits), moderately (e.g., growth traits), or lowly (reproduction traits) heritable. An accurate estimate of heritability is important because it indicates the fraction of the phenotypic superiority of selected parents which should be transmitted to the offspring. Thus, progress from selection may be relatively rapid for some traits (e.g., carcass) and relatively slow for others (e.g., reproduction) even when equally intense selection efforts are made to improve them. For this reason, knowledge of the respective heritabilities is an important factor in determining how to practice selection for several traits simultaneously.

As pointed out by Lush (1945), the most important function of heritability in a genetic study involving quantitative characters is its predictive role in expressing the reliability of the phenotypic value as an estimate of breeding value. The size of the standard error of the estimate of heritability gives some indication of the precision of the estimate.

Since selection for one trait alone is a condition which is seldom desirable in any livestock enterprise, it is obvious that heritabilities are not sufficient to describe adequately the genetic properties of a population or to satisfactorily predict the overall consequences of selection. A more adequate description of the additively genetic causes of variation and covariation of different traits includes the genetic covariances or correlations between the characters considered in selection programs in addition to the genetic variances or heritabilities.

The genetic correlations between two traits may be defined as the ratio of the genetic covariance to the product of their genetic standard deviations (Falconer, 1989). A genetic correlation is thus a measure of the relationship between the genetically additive deviations of the two traits. When the genetic correlation between two traits is positive, simultaneous improvement of the two traits is feasible. A negative genetic correlation, however, implies that selection for one trait will automatically cause some deterioration in the other. If both characters are important from the standpoint of productivity, selection for one of them cannot be maintained for long, but will need to be relaxed while efforts are directed toward repairing the damage done to the other trait. Basing selection on a properly balanced combination of the characters can avoid large fluctuations in any of them; however, the net progress in each trait will still be slower than what could be reached if the traits were independent or favorably correlated.

Phenotypic correlations estimate the extent of association between two traits which can be directly observed in the current flock, either positively or negatively (Falconer, 1989). Hence, the extent to which selection will raise production in the current herd depends on the heritability of production traits and, when more than one trait has to be considered, on the phenotypic and genetic correlations between traits. Hazel (1943) pointed out that one of the most important objectives of estimating phenotypic correlations in genetic studies involving quantitative characters is their use for constructing selection indexes to attain the maximum rate of genetic improvement.

This section reviews and considers part of the available estimates in the literature of genetic parameters for growth, survival, and reproduction traits in sheep.

GROWTH TRAITS

Selection for growth has been one of the most used methods of selection in sheep, but it is not always advantageous (Bradford and Meyer, 1986). Genetic improvement of growth in lambs can be accomplished alternatively by selection for particular weights or gains, crossbreeding between different breeds or by a combination of crossbreeding and selection for desirable weights, which is the procedure ordinarily used to develop composite breeds.

The response to selection is directly related to the level of heritability of the trait. The weights most frequently used as selection criteria are the ones which can be measured early in the aninal's life, such as birth, weaning, six-month, and yearling weights. The interest in different weights is simply in choosing which is the most adequate to use in selection for improved growth to weaning. In terminal-sire breeds, this involves improving the breeding value for direct effects on weaning weight. A common finding is that more progress in weaning weight can be achieved by selection on a postweaning weight than on weaning weight itself, because of the higher direct heritability of the postweaning weight and its high genetic correlation with the direct component of weaning weight (Baker et al., 1979; Atkins, 1986). Bradford (1974) suggested that a weight collected as early as six months of age should be adequate for use in selecting for the direct component of weaning weight in sheep.

Selection for growth should also be an important goal in maternal and general-purpose breeds, provided correlated increases in mature weight would be not too high. Dam breeds contribute one-half of the direct genetic effect and all of the maternal genetic effects expressed in progeny weaning weights, and Smith (1964) pointed out that these contributions need to be considered along with characters such as reproductive rate when selection is in maternal lines. Better parameter estimates should allow more emphasis to be placed on the maternal component of weaning weight in maternal and general-purpose breeds (Van Vleck, 1970).

Throughout a survey into the published literature, several heritability estimates for different weights (birth, weaning, six-month, and yearling) are listed in Table 1.

Estimates of heritability for birth weight range from .07 to .46±.12, with an average of .21. In monotoccous species, an increase in birth weight results in dystocia, but fortunately, in multiple births of sheep the increase in the number of offspring lowers the dystocia possibilities. Therefore, in sheep, selection to increase birth weight should be considered whenever selection for prolificacy is practiced to warrant better survival rate of multiple born lambs.

Heritability estimates for weaning weight range from .02 to .38 with an average of .19. Atkins (1986) reported an estimate of .23±.05 for heritability of six-month weight in Scottish Blackface sheep. The estimates of heritability of yearling weight range from .03 to .89, with an average of .26.

In addition to heritability, it is also important to know the relationships between growth weights and other components of productivity. In this respect, the estimation of the genetic and phenotypic correlations between such traits need to be considered.

Genetic correlations between birth and weaning are usually high (0.4 to 1.0) (Gjedrem, 1967; Martin et al., 1980), although Atkins (1986) and Bennett et al. (1991b) reported low correlations involving birth and weaning weights. Estimates of 1.07, .65±.12, .21±.28, .07, .70±.16, and .68±.20 were found between birth weight and weaning weight by Ercanbrack and Price (1969), Olson et al. (1976), Mavrogenis et al. (1980), Alwari et al. (1982), Fernandes (1985), and Stobart et al. (1986), respectively. Atkins (1986) reported low genetic correlation (.06±.24) between birth weight and six-month weight in Scottish Blackface sheep. In this same research, he also found genetic correlation of .86±.05 between weaning weight and six-month weight. Genetic correlations of .08, .86±.20, .22±.25 between birth weight and yearling weight were described by Alwari et al. (1982), Fernandes (1985), and Stobart et al. (1986), respectively. Genetic correlations of .63, 1.00, .74±.18, and .24±.32 between weaning weight and yearling weight were mentioned by Shelton and Menzies (1968), Alwari et al. (1982), Fernandes (1985), and Stobart et al. (1986), respectively.

Phenotypic correlations of .25, .42, .62, .34, .42, .23, and .13 between birth weight and weaning weight were reported by Dzakuma et al. (1978), Mavrogenis et al. (1980), Figueiredo et al. (1982), Fernandes (1985), Atkins (1986), Stobart et al. (1986), and

TABLE 1. HERITABILITY ESTIMATES (h^2) OF BIRTH WEIGHT (BWT), WEANING WEIGHT (WWT), SIX-MONTH WEIGHT (6WT), AND YEARLING WEIGHT (YWT) REPORTED IN THE LITERATURE

BREED	TRAIT	h^2	REFERENCE
Corriedale	BWT	.07	Butcher et al. (1964)
Mixed	BWT	.45±.17	Osman and Bradford (1965)
Tveter	BWT	.09±.09	Gjedrem (1967)
Crossbred	BWT	.35±.11	Olson et al. (1976)
Hampshire	BWT	.21	Dzakuma et al. (1978)
Synthetic	BWT	.17±.08	Martin et al. (1980)
Chios	BWT	.13±.07	Mavrogenis et al. (1980)
Morada Nova	BWT	.35±.10	Fernandes (1985)
Scottish Blackface	BWT	.13±.03	Atkins (1986)
Merino	BWT	.07±.03	Davis and Kinghorn (1986)
Western Range	BWT	.46±.12	Stobart et al. (1986)
Junin	BWT	.17±.03	Bradford et al. (1989)
Southdown x Romney	BWT	.08±.03	Bennett et al. (1991b)
Targhee	WWT	.08	Hazel and Terrill (1945b)
Hampshire	WWT	.07	Givens et al. (1960)
Tveter	WWT	.22±.11	Gjedrem (1966)
Tjotta	WWT	.07±.08	Gjedren (1966)
Rambouillet	WWT	.38	Basset et al. (1967)
Crossbred	WWT	.18±.09	Olson et al. (1976)
Romney	WWT	.08±.04	Baker et al. (1979)
Chios	WWT	.36±.12	Mavrogenis et al. (1980)
Synthetic	WWT	.23±.08	Martin et al. (1980)
Adal	WWT	.02	Galal and Awgichew (1981)
Morada Nova	WWT	.36±.11	Fernandes (1985)
Scottish Blackface	WWT	.06±.03	Atkins (1986)
Merino	WWT	.35±.06	Davis and Kinghorn (1986)
Western Range	WWT	.28±.11	Stobart et al. (1986)
Southdown x Romney	WWT	.05±.02	Bennett et al. (1991b)
Dorper	WWT	.18±.11	Buvanendran et al .(1992)
Scottish Blackface	6WT	.23±.05	Atkins (1986)
Merino	YWT	.09	Morley (1955)
Rambouillet	YWT	.89	Bassett et al. (1967)
Romnelet	YWT	.03	Vesely et al. (1977)
Hampshire	YWT	.11	Dzakuma et al. (1978)
Adal	YWT	.34	Galal and Angichew (1981)
Awassi	YWT	.10	Alrawi et al. (1982)
Morada Nova	YWT	.29±.13	Fernandes (1985)
Western Range	YWT	.26±.11	Stobart et al. (1986)

Bennett et al. (1991b), respectively. Estimates of .23 and .25 between birth weight and yearling weight were reported by Dzakuma et al. (1978) and Fernandes (1985). Correlations between weaning weight and yearling weight of .65 and .58 for Columbia and Targhee sheep, respectively, were reported by Basuthakur et al. (1973). In addition, estimates of .77 for Hampshire (Dzakuma et al., 1978) and of .49 for Morada Nova sheep (Fernandes, 1985) between the two previous mentioned traits were described in the literature. The trend is for weights at more adjacent ages to be genetically and phenotypically more highly correlated (Gjedrem, 1967; Atkins, 1986).

SURVIVABILITY

Lamb losses may be considered one of the most costly forms of reproductive failure since they happen after the major costs of reproduction have been incurred. Lamb survival is a character potentially affected both by the lamb's own genes for survival (viability) and by the ewe's genes for rearing ability (Piper et al., 1982), these being recognizable as the direct and maternal genetic effects, respectively.

Cundiff et al. (1982) reviewed premises for genetic variation in survival up to weaning across species, and concluded that heritability is low, and tends to be higher when measured as a trait of the dam than as a trait of the offspring itself.

Smith (1977) reported an estimate of direct heritability of .06±.03 in a crossbred flock of sheep. Also, Piper et al. (1982), Fogarty et al. (1985), and Baker and Steine (1986) described estimates of .05±.03, .07±.04, and zero for Merino, Composite, and Norwegian sheep, respectively. In addition, Cundiff et al. (1982) and Gama et al. (1991b) reported heritabilities of .04 (mean of two estimates) and .05, respectively.

Some researchers have described encouraging amounts of genetic variation in survival when measured as a trait of the ewe. Shelton and Menzies (1970) estimated repeatabilities of .06 and .10 for survival up to weaning, as a ewe trait, in two Rambouillet herds kept at Sonora and McGregor, Texas, respectively. Also, Cundiff et al. (1982)

reported heritability of .08 (mean of eight estimates). In addition, Fogarty et al. (1985) reported repeatabilities of .16±.02 and .14±.03 for neonatal and preweaning survival, respectively, in a flock of mixed breeds. In that same study, they mentioned heritability estimates of .00±.04 and .07±.04 for the considered traits, respectively. Atkins (1986) studying genetic components of survival rate in sheep, found heritability estimates of zero and .02, in Scottish Blackface and Norwegian breeds, respectively. Also, Baker and Steine (1986) reported heritability estimate of .02 for survival rate in Norwegian sheep. More recently, Abdulkaliq et al. (1989) found repeatability estimates for preweaning survival rate of .17, .21, and .17 for the Targhee, Columbia and Suffolk breeds, respectively. They also reported estimates of heritability for this same trait in Columbia (.14) and Suffolk (.07).

REPRODUCTIVE TRAITS

The extent to which reproductive performance depends on various genetic sources such as breed, sire, and ram effects is likely to be variable depending on several factors. According to the published literature, differences between sheep breeds in reproductive performance are very pronounced (e.g., differences in litter size - Table 2) but within breeds the genetic differences among individuals are believed to be small. However, the potential for genetic progress of reproductive rate within breeds needs to be known since continued improvement of reproductive performance in commercial flocks depends on the improvement of the constituent purebreds by selection (Martin et al., 1981; Land et al., 1983).

The biological efficiency of meat production in the sheep industry can be greatly improved by increasing the number of lambs weaned per ewe (Large, 1970;). This improvement is the result of reduction in ewe maintenance costs, when divided among the increased number of lambs. To increase the number of lambs weaned, fertility and prolificacy need to be raised by improving the environment and(or) by improving the genetic potential of the flock through selection or crossbreeding with breeds of higher reproductive performance.

Selection for fertility or against barrenness may be done by (a) culling ewes dry at their first potential lambing, (b) culling ewes dry at any lambing season, or (c) culling ewes dry twice. The genetic gain obtained from such policies will depend on the proportion of individuals culled. Because this proportion cannot be very large, to maintain effective number, selection would be more effective if practiced to increase the number of lambs born per ewe lambing, which would raise the number of lambs born and the number of lambs weaned, both in the current flock and in the future generations and will allow higher selection intensity (Turner, 1969a, 1969b). The desirability of culling dry ewes vs selection for multiple births may be highly dependent on environmental factors such as feed and management. Shelton et al. (1966) concluded that culling dry ewes is largely an economic factor and a management decision to be taken from year to year depending on sale value and cost or availability of replacement ewes.

Several studies have reported that genetic improvement of efficiency of lamb production through selection for reproductive traits (Young and Turner, 1965; Shelton et al., 1966; Turner, 1966; Gjedrem, 1966; Turner, 1969a; Large, 1970; Van der Westhuysen, 1973; Barlow and Hodges, 1976; Mann et al., 1978; Walkley and Smith, 1980; Martin et al., 1981; Fogarty, 1984; Bradford, 1985; Hanrahan, 1986; Fahmy, 1990). Based on a survey throughout the published literature, some heritability and repeatability estimates are presented in Table 3 for fertility and litter size at birth, and in Table 4 for litter size at weaning, litter weight at birth and litter weight at weaning.

It is generally accepted that the heritability of fertility under annual lambing is low (zero to .07; Fogarty et al., 1985), while that for litter size is variable (-.15 to .35) but higher, averaging about .07 (Bradford, 1985). Heritability estimates for fertility and litter size at birth, respectively, include values of .02±.04 and .12±.06 in crossbreeds (Clarke and Hohenboken, 1983),

TABLE 2. LITTER SIZE AT BIRTH IN SHEEP CITED IN THE LITERATURE

BREED	COUNTRY	LITTER SIZE	REFERENCE
Columbia	U.S.A.	1.27	Terrill and Stoehr (1939)
Corriedale	U.S.A.	1.18	" " " "
Rambouillet	U.S.A.	1.22	" " " "
Hampshire	U.S.A.	1.54	Sidwell et al. (1962)
Merino	U.S.A.	1.30	" " " "
Shropshire	U.S.A.	1.23	" " " "
Southdown	U.S.A.	1.26	" " " "
Corriedale	Canada	1.45	Vesely and Peters (1965)
Rambouillet	Canada	1.38	" " " "
Romeldale	Canada	1.54	" " " "
Romnelet	Canada	1.35	" " " "
Blackface	G. Britain	1.85	Wiener (1967)
Lincoln	G. Britain	1.56	" "
Southdown	G. Britain	1.42	" "
Welsh Mountain	G. Britain	1.40	" "
Cheviot	G. Britain	1.53	Geisler and Fenlon (1979)
Clun Forest	G. Britain	1.59	" " " "
Derbyshire	G. Britain	1.50	" " " "
Swaledale	G. Britain	1.63	" " " "
Finnsheep	U.S.A.	2.78	Oltenacu and Boylan (1981)
Minnesota 100	U.S.A.	1.09	" " " "
Suffolk	U.S.A.	1.40	" " " "
Targhee	U.S.A.	1.29	" " " "
Ile-de-France	France	1.40	Cahill (1981)
Touabire	Senegal	1.11	Bradford (1983)
Uda	Nigeria	1.14	Dettmers (1983)
Yankasa	Nigeria	1.25	" "
W. Afr. Dwarf	Nigeria	1.46	" "
Santa Ines	Brazil	1.25	Figueiredo et al. (1983)
White	V. Islands	1.64	Hupp and Deller (1983)
West African	Venezuela	1.43	Martinez (1983)
Blackbelly	Barbados	1.84	Patterson (1983)
Persian	T. Tobbago	1.10	Rastogi et al.(1983)
Peul	Mali	1.06	Wilson (1983)
Pelibuey	Mexico	1.22	Zarazua and Padilha (1983)
Morada Nova	Brazil	1.35	Fernandes (1985)
Yankasa	Nigeria	1.06	Oyedipe et al. (1986)
Sali	Zimbabwe	1.35	Chifamba et al. (1988)
Blackhead	Mozambique	1.00	Rocha et al. (1990)
Afar	Ethiopia	1.03	Wilson (1991)
Dorper	Zimbabwe	1.29	" "
Dubasi	Sudan	1.18	" "
Macina	Mali	1.03	" "
Marai	Kenya	1.05	" "
Toronke	Mali	1.05	" "
Tswana	Botswana	1.02	" "
Vogar	Togo	1.40	" "
Watish	Sudan	1.17	" "

TABLE 3. HERITABILITY (h^2) AND REPEATABILITY (r) OF FERTILITY (FE) AND LITTER SIZE AT BIRTH (LSB), PUBLISHED IN THE LITERATURE.

BREED	TRAIT	h^2	r	REFERENCE
Romney	FE	.00-.15		Rae and Ch'ang (1955)
Swed. Landrace	FE	.11		Rendel (1956)
Texel	FE	.03-.17		Sharafeldin (1960)
Rambouillet	FE	.07±.09	.09	Shelton and Menzies (1970)
Crossbred	FE	.02±.04	.15±.03	Clarke and Hohenboken (1983)
Crossbred	FE	.06±.02	.06-.09	Fogarty et al. (1985)
Scot. Blackface	FE	.01±.03	.10±.01	Atkins (1986)
Merino	FE	.11±.05	.17±.01	Davis and Kinghorn (1986)
Targhee	LSB	.29		Karam and Regab (1958)
Texel	LSB	.22±.11		Karam and Regab (1958)
Romney	LSB	.03		Ch'ang and Rae (1961)
Peppin Merino	LSB	.35		Young et al. (1963)
Blackface	LSB	.32	.19	Purser (1965)
Mountain Breeds	LSB	.14±.03	.19	Purser (1965)
Welsh Mountain	LSB	.16±.04	.24	Purser (1965)
Hampshire	LSB		.11	Inskeep et al. (1967)
Merino	LSB	.20		Kennedy (1967)
Columbia	LSB	-.01		Lal (1968)
Rambouillet	LSB	.21±.07		Vakil et al. (1968)
Rambouillet	LSB	.10±.11	.15	Shelton and Menzies (1970)
Columbia	LSB	.05±.11		Basuthakur et al. (1973)
Targhee	LSB	.12±.09		Basuthakur et al. (1973)
Clun Forest	LSB	.08±.05	.12±.02	Forrest and Bichard (1974b)
Galway	LSB	.18	.20±.04	More O'Ferrall (1976)
Iceland	LSB	.19		Jonmundsson (1977)
Merino	LSB	.10		Mann et al. (1978)
Crossbred	LSB		.08-.16	Atkins (1982)
Crossbred	LSB	.12±.06	.19±.05	Clarke and Hohenboken (1983)
Morada Nova	LSB		.20±.04	Fernandes (1985)
Crossbred	LSB	.14±.04	.08-.16	Fogarty et al. (1985)
Scot. Blackface	LSB	.12±.04	.22±.02	Atkins (1986)
Norwegian	LSB	.13		Baker and Steine (1986)
Merino	LSB	.19±.08	.18±01	Davis and Kinghorn (1986)
Columbia	LSB	.35*	.17±.04	Abdulkhaliq et al. (1989)
Suffolk	LSB	.18*	.09±.04	Abdulkhaliq et al. (1989)
Targhee	LSB	.23*	.12±.04	Abdulkhaliq et al. (1989)

*Standard errors of heritability estimates vary from .15 to .23.

TABLE 4. HERITABILITY (h^2) AND REPEATABILITY (r) OF LITTER SIZE AT WEANING (LSW), LITTER WEIGHT AT BIRTH (LWB), AND LITTER WEIGHT AT WEANING (LWW), CITED IN THE LITERATURE.

BREED	TRAIT	h^2	r	REFERENCE
Merino	LSW	.09±.09	.08±.03	Young et al. (1963)
Blackface	LSW	.05±.03		Purser (1965)
Welsh	LSW	.05±.04		Purser (1965)
Hampshire	LSW		.13	Inskeep et al. (1967)
Merino	LSW	.06±.08	.04±.03	Kennedy (1967)
Columbia	LSW	.43±.16		Basuthakur et al. (1973)
Targhee	LSW	.13±.10		Basuthakur et al. (1973)
Galway	LSW	.25		More O'Ferrall (1976)
Crossbred	LSW	.00±.03	.08±.05	Clarke and Hohenboken (1983)
Crossbred	LSW	.02±.07		Martin et al. (1981)
Crossbred	LSW	.10±.05		Fogarty et al. (1985)
Columbia	LSW	.26*	.15	Abdulkhaliq et al. (1989)
Suffolk	LSW	.12*	.10	Abdulkhaliq et al. (1989)
Targhee	LSW	.19*	.13	Abdulkhaliq et al. (1989)
Crossbred	LWB	.24±.09		Martin et al. (1981)
Columbia	LWB	.20*	.21	Abdulkhaliq et al. (1989)
Suffolk	LWB	.28*	.18	Abdulkhaliq et al. (1989)
Targhee	LWB	.12*	.17	Abdulkhaliq et al. (1989)
Purebred	LWW		.21	Gjedrem (1967)
Fine-wool	LWW	.29		Shelton and Menzies (1968)
Columbia	LWW	.50±.18		Basuthakur et al. (1973)
Targhee	LWW	.18±.10		Basuthakur et al. (1973)
Purebred	LWW		.16	Eikje (1975)
Iceland	LWW	.24		Jonmundsson (1976)
Galway	LWW	.25		More O'Ferrall (1976)
Crossbred	LWW	.14±.10		Martin et al. (1981)
Crossbred	LWW	-.05±.02	.09±.05	Clarke and Hohenboken (1983)
Crossbred	LWW	.11±.07	.12±.03	Fogarty et al. (1985)
Columbia	LWW	.28*	.22	Abdulkhaliq et al. (1989)
Suffolk	LWW	.25*	.11	Abdulkhaliq et al. (1989)
Targhee	LWW	.13*	.14	Abdulkhaliq et al. (1989)

*Standard errors of heritability estimates vary from .15 to .23.

.06±.02 and .14±.04 in mixed breeds and crosses (Fogarty et al., 1985), .01±.03 and .12±.04 in the Scottish Blackface (Atkins, 1986), .11±.05 and .19±.08 in a Merino line (Davis and Kinghorn, 1986), and .13 for litter size in Norwegian breeds (Baker and Steine, 1986). In addition, Abdulkhaliq et al. (1989) reported estimates for litter size at birth of .35, .18 and .23 in Columbia, Suffolk and Targhee sheep, respectively, based on sire-of-ewe variance component using half-sib analysis.

Theoretically, repeatability should set the upper limit to heritability assuming the trait being measured at different times is genetically identical (Falconer, 1989). However, when reproduction results in production of one or more lambs, it has been suggested that an adverse effect on the dam such as physiological or nutritional stress may lower the repeatability (Shelton and Menzies, 1970). Using multiple records on dams is one common way for improving the heritability and(or) the accuracy of the estimated breeding value of the traditional reproduction characters. Such better estimates and(or) accuracies result in higher response to selection, although this is likely to increase generation interval since, as pointed out by Bradford (1985), most ewes are required to lamb at least twice and probably three or four times, to record the parameters and to keep flock numbers. The first lambing record of ewes commonly has a lower repeatability than that of later parities (Atkins, 1986) and the heritability may also be lower (Young et al., 1963). Results on the later point are not consistent, and it may be that the usefulness of records at early ages, or at first lambing, largely depends on breed and environmental factors. Repeatability estimates for fertility and litter size at birth, respectively, from recent studies include values of .06 to .09 and .08 to .16 (Fogarty et al., 1985), .10±.01 and .22±.02 (Atkins, 1986), .17±.01 and .18±.01 (Davis and Kinghorn, 1986), and .09 to .12 for litter size at birth (Abdulkhaliq et al., 1989).

It is desired to complement selection for litter size at birth with selection for any improved capacity to rear lambs that might be possible. This directs attention on litter size at weaning, that can be considered then both as the goal and as a practical selection criterion. There are studies reporting the repeatability (Inskeep et al., 1967) or heritability (More O'Ferrall, 1976) of litter size at weaning to be larger than that for litter size at birth. Conversely, more frequently the opposite is true (Turner, 1969a; Eikje, 1975; Clarke and Hohenboken, 1983; Atkins, 1986; Baker and Steine, 1986; Davis and Kinghorn, 1986; Abdulkhaliq et al., 1989). It appears that when there is little genetic variation in rearing ability, selection based on litter size at weaning makes inadequate use of information on litter size at birth. Selection in these situations should be better based on litter size at birth, considering its genetic correlation with litter size at weaning is positive. The heritability and repeatability estimates for litter size at weaning shown in Table 4 range from zero to .43 and .04 to .15, respectively.

Very few estimates of heritability and repeatability of litter weight at birth have been published in the literature (Table 4). Martin et al. (1981) working with crossbred ewes reported a value of .24±.09 for heritability of litter weight at birth. Recently, Abdulkhaliq et al. (1989) working with Columbia, Suffolk and Targhee, estimated heritability and repeatability of litter weight at birth by the paternal half-sib analysis. Their estimates of heritability and repeatability for this trait ranged from .12 to .28 and .17 to .21, respectively.

A wide range of estimates for heritability of litter weight at weaning has been cited in the literature (Table 4). Shelton and Menzies (1968b) estimated that heritability of litter weight at weaning was .29. Basuthakur et al. (1973) working with Columbia and Targhee sheep reported estimates for the same trait of .50±.18 and .18±.10, respectively. Martin et al. (1981) also estimated heritability of litter weight at weaning using the paternal half-sib analysis (.14±.10) and daughter-dam regression (-.08±.06) in crossbred sheep. Another negative value (-.05±.02) for the same character also was reported by Clarke and Hohenboken (1983), studying reproductive performance of crossbred sheep. Fogarty et al. (1985) working with Dorset, Finnsheep, Rambouillet, Suffolk, and Targhee and their crosses, reported heritability estimates of .11±.07 for litter weight at weaning by the paternal half-sib method. More recently, Abdulkhaliq et al. (1989) found estimates of heritability for this same trait of .28, .25 and .13 for the Columbia, Suffolk and Targhee sheep, respectively.

Repeatability estimates for litter weight at weaning shown in Table 4 vary from .09 to .22. Clarke and Hohenboken (1983) studying reproductive performance of crossbred sheep, reported a low estimate of repeatability for litter weight at weaning (.09±.05). Fogarty et al. (1985) also reported a repeatability estimate in crossbred sheep for this same trait of .12±.03. Additional estimates for repeatability of litter weight at weaning are provided by Abdulkhaliq et al. (1989) working with Columbia, Suffolk and Targhee breeds and the figures were .22, .11 and .14, respectively.

In addition to heritabilities and repeatabilities, estimation of the genetic and phenotypic correlations between reproductive traits and between them and other productive characters are important in order to design an effective selection scheme as a possible way to improve total sheep performance (Turner, 1969a; Bradford and Meyer, 1986).

Purser (1965) reported genetic correlations of .44±.11 and of .78±.08 between dam live weight and litter size for Blackface and Welsh Mountain ewes, respectively. Phenotypic correlations of .23±.01 and .25±.02 for the same traits in the respective ewes were also reported. Gjedrem (1966) reported a negative genetic correlation of -.46±.16 between litter size at birth and weaning weight of the lambs. Shelton and Menzies (1968a) reported genetic correlations of -.03 and .18 between the number of lambs born and, weaning and yearling weights, respectively. Fogarty et al. (1982) reported genetic correlations of -.22±.35, -.09±.30, and -.18±.33, between fertility and neonatal survival, postnatal survival and weaning weight, respectively, for Dorset, Finnsheep, Rambouillet, Suffolk, Targhee, and various generations of crosses in the formation of two composite lines. Genetic correlations of -.30±.32, -.32±.28, and -.39±.24, between litter size at birth and, neonatal survival, postnatal survival and weaning weight, respectively, in the same breeds, were also reported.

As can be seen, particular studies tend to present negative genetic correlations between reproductive traits with characters that are indicative of growth and(or) adaptability. In those cases, the negative relationships suggest the need of inclusion of reproductive traits in the selection indices in order to prevent selection against them, whenever traits negatively genetically correlated with reproductive traits are included in the index.

Genetic correlations between the various reproductive traits have been reported by some researchers (Basuthakur et al., 1973; More O'Ferrall, 1976; Martin et al., 1981; Fogarty et al., 1985; and Abdulkhaliq et al., 1989). More O'Ferrall (1976) estimated genetic correlations between: litter size at birth and litter size at weaned (1.16); litter size at birth and litter weight at weaning (1.20); and between litter size at weaning and litter weight at weaning (.88). Martin et al. (1981) found genetic correlations between number of lambs weaned and, birth litter weight and weaning litter weight of 1.09±.45 and .59±.32, respectively. They also found a genetic correlation of .80±.18, between birth litter weight and weaning litter weight. Fogarty et al. (1985) reported genetic correlations of .70±.18, .45±.30 and .66±.19 between fertility and, number of lambs born per ewe mated, number of lambs weaned per ewe mated, and total weight of lamb weaned per ewe mated. Corresponding figures of .57±.22, -.18±.33 and -.12±.27 between litter size at birth and, number of lambs born per ewe mated, number of lambs weaned per ewe mated, and total weight of lamb weaned per ewe mated, respectively, were also reported.

Phenotypic correlations between various reproductive component traits have been estimated by More O'Ferrall (1976). They reported phenotypic correlations between litter size at birth and, litter size at weaning and litter weight at weaning of .63 and .54, respectively, in Clun Forest sheep. Martin et al. (1981) also estimated the phenotypic correlations between several reproductive traits. They found that the correlations between litter size at birth and, birth litter weight, number of lambs weaned, and weaned litter weight, were .75, .69, and .47, respectively. They also calculated the correlations between number of lambs weaned and, birth litter weight and weaned litter weight, the figures were .64 and .87, respectively, while correlation between birth litter weight and weaned litter weight was .59. Phenotypically, according to Fogarty et al. (1982), fertility is positively correlated with number of lambs weaned and weaned litter weight (.61±.01 and .61±.01, respectively). Estimates of phenotypic correlations between litter traits (litter size at birth and at weaning, litter weight at birth and at weaning) in Columbia, Suffolk and Targhee breeds were reported by Abdulkhaliq et al. (1989). The phenotypic correlations, in the three breeds, ranged from .37 (between litter size at birth and weaning litter weight) to .93 (between litter size at weaning and weaned litter weight), with higher correlations occurring where a part-whole relationship existed.

ADJUSTMENT FACTORS

Various studies have determined adjustment factors for environmental sources of variation, such as age of dam, type of birth-rearing, and sex, that need to be used in selection programs for livestock species (Anderson and Wilham, 1978; Nelson and Kress, 1981). The adjustment factors used by the National Sheep Improvement Program in the USA, assume a linear rate of growth from birth to weaning. However, some authors studying beef cattle concluded this assumption is incorrect (Nelson and Kress, 1981; Woodward et al., 1989). Boggess et al. (1991) evaluated linear adjustments for sheep weaning weights to an age-constant basis. They concluded that a linear age adjustment is appropriate for preweaning weights if interval period of weaning is ± 7 days. No similar studies, estimating correction factors for sex of lamb, age of dam, and type of birth-rearing, were found in the literature for pre- and post-weaning weights in hair sheep.

CHAPTER III

MATERIALS AND METHODS

The data used in this analysis were made available by the Ceara State Agricultural Research Agency (EPACE), Ceara, Brazil, and represent the performance of an unselected Morada Nova flock over the years of 1980 through 1991.

BREED DESCRIPTION

The Morada Nova sheep comes closest to being a native type unique to Brazil and it is found throughout the "drought polygon" of Northeast Brazil (Shelton and Figueiredo, 1981).

The origin of this breed is a subject of controversy. According to Domingues (1954), who first named this breed, the Morada Nova sheep is directly descended from the Portuguese Bordaleiro sheep, which were introduced into Brazil during the colonial time (1500 to 1822). Notwithstanding, Mason (1980) suggested that it is descended principally from West African sheep brought to Brazil by slave ships from Africa. Today the most accepted theory is that the breed was developed from crosses between the Bordaleiro and West African sheep. This concurs with the author's opinion.

The Morada Nova sheep is considered a dual-purpose breed for meat and skin (hides) production. It is a small sheep (average weight range from 35-45 kg and 25-35 kg for an adult male and female, respectively) but well adapted to the stress for environmental conditions of the Northeast Brazil (NEB).

There are two types of coat color for the breed (red and white) which are accepted by the Associação Brasileira de Criadores de Ovinos (ABCO). However, the red coat color (varying from dark red to cream) is the most preferable type among producers. This research was conducted with the red Morada Nova type. Breed standards defined by ABCO (1977) include the following: no horns; short pointed shell-shaped ears; long head; subconvex profile; short and slightly sloping rump; short to medium length thin tail; red or white hair color; pigmented skin, mucous membranes, and hooves; and short, thick, shiny hair. Disqualifying attributes include: wool; horns; unpigmented skin, hooves and mucous membranes; large or pendent ears; beard or mane; spots of any color; and genital defects.

FLOCK CHARACTERISTICS

The experimental Morada Nova flock belongs to EPACE and was housed at the Iracema Farm, Quixada, Ceara, Brazil, located at 5^{o} South latitude at an altitude of approximately 180 meters. During the experimental period, the average temperature ranged between 26.4 and 27.8 ^{o}C indicating little seasonal variation. The annual rainfall (Figure 3) was highly variable but averaged about 701 mm, lower than the expected average (800 mm) for this area. Most of the precipitation occurred from January through May in a very irregular distribution (Figure 4).

The flock was comprised of 96 to 313 breeding ewes and 5 to 18 sires (Table 5) and was established with the intention of being representative of the Morada Nova breed. Over the experimental period, the flock was closed to outside animals except for the use, in the breeding seasons of 1986 and 1987, of three rams borrowed from sheep producers of the region. These rams were considered representative of rams available in these years. Replacement rams within the flock were used for breeding with an average age of 18 months. Only rams free of faults of the testicles, legs, mouth, and breed pattern were used. Selection intensity was generally weak. Except for the culling of a small percentage (less than 15%) of physically unsound, unhealthy lambs and(or) lambs without breed

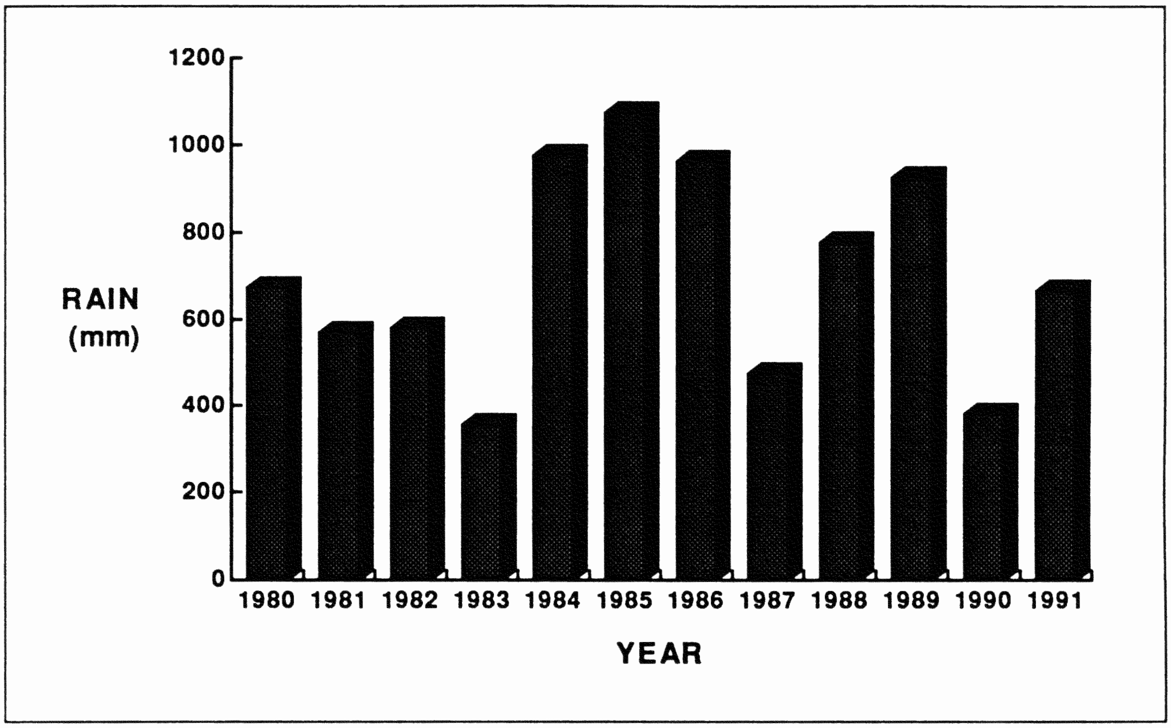

FIGURE 3. RAINFALL (mm) DISTRIBUTION BY YEAR DURING THE RESEARCH TIME AT THE IRACEMA FARM, EPACE, QUIXADA, CEARA, BRAZIL

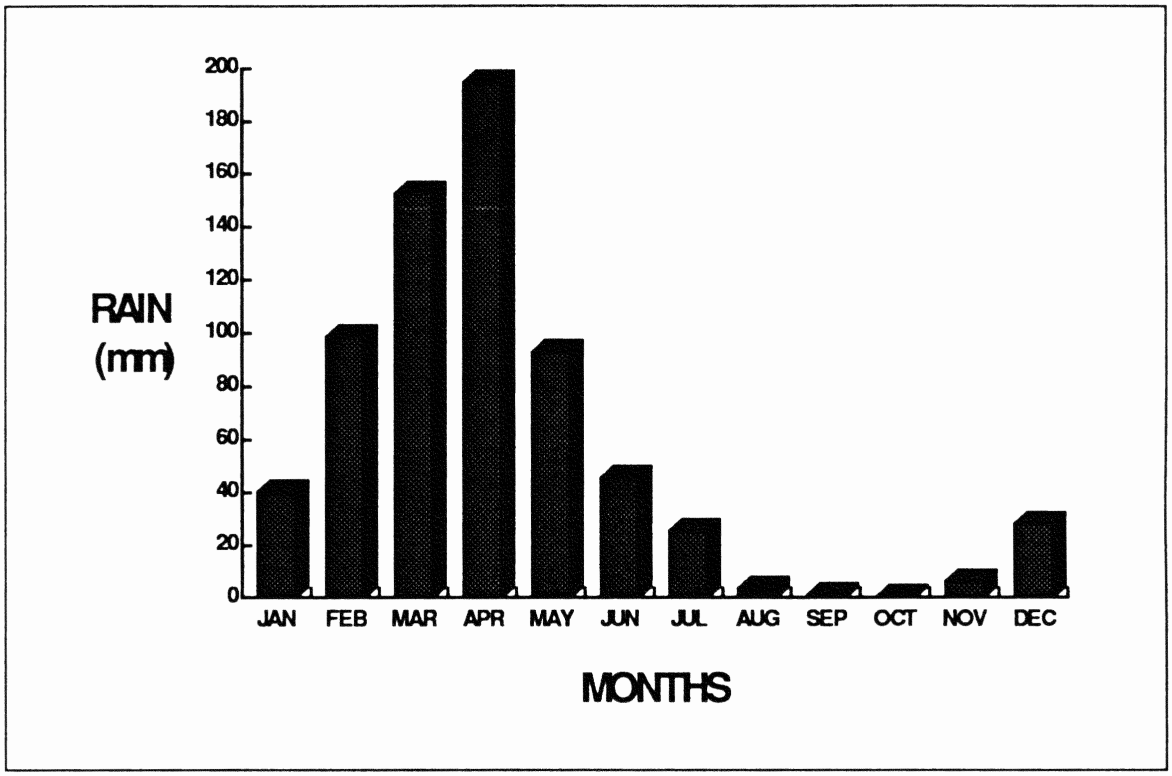

FIGURE 4. AVERAGE ANNUAL RAIN (mm) DISTRIBUTION BY MONTH DURING THE EXPERIMENTAL PERIOD (1980 TO 1991) AT THE IRACEMA FARM, EPACE, QUIXADA, CEARA, BRAZIL

pattern, all ewe lambs entered the flock for the first breeding between 17 to 19 months of age. Adult ewes were culled only if they had health problems (principally udder faults and caseous of lymphadenitis) and(or) failed to rear any lambs in two consecutive years after their first opportunity. The annual attrition rate of ewes, comprising both mortality and culling, averaged about 15%.

FLOCK MANAGEMENT

During the experimental period, management procedures and pasture conditions remained relatively stable. Differences of forage availability among the years were a reflection of the amount (Figure 3) and distribution (Figure 4) of rainfall that occurred in those years. It is important to mention that three droughts occurred during the course of this research (1980 to 1983; 1987 to 1988; and 1990 to 1991).

The Morada Nova sheep flock was raised on native pastures (Caatinga), divided into four groups (sires, breeding ewes, male lambs, and ewe lambs), throughout the year with mineral supplementation provided ad-libitum. The herd health program included vaccinations against rabies and drenching for internal parasites as necessary to insure survival. All ewes were managed as a single flock except for a period of four weeks after lambing, when ewes and their lambs were divided into small groups based on age of lambs. After this period they formed one group up to weaning time.

The breeding season lasted sixty days each year during November to December with subsequent lambing in April and May. The rams were fed 200 g per head per day of a mixture of equal parts of corn and cottonseed meal during the mating season. The females were kept with vasectomized males to detect estrus. This was observed twice (early morning and late afternoon) each day and ewes standing in heat were bred by natural service in the corral by a previously selected ram. Weaning was at 112 days of lamb age and normally occurred from August to September. At weaning time, male lambs were separated from ewe lambs and raised in different paddocks but under similar

TABLE 5. DISTRIBUTION OF THE EXPERIMENTAL MORADA NOVA FLOCK PER YEAR AT THE IRACEMA FARM, EPACE, QUIXADA, CEARA, BRAZIL.

YEAR (a/b)	No. OF SIRES USED	No. OF BREEDING EWES	NUMBER OF LAMBS			
			AT BWT [c]	AT WWT [d]	AT WT6 [e]	AT YWT [f]
1980/1981	7	121	96	82	81	79
1981/1982	8	203	260	214	196	184
1982/1983	11	271	305	262	240	222
1983/1984	16	302	357	283	243	223
1984/1985	18	302	320	237	209	178
1985/1986	18	309	359	291	251	192
1986/1987	18	260	206	172	150	87
1987/1988	18	313	367	290	261	87
1988/1989	17	249	274	248	223	120
1989/1990	18	197	211	188	114	79
TOTAL	149	2226	2755	2267	1968	1451

[a]Year of breeding

[b]Year of lambing

[c]BWT = Birth weight

[d]WWT = Weaning weight

[e]WT6 = Weight at six months

[f]YWT = Yearling weight

management conditions and forage availability.

DATA RECORDED

The following data were collected from 1980 to 1991 in the different phases of this research:

Breeding: (ewe) identification tag, weight, age, coat color, body condition score, date of breeding, and identification of sire used.

Lambing: individual number of lambs, identification of dam and sire, date of birth, lamb birth weight, ewe weight, sex, and type of birth.

Weaning: date, lamb weight, and type of rearing.

Postweaning: lamb weights at six- and 12-months of age.

Routine Data: cause of removal (death date and reason, culled date and reason), dates of vaccinations, and dates of clinical and parasite treatments.

The following performance measures were defined for analysis and, where necessary, were derived from the available records:

a) birth weight (BWT). Weight of each individual lamb within 12 hours of birth.

b) survival rate up to weaning (SRW). Alive at weaning or not, for all lambs born. Lambs fostered or reared in the nursery were excluded.

c) weaning weight (WWT). Weight of each lamb weaned at approximately 112 days of age. Fostered and nursery-reared lambs were excluded.

d) 6-month weight (WT6). Weight of each lamb, remaining in the project, at approximately 180 days of age.

e) yearling weight (YWT). Weight of each lamb remaining in the study, at approximately 365 days of age.

f) mate rate (MAR). Whether or not a ewe bred during the breeding season.

g) parturition rate (PAR). Whether or not a mated ewe lambed in the following lambing period.

h) litter size at lambing (LSL). The number of lambs born to a ewe at each lambing.

i) litter weight at lambing (LWL). Total weight of lambs born per ewe lambing.

j) litter size at weaning (LSW). The number of lambs reared by ewes to weaning, for each ewe lambing. Lambs fostered or raised in the nursery were excluded.

l) litter weight at weaning (LWW). Total weight of lambs weaned per ewe lambing. Fostered and nursery-reared lambs were excluded.

m) lamb survival rate up to weaning as a trait of the ewe (LSR=LSW/LSL). The number of lambs reared by the ewe and alive at weaning time per the number of lambs born to a ewe at each lambing.

STATISTICAL PROCEDURES

The number of individual records collected at different phases of this research were unequal for both reproduction and growth characters. It was, therefore, necessary to analyze these data separately in order to utilize the maximum number of records available for each specific trait.

Because of unequal subclass numbers, least-squares analysis variance techniques (Harvey, 1977) using the mixed model least-squares and maximum likelihood computer program (LSMLMW & MIXMDL) (Harvey, 1990) were used for estimating the genetic and environmental sources of variation affecting each growth and reproductive trait studied in this research. Estimates of heritability for the different characters were obtained by paternal half-sib correlations (Falconer, 1989) using LSMLMW & MIXDML (Harvey, 1990). Using the same program, analysis of variance and covariance procedures were performed to calculate the genetic and phenotypic correlations between the considered characters. To estimate the genetic parameters, all environmental effects were treated as fixed and, sire and(or) ewe as random effects.

Growth Traits

The analysis of birth weight (BWT) was based on records of 2755 lambs sired by 76 different sires and born during the years of 1981 to 1990 (Table 5).

Weaning weight was analyzed from individual records of 2267 lambs sired by 76 different sires and weaned from 1981 to 1990 according to the respective year of birth. Weaning weight of lambs was adjusted for 112 days of age using the following formula:

$$WWT = \{[(\frac{(WWT_i - BWT)}{(AWWT_i)}) X (112)] + (BWT)\}$$

where:

WWT = adjusted weaning weight of lambs at 112 days of age.

WWT_i = actual weaning weight of lamb at weaning time.

BWT_i = weight of lamb at birth.

AWWTi = actual age of lamb at weaning, i.e., number of days between date of birth and actual weaning.

The analysis of weight at six months of age (WT6) was based on records of 1968 lambs sired by 76 different sires. Weights of lambs at this age were adjusted to 180 days of age based on this formula:

$$WT6 = \{[(\frac{(WT6_i - WWT_i)}{(A6M)}) X (180 - 112)] + (WWT)\}$$

where:

WT6 = adjusted 6-month weight of lambs at 180 days of age.

$WT6_i$ = actual weight of lamb at 6-months of age.

WWT_i = actual weaning weight of lamb at weaning time.

A6M = number of days between weaning time and 6-month time.

WWT = adjusted weaning weight of lambs at 112 days of age.

Yearling weight was analyzed based on 1451 individual lamb records. Those lambs were progeny of 76 different sires, and reached 12 months of age during the years 1982 to 1991 according to the respective year of birth. Yearling weights of lambs were adjusted to 365 days of age using the following formula:

$$YWT = \{[(\frac{(YWT_i - WWT_i)}{(AYT_i)}) \text{ X } (365 - 112)] + (WWT)\}$$

where:

YWT = yearling weight of the lamb adjusted for 365 days of age.

YWT_i = actual yearling weight at yearling time.

WWT_i = actual weaning weight of lamb at weaning time.

AYT_i = number of days between weaning and yearling time.

WWT = adjusted weaning weight of lambs at 112 days of age.

The following general linear model was used for analysis of BWT, WWT, WT6, YWT, and SRW, and estimation of variance components for heritabilities and genetic and phenotypic correlations through paternal half-sib procedures:

$$\mathbf{Y_{ijklmno}} = \mu + R_i + P_j + S_k + T_l + A_m + (PT)_{jl} + (ST)_{kl} + (AT)_{ml} + W_n + \epsilon_{ijklmno},$$

where:

$\mathbf{Y_{ijklmno}}$ = observed value for BWT, WWT, WT6, YWT, and SRW measured on the o^{th} lamb of the m^{th} age of dam class and n^{th} weight, l^{th} type of birth and(or) rearing class, k^{th} sex class, sired by the i^{th} sire in the j^{th} year.

μ = overall mean.

$\mathbf{R_i}$ = effect of the i^{th} sire.

$\mathbf{P_j}$ = j^{th} year of birth effect.

$\mathbf{S_k}$ = k^{th} sex class of lamb effect.

$\mathbf{T_l}$ = l^{th} type of birth and(or) rearing class effect.

A_m = m^{th} age of dam class effect.

$(PT)_{jl}$ = effect of interaction between the j^{th} year of birth and the l^{th} type of birth and(or) rearing class.

$(ST)_{kl}$ = effect of interaction between the l^{th} type of birth and(or) rearing in the k^{th} sex class of lamb.

$(AT)_{ml}$ = effect of interaction between the m^{th} age of ewe with l^{th} type birth and(or) rearing class.

W_n = n^{th} effect of weight of ewe.

$\epsilon_{ijklmno}$ = random effect, ϵ's assumed NID $(0, \sigma^2)$.

Reproductive Traits

The analyses of mate rate (MAR) and parturition rate (PAR) were based on records of 2527 exposed ewes and 2465 bred ewes during the years of 1980 to 1989 and 1981 to 1990, respectively.

Litter size at lambing (LSL), litter size at weaning (LSW), litter weight at lambing (LWL), litter weight at weaning (LWW), and lamb survival rate up to weaning as a ewe trait (LSR) were analyzed using 2226 individual lambings from 806 different ewes throughout the years 1981 to 1991.

Litter weight at weaning (LWW) was adjusted to 112 days of age based on the following formula:

$$LWW = \{[(\frac{(LWW_i - LWL)}{(ANW_i)}) \ X \ (112)] + (LWL)\}$$

where:

LWW = adjusted litter weight to 112 days at weaning per ewe lambing.

$\mathbf{LWW_i}$ = actual litter weight at weaning time

LWL = litter weight at birth per ewe lambing.

$\mathbf{ANW_i}$ = number of days between lambing and weaning.

To analyze MAR, PAR, and LSL, the following general linear model was used:

$$Y_{ijklmno} = \mu + E_i + P_j + A_k + B_l + C_m + (AB)_{kl} + W_n + \epsilon_{ijklmno}$$

where,

$Y_{ijklmno}$ = the oth record (MAR, PAR and LSL) on the ith ewe of kth age class, lth body condition score, mth coat color class, and nth weight in the jth year.

μ = overall mean.

E_i = effect of the ith ewe.

P_j = jth year of breeding or lambing effect.

A_k = kth age of dam class effect.

B_l = lth ewe body condition score effect.

C_m = effect of the mth coat color class.

$(AB)_{kl}$ = effect of interaction between kth age of ewe class and lth ewe body condition score.

W_n = nth effect of weight of ewe.

$\epsilon_{ijklmno}$ = random effect, ϵ's assumed NID $(0, \sigma^2)$.

The following general linear model was used for analysis of LSW, LWL, LWW, and LSR, and estimation of variance components for heritabilities and genetic and phenotypic correlations through paternal half-sib families was:

$$Y_{ijklmno} = \mu + S_i + P_j + A_k + B_l + C_m + W_n + T_o + (AB)_{kl} + \\ +(AT)_{ko} + (PT)_{jo} + \epsilon_{ijklmnop},$$

where:

$Y_{ijklmnop}$ = observed value for LSW, LWL, LWW, and LSR measured on the pth ewe of the kth age class, lth body condition score, mth coat color type, nth weight, sired by the ith sire in the jth year.

Si = effect of the ith sire of ewe.

P_j, A_k, B_l, C_m, W_n, and $(AB)_{kl}$ = all the terms retain the previous meaning.

T_o = oth type of lambing effect.

$(AT)_{ko}$ = effect of interaction between k^{th} age of ewe class and o^{th} type of lambing class.

$(PT)_{jo}$ = effect of interaction between j^{th} year effect and o^{th} type of lambing class.

$\in_{ijklmnop}$ = random error, $\in$'s assumed NID $(0, \sigma^2)$.

CHAPTER IV

GENETIC AND ENVIRONMENTAL EFFECTS ON GROWTH TO A YEAR OF AGE AND VIABILITY OF MORADA NOVA LAMBS IN NORTHEASTERN BRAZIL

ABSTRACT

Records from an unselected flock of Morada Nova hair sheep collected over an11-year period (1981 to 1991) were used to evaluate genetic and environmental sources of variation influencing growth traits and survivability, and to obtain estimates of phenotypic and genetic covariances among those traits. Weights considered were: birth (BWT), weaning (WWT), six-month (WT6), and yearling (YWT). Survival rates from birth to weaning (SRW) and birth to yearling (SRY), as traits of lambs, were also analyzed. The effects of year of birth (YB), sex of lamb (SL), type of birth/rearing (TB), and weight of ewe at lambing (WE) were important (P<.01) sources of variation to explain differences in BWT, WWT, WT6, and YWT. Males (ML) were heavier than female lambs (FL) at all ages. Single lambs born and raised as singles (SS) weighed more at all ages than twins raised as singles (TS) or twins raised as twins (TT). Also TS lambs consistently presented higher weights at all phases than TT lambs. Age of ewe at lambing (AE) had a significant effect on BWT, WWT, and WT6. The interaction YB*TB had a marked influence (P<.01) on WWT, WT6, and YWT; while the AE*TB interaction was only important (P<.05) for WWT and WT6. Lamb survival rates, SRW and SRY, were both significantly affected by YB, TB, and WE. Twin lambs had 20 and 34% lower SRW and SRY, respectively, than single lambs. Lambs born to heavier ewes had better SRW and SRY, and linear regression coefficients of .01 and .01 were found for WE in relation to SRW and SRY, respectively. The effect of age of ewe (AE) was only significant for SRW; while sex of lamb (SL) influenced (P<.01) only SRY. Females had 6% better SRY than male lambs. The YB*TB only affected (P<.01) SRW. Heritabilities and genetic and phenotypic correlations for growth traits were estimated by half-sib analyses. The heritability estimates for BWT, WWT, WT6, and YWT were .06±.03, .08±04, .06±.04, and .14±.06, respectively. All genetic and phenotypic correlations among lamb weights were high and positive. Direct selection to increase WWT or WT6 should be one of the choices to genetically improve lamb growth performance. Adjustment factors for sex of lamb, type of birth/rearing, and age of ewe at lambing need to be estimated and considered in selection programs to improve survival and growth performance of Morada Nova lambs.

Key Words: Hair Sheep, Growth Traits, Survival Rate, Environmental Factors, Heritability, Genetic Correlation, Phenotypic Correlation, Morada Nova Sheep.

Introduction

Morada Nova sheep in the Northeast Brazil (NEB) are used as dual-purpose animals for the production of meat and hides. More details on breed characteristics were presented in Chapter III.

Hair sheep have become an important animal resource, as a source of meat protein and as a tool for farmers to harvest protein and energy from harsh environments, such as NEB, where other domestic ruminants are not well suited (Fitzhugh and Bradford, 1983).

Body weights and lamb survival rate are among the most economically important traits (Turner, 1969a; Dickerson, 1970; Bradford, 1985). Knowledge of the particular traits and phase of the animal's growth and survival upon which to base selection is, therefore, of utmost importance.

Breeding schemes designed to improve efficiency of sheep production require knowledge of the genetic and phenotypic parameters for traits of economic importance, such as growth and survivability, as well as the effects of the environmental and genetic sources of variation affecting those traits, since they are the prerequisites for development of those breeding programs. Despite the importance of sheep production to NEB little research has been done and published in relation to the above mentioned needs. Specifically, there is a dearth of information regarding those points for hair sheep breeds, such as Morada Nova.

The primary purposes of this study were (1) to examine the relative importance of genetic and environmental sources of variation influencing growth traits and survival rate of Morada Nova lambs, and (2) to obtain estimates of genetic and phenotypic parameters for these characteristics in Morada Nova sheep.

Materials and Methods

Sheep and Environment

The lambs considered in this study were born from 1981 through 1990 at the Iracema Farm, EPACE, Quixada, Ceara, Brazil. Details of the characteristics of the region, the flock and its management are described in Chapter III. Management practices were consistent between years. All lambs were born during the months of April and May, and weaned in the months of August and September at approximately 112 days of age. Male and female lambs were raised under native pasture together with their dams up to weaning. Ram and ewe lambs were separated at weaning with one grazing mob for each sex, but under similar conditions of management and forage availability up to one year of age. Access to mineral supplementation ad-libitum was provided throughout the year.

Data and Measurements

Growth traits considered in this research were: birth weight (BWT), weaning weight (WWT), six-month weight (WT6), and yearling weight (YWT). Survival rates of lambs, birth to weaning (SRW) and birth to yearling (SRY), also were analyzed.

Individual adjusted WWT, WT6 and YWT to a common age of 112, 180, and 365 days, respectively, were calculated prior to analysis using the specific equation for each weight as previously described in Chapter III.

The distribution of number of lambs per year at different ages is shown in Table 5. During the experimental period 76, different sires (Table 6) were used, but the frequency was not equal among sires.

TABLE 6. DISTRIBUTION OF SIRES USED DURING THE EXPERIMENTAL PERIOD.

	Number of Sires (NS)	Number of Years (NY)
	1	6
	3	5
	5	4
	9	3
	23	2
	35	1
Total	76	149[a]

[a]Total Number of Sire x Year Subclasses

There were 2,755 lambs with records for both BWT and SRW (Table 5). Only twenty-seven triplet lambs (less than 1%) were included and considered as twins in the BWT and SRW analyses.

The analysis of WWT was based on records of 2267 lambs (Table 5), and records from 18 triplet lambs were considered as twins. Six-month weight was analyzed from individual records of 1968 lambs (Table 5), and data of 13 lambs born as triplets were used as if those lambs were born twins. The analyses of YWT and SRY were based on records of 1451 and 2145 lambs, respectively (Table 5). Seven triplet lamb records were computed as data of twin lambs.

Statistical Procedures

Data on birth weight (BWT), weaning weight (WWT), six-month weight (WT6), yearling weight (YWT), survival rate of lambs to weaning (SRW), and survival rate to yearling (SRY) were analyzed by LSMLMW & MIXDML (Harvey, 1990).

The following general linear model was assumed to analyze the genetic and environmental factors influencing BWT, WWT, WT6, YWT, SRW, and SRY, and to estimate variance components for heritabilities and genetic and phenotypic correlations through paternal half-sib procedures (Falconer, 1989):

$\mathbf{Y_{ijklmno}} = \mu + R_i + P_j + S_k + T_l + A_m + (PT)_{jl} + (ST)_{kl} + (AT)_{ml} + W_n + \epsilon_{ijklmno}$, where $\mathbf{Y_{ijklmno}}$ = observed value for BWT, WWT, WT6, YWT, SRW, and SRY measured on the o^{th} lamb of the m^{th} age of dam class, l^{th} type of birth and(or) rearing class, k^{th} sex class, sired by the i^{th} sire in the j^{th} year, μ = overall mean, $\mathbf{R_i}$ = random effect of the i^{th} sire, $\mathbf{P_j}$ = j^{th} year of birth fixed effect, $\mathbf{S_k}$ = k^{th} sex class of lamb effect, $\mathbf{T_l}$ = l^{th} type of birth and(or) rearing class effect, $\mathbf{A_m}$ = m^{th} age of dam class effect, $\mathbf{(PT)_{jl}}$ = effect of interaction between the j^{th} year of birth and the l^{th} type of birth and(or) rearing class, $\mathbf{(ST)_{kl}}$ = effect of interaction between the l^{th} type of birth and(or) rearing in the k^{th} sex class of lamb, $\mathbf{(AT)_{ml}}$ = effect of interaction between the m^{th} age of ewe with

l^{th} type birth and(or) rearing class, $\mathbf{W_n}$ = n^{th} effect of weight of ewe (covariate), $\in_{\mathbf{ijklmno}}$ = random residual effect, **e's** assumed NID (0, σ^2).

The analysis of paternal half-sib families provided the crossclassified "family" variance component, i.e., the sire variance component (σ^2_s), and the within family variance component (σ^2_e) (Harvey, 1990). The sire variance component (σ^2_s) multiplied by four and divided by the total phenotypic variance (σ^2_p) produced the heritability (h^2) estimate from paternal half-sibs:

$$\mathbf{h^2} = \frac{4\hat{\sigma}^2_s}{\hat{\sigma}^2_p} = \frac{4\hat{\sigma}^2_s}{\hat{\sigma}^2_s + \hat{\sigma}^2_e}.$$

The genetic correlation between two traits (i and j) measured in the same individual, denotes the relationship between two traits due to additive genetic effects of genes affecting both characters (Falconer, 1989). It was estimated by the following formula:

$$r_{g_i g_j} = \frac{\mathrm{Cov}\,(\hat{G}_i\,,\,\hat{G}_j)}{\hat{\sigma}_{g_i}.\hat{\sigma}_{g_j}} = \frac{\mathrm{Cov}\,(\hat{S}_i\,,\,\hat{S}_j\,)}{\hat{\sigma}_{s_i}\,.\,\hat{\sigma}_{s_j}}\text{, where:}$$

$r_{g_i g_j}$ = genetic correlation between i and j traits.

$\mathrm{Cov}\,(\hat{G}_i\,,\,\hat{G}_j)$ = additive genetic covariance of traits i and j.

$\mathrm{Cov}\,(\hat{S}_i\,,\,\hat{S}_j)$ = sire covariance for traits i and j.

$\hat{\sigma}_{g_i}$ and $\hat{\sigma}_{g_j}$ = additive genetic standard deviations for traits i and j; and,

$\hat{\sigma}_{s_i}$ and $\hat{\sigma}_{s_j}$ = sire standard deviations for traits i and j.

The approximate standard errors for parameter estimates (heritability and genetic correlations) are those given by the program, which were developed from theory and formulas provided by Tallis (1959) and Swiger et al. (1964).

The phenotypic correlation between two traits (i and j) is estimated by the following formula:

$$r_{P_{ij}} = \frac{\hat{\sigma}_{e_{(ij)}} + \hat{\sigma}_{s_{(ij)}}}{\sqrt{[\hat{\sigma}^2_{e_i} + \hat{\sigma}^2_{s_i}][\hat{\sigma}^2_{e_j} + \hat{\sigma}^2_{s_j}]}}$$ (Harvey, 1990), where:

$r_{P_{ij}}$ = phenotypic correlation between i and j traits.

$\hat{\sigma}_{e_{(ij)}}$ = within family covariance between traits i and j.

$\hat{\sigma}_{s_{(ij)}}$ = sire covariance for traits i and j.

$\hat{\sigma}^2_{s_i}$, $\hat{\sigma}^2_{s_j}$ = sire variances for traits i and j; and

$\hat{\sigma}^2_{e_i}$, $\hat{\sigma}^2_{e_j}$ = within family variances for traits i and j.

Results

Environmental Factors

Growth Traits

The least-squares analysis of variance for birth weight (BWT) is shown in Table 7. Birth weight (BWT) was influenced (P<.01) by year of birth (YB), sex of lamb (SL), type of birth (TB), age of ewe (AE), and weight of ewe at lambing (WE). However, interactions of YB*TB, AE*TB, and SL*TB did not have significant effects on BWT of Morada Nova lambs (Table 7).

Least-squares means and standard errors for BWT are shown in Tables 8, 9 and 10. The overall mean for BWT based on 2,755 records of Morada Nova lambs was 2.21±.01 kg (Table 8). Lambs born in 1981, 1982, 1983, and 1984 had the heaviest birth weights (2.30±.11, 2.40±.09, 2.34±.05, and 2.34±.05 kg, respectively), while lambs born in 1985, 1986, and 1987 (2.06±.05, 2.07±.04, and 2.04±.05 kg, respectively) had the

TABLE 7. ANALYSIS OF VARIANCE FOR BIRTH AND WEANING WEIGHTS OF MORADA NOVA LAMBS INCLUDING SIRE OF LAMB AS RANDOM EFFECT

SOURCE OF VARIATION	BIRTH WEIGHT DF	BIRTH WEIGHT MEAN SQUARES	WEANING WEIGHT DF	WEANING WEIGHT MEAN SQUARES
Sire of Lamb	75	0.277388**	75	4.323315**
Year of Birth (YB)	9	0.694287**	9	62.988498**
Sex of Lamb (SL)	1	4.960089**	1	26.034070**
Type Birth/Rearing (TB)	1	82.285636**	2	743.232981**
Age of Ewe (AE)	5	1.097246**	5	7.368530*
YB * TB	9	0.175616	18	17.741654**
SL * TB	1	0.225337	2	6.718384+
AE * TB	5	0.393028+	10	6.505558*
Weight of Ewe	1	18.967803**	1	380.833502*
Error	2647	0.186676	2146	2.846412

+P < .10

*P < .05

**P < .01

TABLE 8. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH AND WEANING WEIGHTS OF MORADA NOVA LAMBS IN RELATION TO MAJOR EFFECTS

FACTORS	BIRTH WEIGHT (kg) No. LAMBS	BIRTH WEIGHT (kg) LSM ± SE	WEANING WEIGHT (kg) No. LAMBS	WEANING WEIGHT (kg) LSM ± SE
Overall	**2755**	**2.21 ± .01**	**2267**	**10.93 ± .09**
Year of Birth (YB)				
1981	96	2.30 ± .11	82	11.72 ± .56
1982	260	2.40 ± .09	214	11.88 ± .41
1983	305	2.34 ± .05	262	10.00 ± .25
1984	357	2.34 ± .05	283	9.23 ± .22
1985	320	2.06 ± .05	237	9.27 ± .23
1986	359	2.07 ± .04	291	10.17 ± .21
1987	206	2.04 ± .05	172	12.82 ± .29
1988	367	2.14 ± .04	290	11.66 ± .22
1989	274	2.15 ± .05	248	10.84 ± .28
1990	211	2.23 ± .06	188	11.71 ± .39
Sex of Lamb (SL)				
Male (ML)	1416	2.26 ± .02	1151	11.09 ± .11
Female (FL)	1339	2.16 ± .02	1116	10.78 ± .11
Type of Birth/Rearing (TB)				
Single as Single (SS)	1708	2.44 ± .02	1530	12.33 ± .08
Twin as Twin (TT)	1047	1.97 ± .02	546	9.83 ± .12
Twin as Single (TS)	--	--	191	10.64 ± .19
Age of Ewe (AE)				
One yr. to < two yrs. (1Y)	661	2.11 ± .02	545	10.92 ± .15
Two yrs to < three yrs. (2Y)	660	2.25 ± .02	568	11.30 ± .13
Three yrs. to < four yrs. (3Y)	576	2.25 ± .02	476	10.97 ± .13
Four yrs. to < five yrs. (4Y)	414	2.21 ± .03	335	10.96 ± .15
Five yrs. to < six yrs. (5Y)	255	2.20 ± .03	196	10.85 ± .18
Older than six yrs. (6Y)	189	2.22 ± .03	147	10.58 ± .20

TABLE 9. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH AND WEANING WEIGTHS OF MORADA NOVA LAMBS IN RELATION THE INTERACTION YEAR OF BIRTH*TYPE OF BIRTH (YB*TB)

		BIRTH WEIGHT (kg)		WEANING WEIGHT (kg)	
FACTORS		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: YB * TB					
Year of Birth	Type of Birth				
1981	SS	74	2.61 ± .11	68	13.39 ± .48
1981	TT	22	2.00 ± .13	10	10.64 ± .69
1981	TS	---	--	4	11.11 ± .99
1982	SS	131	2.63 ± .10	122	14.61 ± .42
1982	TT	129	2.16 ± .09	72	10.25 ± .43
1982	TS	---	--	20	10.78 ± .55
1983	SS	152	2.58 ± .06	143	11.67 ± .25
1983	TT	153	2.11 ± .06	102	8.22 ± .27
1983	TS	---	--	17	10.13 ± .47
1984	SS	209	2.57 ± .05	194	10.10 ± .23
1984	TT	148	2.10 ± .05	46	8.31 ± .32
1984	TS	---	--	43	9.29 ± .33
1985	SS	210	2.26 ± .05	175	10.22 ± .21
1985	TT	110	1.85 ± .06	34	8.40 ± .35
1985	TS	---	--	28	9.20 ± .37
1986	SS	227	2.26 ± .05	198	11.37 ± .20
1986	TT	132	1.89 ± 05	68	9.28 ± .27
1986	TS	---	--	25	9.86 ± .38
1987	SS	146	2.25 ± .05	123	14.21 ± .23
1987	TT	60	1.82 ± .07	42	11.69 ± .32
1987	TS	---	--	7	12.57 ± .68
1988	SS	209	2.39 ± .05	179	12.81 ± .22
1988	TT	158	1.89 ± .05	78	10.71 ± .27
1988	TS	---	--	33	11.46 ± .35
1989	SS	191	2.36 ± .05	178	11.72 ± .24
1989	TT	83	1.94 ± .07	60	10.13 ± .31
1989	TS	---	--	10	10.68 ± .58
1990	SS	159	2.48 ± .06	150	13.23 ± .27
1990	TT	52	1.97 ± 08	34	10.64 ± .38
1990	TS	---	--	4	11.26 ± .92

TABLE 10. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH AND WEANING WEIGTHS OF MORADA NOVA LAMBS CONSIDERING THE INTERACTIONS AGE OF EWE*TYPE OF BIRTH (AE*TB) AND SEX OF LAMB*TYPE OF BIRTH (SL*TB)

FACTORS		BIRTH WEIGHT (kg)		WEANING WEIGHT (kg)	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: AE * TB					
Age of Ewe	Type of Birth				
1Y	SS	495	2.29 ± .02	427	12.02 ± .11
2Y	SS	423	2.51 ± .02	387	12.50 ± .11
3Y	SS	320	2.49 ± .03	294	12.66 ± .12
4Y	SS	226	2.47 ± .03	206	12.65 ± .14
5Y	SS	143	2.41 ± .04	126	12.38 ± .17
6Y	SS	101	2.47 ± .05	90	11.78 ± .20
1Y	TT	166	1.93 ± .04	86	9.93 ± .21
2Y	TT	237	1.99 ± .03	139	10.03 ± .17
3Y	TT	256	2.01 ± .03	137	9.80 ± .18
4Y	TT	188	1.95 ± .04	94	9.95 ± .21
5Y	TT	112	1.98 ± .04	50	9.48 ± .27
6Y	TT	88	1.97 ± .05	40	9.76 ± .30
1Y	TS	---	--	32	10.82 ± .35
2Y	TS	---	--	42	11.36 ± .29
3Y	TS	---	--	45	10.46 ± .29
4Y	TS	---	--	35	10.27 ± .34
5Y	TS	---	--	20	10.71 ± .42
6Y	TS	---	--	17	10.20 ± .45
Interaction: SL * TB					
Sex of Lamb	Type of Birth				
Male	SS	878	2.49 ± .02	780	12.61 ± .09
Male	TT	538	2.01 ± .02	272	9.96 ± .14
Male	TS	---	--	99	10.69 ± .23
Female	SS	830	2.39 ± .02	750	12.05 ± .10
Female	TT	509	1.94 ± .02	274	9.69 ± .14
Female	TS	---	--	92	10.58 ± .23

lowest BWT's, and lambs born in 1988, 1989, and 1990 (2.14±.04, 2.15±.05. and 2.23±.06 kg, respectively) presented intermediate BWT's (Table 8). Linear orthogonal contrasts showed that the mean of BWT for lambs born in 1981 through 1984, and for lambs born in 1988 through 1990, were higher (P<.05) than the mean of BWT of lambs born in 1985 through 1987. However, the mean BWT of lambs born in 1981 through 1984 were similar (P>.05) to the mean of lambs born in 1988 through 1990.

Male lambs were heavier (P<.01) than female lambs at birth (2.26 vs 2.16 kg). Single lambs (2.44±.02 kg) had higher BWT than twin lambs (1.97±.02 kg) (Table 8).

Birth weight increased with age of ewe. Ewes that were one year to less than two years old (1Y) produced the lightest lambs (Table 8). Linear orthogonal contrast showed that 1Y ewes produced lighter (P<.05) lambs at birth than the mean BWT of lambs born to ewes 2 years of age through older than 6 years of age (2Y, 3Y, 4Y, 5Y, and 6Y ewes). Weight of ewe at lambing (WE) significantly affected BWT, and the linear regression coefficient of WE to BWT was.03±.00.

Weaning weight (WWT) was highly influenced by year of birth (YB), sex of lamb (SL), type of birth/rearing (TB), and interaction YB*TB (Table 7). In addition, WWT was affected (P<.05) by age of ewe (AE), weight of ewe (WE), and interaction AE*TB. An overall mean of 10.93±.09 kg for WWT was calculated based on 2,267 weights of Morada Nova lambs (Table 8).

Lambs born and weaned in 1984 and 1985 had the lowest WWT (9.23±.22 and 9.27±.23 kg), while lambs born in 1981, 1982, and 1987 weighed 11.72±.56, 11.84±.41, and 12.82±.29 kg, respectively (Table 8).

Ram lambs were 0.31 kg heavier (P<.01) than ewe lambs at weaning. Single lambs (born and raised as single = SS) were weaned at 12.33±.08 kg versus 9.83±.12 kg for twins born and raised as twins (TT), and 10.64±.19 kg for twins raised as single (TS). The linear contrast between the mean WWT of SS lambs vs the mean WWT of TT and TS was significant (P<.05). Other contrast showed that TS lambs had higher (P<.05) WWT than TT lambs.

Weaning weights ranged from 10.58±.20 kg for lambs born to older than six years ewes (6Y) up to 11.30±.13 kg for lambs born to two years to less than three years old ewes (2Y) (Table 8). The linear contrast between WWT of lambs from 2Y ewes vs the mean WWT of lambs born to other ewes (1Y, 3Y, 4Y, 5Y, and 6Y) was significant; however, the contrast involving lambs from 1Y ewes vs lambs from 6Y ewes was not significant. Weight of ewe at lambing (WE) had higher effect (P<.05) on WWT. A positive linear regression of .14±.01 was found for WE regard to WWT.

A highly significant interaction between YB*TB was found (Table 7). Twin lambs (born and raised as twins = TT) lambed in 1983, 1984 and 1985 weighed only 8.22±.27, 8.31±.32, and 8.40±.35 kg, respectively, at weaning, while single lambs born and raised as singles (SS) in 1981 and 1990 had high WWT (13.39±.48 and 13.23±.27 kg) (Table 9).

Age of ewe x type of birth/rearing (AE*TB) had a significant effect on WWT of Morada Nova lambs (Table 7). Single lambs born and raised as singles (SS) from ewes of 1Y and 6Y age classes were lighter at weaning than SS lambs from ewes of 2Y, 3Y, 4Y and 5Y age classes (Table 10). The linear contrast between of the mean of WWT of 1Y*SS and 6Y*SS lambs vs the mean of WWT of 2Y*SS, 3Y*SS, 4Y*SS, and 5Y*SS lambs was significant (Table 10). Twin lambs born and raised as twins (TT) from ewes of different classes of age (1Y through 6Y) had similar WWT's. Twin lambs raised as singles (TS) born to 2Y ewes weighed 11.36±.29 kg, while TS lambs from 6Y ewes weighed 10.20±.45 kg at weaning (Table 10).

The interaction between sex of lamb x type of birth/rearing did not affect (P<.05) WWT (Table 7).

Weight at six-month of age (WT6) was influenced (P<.05) by year of birth (YB), sex of lamb (SL), type of birth/rearing (TB), weight of ewe at lambing (WE) and YB*TB at P<.01, and by age of ewe (AE) and AE*TB. The sex of lamb x type of birth/rearing interaction was not significant (Table 11).

Morada Nova lambs, on average, had WT6 of 12.80±.11 kg (Table 12). Lambs weighed from 11.45±.28 kg (YB=1984) up to 13.98±.36 (YB=1987) at six-months of age. Male lambs' WT6 were higher than female lambs' WT6 (13.00±.13 vs 12.60±.13 kg). At six-months of age, single lambs born and raised as singles (SS) weighed 14.08±.10 kg, twin lambs born twins but raised as singles (TS) 12.65±.24 kg, and twin lambs born and raised as twins (TT) 11.68±.14 kg. Six-month weight increased from 12.83±.18 kg for lambs born to one year to less than two year-old ewes (1Y) up to 13.24±.15 kg for lambs born from two-year to less than three-old ewes (2Y), and then decreased to 12.64±.24 kg and 12.38±.26 kg for lambs born to five-years to less than six-year old ewes (5Y) and older than six-year ewes (6Y), respectively. Weight of ewe at lambing (WE) had a significant effect on WT6 (b= .17±.01).

Single lambs born and raised as singles (SS) in 1981, 1982 and 1987 were the heaviest at six-months of age (15.21±.52, 15.22±.50, and 15.40±.27 kg, respectively), while twin lambs born and raised as twins in 1983 had the lowest WT6 (9.79±.032 kg) (Table 13).

The interaction between age of ewe and type of birth/rearing (AE*TB) showed a significant influence on WT6 (Table 11). At six months of age, SS lambs born to 1Y and 6Y ewes were lighter than SS born to 2Y, 3Y, 4Y, and 5Y ewes (Table 14). Single lambs (SS) born to 1Y and 6Y ewes were similar at WT6 (P>.05). Twin lambs born and raised as twins (TT) from 5Y and 6Y ewes had lower WT6 than other TT lambs born to 1Y, 2Y, 3Y, and 4Y ewes (Table 14). Twin lambs raised as singles (TS) born to 2Y ewes had higher WT6 (13.39±.36 kg) than TS from 1Y, 3Y, 4Y, 5Y, and 6Y ewes (12.90±.43, 12.30±.35, 12.25±.44, 12.75±.59, and 12.33±.63 kg, respectively) (Table 14).

TABLE 11. ANALYSIS OF VARIANCE FOR SIX-MONTH AND YEARLING WEIGHTS OF MORADA NOVA LAMBS

SOURCE OF VARIATION	SIX-MONTH WEIGHT DF	SIX-MONTH WEIGHT MEAN SQUARES	YEARLING WEIGHT DF	YEARLING WEIGHT MEAN SQUARES
Sire of Lamb	75	4.974301*	75	9.493949**
Year of Birth (YB)	9	19.160823**	9	36.784578**
Sex of Lamb (SL)	1	34.501688**	1	72.167007**
Type Birth/Rearing (TB)	2	539.247504**	2	233.654820**
Age of Ewe (AE)	5	8.284963*	5	10.641378
YB * TB	18	21.322133**	18	14.954021**
SL * TB	2	0.345962	2	1.918418
AE * TB	10	7.493186*	10	10.407714+
Weight of Ewe	1	476.319810**	1	388.450624**
Error	1844	3.626767	1327	5.881480

+P < .10
*P < .05
**P < .01

TABLE 12. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SIX-MONTH AND YEARLING WEIGHTS OF MORADA NOVA LAMBS IN RELATION TO THE MAJOR FACTORS

FACTORS	SIX-MONTH WEIGHT (kg)		YEARLING WEIGHT (kg)	
	No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Overall	**1968**	**12.80 ± .11**	**1451**	**18.60 ± .20**
Year of Birth (YB)				
1981	81	13.67 ± .65	79	20.41 ± .89
1982	196	12.80 ± .48	184	17.66 ± .67
1983	240	12.19 ± .31	222	16.49 ± .44
1984	243	11.45 ± .28	223	17.66 ± .41
1985	209	12.06 ± .30	178	18.87 ± .42
1986	251	12.59 ± .27	192	17.97 ± .43
1987	150	13.98 ± .36	87	20.23 ± .63
1988	261	13.22 ± .26	87	19.42 ± .51
1989	223	12.99 ± .35	120	19.73 ± .64
1990	114	13.07 ± .47	79	17.58 ± .84
Sex of Lamb (SL)				
Male (ML)	968	13.00 ± .13	676	18.95 ± .23
Female (FL)	1000	12.60 ± .13	775	18.25 ± .23
Type of Birth/Rearing (TB)				
Single as Single (SS)	1378	14.08 ± .10	1074	19.66 ± .18
Twin as Twin (TT)	441	11.68 ± .14	265	17.63 ± .26
Twin as Single (TS)	149	12.65 ± .24	112	18.51 ± .41
Age of Ewe (AE)				
One yr. to < two yrs. (1Y)	483	12.83 ± .18	383	18.67 ± .30
Two yrs to < three yrs.(2Y)	515	13.24 ± .15	387	19.00 ± .25
Three yrs. to < four yrs. (3Y)	413	12.86 ± .16	294	18.45 ± .27
Four yrs. to < five yrs. (4Y)	283	12.86 ± .19	205	19.09 ± .32
Five yrs. to < six yrs. (5Y)	160	12.64 ± .24	106	18.25 ± .44
Older than six yrs. (6Y)	114	12.38 ± .26	76	18.15 ± .41

TABLE 13. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SIX-MONTH AND YEARLING WEIGTHS OF MORADA NOVA LAMBS IN RELATION TO THE INTERACTION YEAR OF BIRTH*TYPE OF BIRTH/REARING(YB*TB)

FACTORS		SIX-MONTH WEIGHT (kg)		YEARLING WEIGHT (kg)	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: YB * TB					
Year of Birth	Type of Birth				
1981	SS	67	15.21 ± 0.56	66	21.63 ± 0.76
1981	TT	10	13.10 ± 0.79	10	20.69 ± 1.05
1981	TS	4	12.69 ± 1.14	3	18.91 ± 1.62
1982	SS	112	15.22 ± 0.50	109	19.83 ± 0.68
1982	TT	65	11.18 ± 0.52	58	15.79 ± 0.72
1982	TS	19	11.99 ± 0.64	17	17.35 ± 0.90
1983	SS	135	13.65 ± 0.29	127	17.89 ± 0.42
1983	TT	92	9.79 ± 0.32	82	14.23 ± 0.47
1983	TS	13	13.13 ± 0.59	13	17.36 ± 0.78
1984	SS	178	12.27 ± 0.27	170	18.42 ± 0.39
1984	TT	34	10.46 ± 0.41	27	16.76 ± 0.59
1984	TS	31	11.63 ± 0.42	26	17.81 ± 0.61
1985	SS	167	12.95 ± 0.25	138	19.81 ± 0.37
1985	TT	22	11.45 ± 0.48	21	18.40 ± 0.65
1985	TS	20	11.78 ± 0.50	19	18.41 ± 0.67
1986	SS	182	13.91 ± 0.24	156	19.02 ± 0.36
1986	TT	48	11.55 ± 0.35	21	17.03 ± 0.65
1986	TS	21	12.31 ± 0.48	15	17.86 ± 0.75
1987	SS	112	15.40 ± 0.27	70	20.91 ± 0.42
1987	TT	32	12.58 ± 0.40	14	18.74 ± 0.75
1987	TS	6	13.96 ± 0.84	3	21.04 ± 1.54
1988	SS	170	14.15 ± 0.26	66	19.98 ± 0.46
1988	TT	68	12.36 ± 0.33	11	19.34 ± 0.88
1988	TS	23	13.15 ± 0.46	10	18.97 ± 0.85
1989	SS	163	13.36 ± 0.28	104	20.31 ± 0.47
1989	TT	52	12.48 ± 0.37	12	18.35 ± 0.84
1989	TS	8	13.12 ± 0.73	4	20.52 ± 1.34
1990	SS	92	14.63 ± 0.36	68	18.84 ± 0.58
1990	TT	18	11.81 ± 0.54	9	16.99 ± 1.00
1990	TS	4	12.77 ± 1.08	2	16.90 ± 1.94

TABLE 14. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SIX-MONTH AND YEARLING WEIGTHS OF MORADA NOVA LAMBS BY THE INTERACTIONS AGE OF EWE*TYPE OF BIRTH (AE*TB) AND SEX OF LAMB*TYPE OF BIRTH (SL*TB)

FACTORS		SIX-MONTH WEIGHT (kg)		YEARLING WEIGHT (kg)	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: AE * TB					
Age of Ewe	Type of Birth				
1Y	SS	388	13.70 ± .13	319	19.23 ± 0.22
2Y	SS	357	14.32 ± .13	280	19.78 ± 0.22
3Y	SS	265	14.46 ± .14	207	19.76 ± 0.23
4Y	SS	188	14.44 ± .16	142	20.31 ± 0.27
5Y	SS	108	14.11 ± .21	76	19.77 ± 0.34
6Y	SS	72	13.41 ± .25	50	19.12 ± 0.39
1Y	TT	68	11.88 ± .26	44	18.54 ± 0.44
2Y	TT	121	12.02 ± .21	73	18.24 ± 0.37
3Y	TT	109	11.82 ± .22	60	17.24 ± 0.39
4Y	TT	72	11.89 ± .27	47	18.05 ± 0.45
5Y	TT	40	11.05 ± .33	24	16.62 ± 0.56
6Y	TT	31	11.40 ± .38	17	17.10 ± 0.65
1Y	TS	27	12.90 ± .43	20	18.23 ± 0.67
2Y	TS	37	13.39 ± .36	34	18.98 ± 0.50
3Y	TS	39	12.30 ± .35	27	18.36 ± 0.58
4Y	TS	23	12.25 ± .44	16	18.91 ± 0.71
5Y	TS	12	12.75 ± .59	6	18.37 ± 1.09
6Y	TS	11	12.33 ± .63	9	18.22 ± 0.90
Interaction: SL * TB					
Sex of Lamb	Type of Birth				
Male	SS	676	14.31 ± .11	496	19.93 ± 0.20
Male	TT	219	11.88 ± .17	125	17.97 ± 0.30
Male	TS	73	12.83 ± .28	55	18.97 ± 0.46
Female	SS	702	13.84 ± .11	578	19.40 ± 0.19
Female	TT	222	11.48 ± .16	140	17.29 ± 0.30
Female	TS	76	12.48 ± .29	57	18.06 ± 0.50

The interaction of sex of lamb x type of birth/rearing was not a significant source (P>.05) of variation for WT6 (Table 11).

The significant sources of variation for yearling weight (YWT) of Morada Nova lambs were year of birth (YB), sex of lamb (SL), type of birth/rearing (TB), weight of ewe at lambing (WE), and the interaction of YB*TB. Age of ewe (AE) and the interactions SL*TB and AE*TB did not significantly affect (P>.05) YWT (Table 11).

Lambs born in 1981 and 1987 weighed more than 20 kg at 12 months of age, while lambs born in 1983 weighed only 16.49±.44 kg. Male lambs were heavier (P<.01) than female lambs as yearlings, and ram lambs weighed 700 g more than ewe lambs at this age (Table 12). At one year of age, single lambs raised as singles (SS) weighed 19.66±.18 kg, twins lambs raised as twins (TT) 17.63±.26, and twins raised as singles (TS) 18.51±.41 kg. The linear orthogonal contrast of the YWT of SS lambs vs the YWT mean of TT and TS lambs was significant. In addition, another contrast showed a significant difference in YWT between TS and TT. A positive linear regression coefficient of .17±.02 was found for weight of ewe at lambing in relation to YWT (Table 12).

Twin lambs raised as twins (TT) born in 1982 and 1983 weighed only 15.79±.72 and 14.23±.47 kg at yearling, while TT lambs born in 1981 weighed more than 20 kg at the same age. Also, single lambs raised as singles (SS) and twin lambs raised as singles (TS) born in 1981, 1987, and 1989 had YWT over than 20 kg (Table 13).

LAMB SURVIVAL

The analysis of variance for survival rate of lamb up to weaning (SRW) is presented in Table 15. Least-squares means for SRW in relation to the major effects and the two-level interactions between those major factors (YB*TB, AE*TB, SL*TB) are shown in Tables 16, 17, and 18.

Year of birth (YB), type of birth (TB), age of ewe (AE), weight of ewe at lambing (WE), and the interaction YB*TB were important (P<.01) sources of variation of SRW.

TABLE 15. ANALYSIS OF VARIANCE FOR SURVIVAL RATE OF MORADA NOVA LAMBS: BIRTH UP TO WEANING (SRW) AND BIRTH UP TO YEARLING (SRY)

SOURCES OF VARIATION	SRW DF	SRW MEAN SQUARES	SRY DF	SRY MEAN SQUARES
Sire of Lamb	75	0.128810	75	0.161955
Year of Birth (YB)	9	0.430987**	9	0.455142**
Sex of Lamb (SL)	1	0.267508	1	1.724508**
Type Birth (TB)	1	15.298439**	1	31.161632**
Age of Ewe (AE)	5	0.453069**	5	0.398377+
YB * TB	9	0.394997**	9	0.343013+
SL * TB	1	0.058174	1	0.023229
AE * TB	5	0.092537	5	0.168371
Weight of Ewe	1	3.233881**	1	3.498254**
Error	2647	0.133114	2037	0.185172

+P < .10
*P < .05
**P < .01

Sex of lamb (SL), and the interactions SL*TB and AE*TB did not contribute (P>.05) to explain variation in SRW (Table 15).

Morada Nova lambs, on average, had SRW of .79±.01 (79%). Lambs born in 1981 and 1985 had lowest SRW (71%), while lambs born in 1989 showed SRW of 90%. Survival rate (SRW) for single lambs was higher (P<.01) than for twins (89 vs 69%) (Table 16). Lambs born to ewes that were less than two-years old (1Y) and two year to less than three-year old ewes (2Y) had SRW higher than 80%, against SRW of 73% for lambs born to five year to less than six-year old ewes (5Y). The linear orthogonal contrast of the SRW mean of lambs born to 1Y and 2Y vs the SRW mean of lambs from 5Y and 6Y ewes was significant (Table 16). Twin lambs (TT) born in 1981 and 1985 had very low SRW (56 and 57%), while SRW of TT in 1989 was 84%. Survival rates (SRW) for single lambs (SS) born in 1983, 1984, 1989, and 1990 were higher than 90%, but SRW of SS born in 1987 was only 80% (Table 18).

Least-squares analysis of variance for survival of lamb from birth up to yearling (SRY) is shown in Table 15. The overall mean of SRY based on records of 2,145 lambs was 63%. Year of birth (YB), sex of lamb (SL), type of birth (TB), and weight of ewe at lambing (WE) were highly significant sources of variation affecting SRY (Table 15).

Only lambs born in 1989 had SRY higher than 70%, against SRY of 57 and 50% for lambs born in 1985 and 1988, respectively. Survival rate up to yearling (SRY) was higher for ewe lambs than ram lambs (66 vs 60%). Twin lambs had lower (46% vs 80%) SRY than single lambs (Table 16).

Age of ewe (AE) and the interactions YB*TB, SL*TB and AE*TB did not have significant influence on SRY (Table 15).

Weight of ewe at lambing (WE) influenced significantly both survival rates (SRW and SRY) (Table 15), and a positive linear regression coefficient of .01 was found for WE in relation to SRW and SRY (Table 16).

TABLE 16. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SURVIVAL RATE OF MORADA NOVA LAMBS: BIRTH UP TO WEANING (SRW) AND BIRTH UP TO YEARLING (SRY) IN RELATION TO THE MAJOR EFFECTS

FACTORS	SRW		SRY	
	No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Overall	**2755**	**.79 ± .01**	**2145**	**.63 ± .01**
Year of Birth (YB)				
1981	96	.71 ± .09	96	.66 ± .11
1982	260	.75 ± .08	256	.61 ± .09
1983	305	.84 ± .04	305	.68 ± .05
1984	357	.78 ± .04	347	.60 ± .05
1985	320	.71 ± .04	294	.57 ± .05
1986	359	.81 ± .04	300	.60 ± .05
1987	206	.79 ± .04	129	.65 ± .06
1988	367	.75 ± .04	165	.50 ± .05
1989	274	.90 ± .04	150	.74 ± .07
1990	211	.84 ± 05	103	.68 ± .08
Sex of Lamb (SL)				
Male (ML)	1416	.78 ± .01	1051	.60 ± .02
Female (FL)	1339	.80 ± .01	1094	.66 ± .02
Type of Birth (TB)				
Single (SB)	1708	.89 ± .01	1341	.80 ± .02
Twin as Twin (TB)	1047	.69 ± .01	804	.46 ± .02
Age of Ewe (AE)				
One yr. to < two yrs. (1Y)	661	.83 ± .02	550	.66 ± .03
Two yrs to < three yrs. (2Y)	660	.83 ± .02	528	.68 ± .02
Three yrs. to < four yrs. (3Y)	576	.80 ± .02	441	.63 ± .02
Four yrs. to < five yrs. (4Y)	414	.78 ± .02	318	.62 ± .03
Five yrs. to < six yrs. (5Y)	255	.73 ± .02	182	.55 ± .03
Older than six yrs. (6Y)	189	.75 ± .03	126	.62 ± .04

TABLE 17. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SURVIVAL RATE OF MORADA NOVA LAMBS: BIRTH UP TO WEANING (SRW) AND BIRTH UP TO YEARLING (SRY) IN RELATION TO THE INTERACTION YEAR OF BIRTH*TYPE OF BIRTH (YB*TB)

FACTORS		SRW		SRY	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: YB * TB					
Year of Birth	Type of Birth				
1981	SB	74	.86 ± .09	74	.82 ± .11
1981	TB	22	.56 ± .11	22	.49 ± .14
1982	SB	131	.87 ± .08	129	.75 ± .10
1982	TB	129	.63 ± .08	127	.47 ± .09
1983	SB	152	.92 ± .05	152	.79 ± .06
1983	TB	153	.75 ± .05	153	.57 ± .06
1984	SB	209	.94 ± .04	206	.82 ± .05
1984	TB	148	.62 ± .05	141	.39 ± .06
1985	SB	210	.85 ± .04	186	.76 ± .05
1985	TB	110	.57 ± .05	108	.37 ± .06
1986	SB	227	.89 ± .04	203	.80 ± .05
1986	TB	132	.72 ± .04	97	.39 ± .06
1987	SB	146	.80 ± .04	96	.73 ± .06
1987	TB	60	.78 ± .06	33	.56 ± .09
1988	SB	209	.84 ± .04	96	.69 ± .06
1988	TB	158	.67 ± .04	69	.31 ± .07
1989	SB	191	.95 ± .05	121	.94 ± .07
1989	TB	83	.84 ± .06	29	.55 ± .10
1990	SB	159	.94 ± .05	78	.90 ± .09
1990	TB	52	.73 ± .07	25	.46 ± .11

TABLE 18. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR SURVIVAL RATE OF MORADA NOVA LAMBS: BIRTH UP TO WEANING (SRW) AND BIRTH UP TO YEARLING (SRY) BY THE INTERACTIONS AGE OF EWE*TYPE OF BIRTH (AE*TB) AND SEX OF LAMB*TYPE OF BIRTH (SL*TB)

FACTORS		SRW		SRY	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: AE * TB					
Age of Ewe	Type of Birth				
1Y	SB	495	.90 ± .02	420	.80 ± .02
2Y	SB	423	.92 ± .02	342	.83 ± .02
3Y	SB	320	.90 ± .02	249	.82 ± .03
4Y	SB	226	.88 ± .03	168	.82 ± .04
5Y	SB	143	.85 ± .03	99	.74 ± .05
6Y	SB	101	.87 ± .04	63	.79 ± .06
1Y	TB	166	.75 ± .03	130	.53 ± .04
2Y	TB	237	.74 ± .03	186	.52 ± .04
3Y	TB	256	.70 ± .03	192	.45 ± .03
4Y	TB	188	.68 ± .03	150	.43 ± .04
5Y	TB	112	.61 ± .04	83	.36 ± .05
6Y	TB	88	.63 ± .04	63	.45 ± .06
Interaction: SL * TB					
Sex of Lamb	Type of Birth				
Male	SB	878	.88 ± .01	641	.77 ± .02
Male	TB	538	.67 ± .02	410	.42 ± .03
Female	SB	830	.89 ± .01	700	.83 ± .02
Female	TB	509	.70 ± .02	394	.49 ± .03

Genetic Parameters

Heritabilities were estimated for all growth traits in this study using half-sib progenies of 76 different sires. The estimates, the respective standard errors, and the 'K' values for each trait are shown in Table 19.

Heritabilities were .06±.03 for birth weight (BWT), .08±.04 for weaning weight (WWT), .06±.04 for weight at six-month of age (WT6), and .14±.06 for yearling weight (YWT).

TABLE 19. AVERAGE NUMBER OF OFFSPRING PER SIRES (K_h), HERITABILITIES (h^2), AND GENETIC AND PHENOTYPIC CORRELATIONS BETWEEN GROWTH TRAITS IN MORADA NOVA SHEEP[a]

TRAITS	K_h	BWT	WWT	WT6	YWT
Birth Weight (BWT)	33.4	.06 ± .03	.55±.30	.53±.34	.97±.34
Weaning Weight (WWT)	27.2	.33	.08 ± .04	.98±.08	.84±.14
Six-Month Weight (WT6)	23.5	.31	.82	.06±.04	.88±.12
Yearling Weight (YWT)	17.1	.26	.62	.72	.14±.06

[a]Heritability estimates at diagonal, genetic correlations above diagonal, and phenotypic correlations below.

Genetic and phenotypic correlations among those growth traits were all positive (Table 19). The genetic correlations were .55±.30, .53±.34, and .97±.34, between BWT and WWT, BWT and WT6, and BWT and YWT, respectively; .98±.08 and .84±.14, between WWT and WT6, and WWT and YWT, respectively; and .88±.12 between WT6 and YWT. The phenotypic correlations between those growth traits ranged from .26 (between BWT and YWT) to .82 (between WWT and WT6).

Heritabilities for both survival rates (SRW and SRY), as a trait of the lamb, could not be estimated in this study since the sire of lamb was not a significant effect, and the sire components of variance were negative. Genetic correlations between SRW, SRY, and growth traits, also were not estimated for the same reason.

Positive phenotypic correlations of .33 and .22 were found between SRW and BWT, and between SRY and BWT, respectively.

Discussion

The present study is one of the few to attempt to investigate the environmental and genetic factors affecting growth traits and survivability of Morada Nova lambs, as well as, to estimate genetic and phenotypic parameters for those traits.

Environmental Factors

The effect of year was an important factor for all growth traits (BWT, WWT, WT6, and YWT) and for both lamb survival rates (SRW and SRY). This influence of year on those characters was expected from literature reports and from the unique climatic pattern of the NEB. Similar findings have been reported for those growth traits (Dickerson et al., 1975; Fogarty et al., 1984; Kaushish et al., 1990; Kabuga and Akowuak, 1991; Buvanendran et al., 1992; Nawaz and Meyer, 1992) and for survivability of lambs (Dickerson and Glimp, 1975; Fogarty et al., 1984; Younis et al., 1990; Iniguez et al., 1991; Kleemann et al., 1991; Nawaz and Meyer, 1992). However, there are some reports that described no significant year effect on survivability of lambs (Vesely et al., 1977; Fernandes, 1985) and on growth traits (Hohenboken et al., 1976b; Galal and Awgichew, 1981; Iniguez et al., 1991). There was a large variation in rainfall amount and distribution across years, and across months within year (Figures 2 and 3, Chapter III). It is important to mention that three major drought periods occurred during the experimental period (1981 to 1991) and, certainly, this fact contributed to the year effect on those traits.

Year 'per se' does not affect animal performance, but its effects are the 'result' of all occurrences which happened in that specific year. Among the most relevant events determining the year effect are amount and distribution of rainfall, disease problems, management practices, etc. Year may also reflect genetic changes occurring in the population although such changes are usually too small to be observed and considered in a short period of time.

It is also necessary to mention that it is suspected that the year effect includes all the modifications that occurred in pasture disposability and deterioration at the Iracema Farm. Such an effect is the possible result of decrease of forage availability, due to heavy grazing, in the palatable annual grass and forb species. The most palatable annual forage species have a tendency to decrease with time. The peak of forage quantity and quality normally occurs throughout the first to third year, depending on annual rainfall patterns, after improvement practices had been applied to native pasture (Caatinga). It is a common practice to increase the holding capacity of the pastures by clearcutting and burning the brush of Caatinga. This permits annual species of grass and forbs to produce abundantly in the early years after improvement, but they will normally decrease again as the frequency of brush increases and as the animal heavily grazes those desirable forage species, and consequently they would be substituted by undesirable species (invaders). Forage deterioration, no doubt, is included in the year effect, and efforts to estimate and minimize this effect need to be considered.

Despite the significance ($P<.01$) of sex of lamb on all growth traits found in this study, its magnitude may be considered smaller than what would be expected based on the published literature, especially for post-weaning weights. A possible explanation for the similarity of weights of males and females, is the fact that lambs were raised under poor nutritional management conditions. This was especially true after weaning, which occurred at the beginning of the dry season, and consequently ram lambs did not have opportunities to express their potential for growth. Differences in weights of lamb at different age phases due to sex reported in this research, however, are in complete agreement with results reported by other researchers (Brown et al., 1961; Dickerson et al., 1975; Galal and Awgichew, 1981; Alwari et al., 1982; Bennett et al. 1991a; Kabuga and Akowuah, 1991; Kleemann et al., 1991; Buvanendran et al., 1992; Nawaz and Meyer, 1992). Very similar results were also described by Kaushish et al. (1990), studying growth performance of Malpura and Avikaline lambs. They reported that males were heavier than females by 0.14, 0.10, and 0.90 kg at birth, weaning and six-months of age, respectively. Conversely some authors described a non-significant effect on growth traits due to sex of lamb (Bodisco et al., 1973; Gour et al., 1977; Singh et al., 1982; Eltawil and Narendran, 1990; Olthoff and Boylan. 1991).

Sex of lamb did not have a significant effect on SRW, but it affected ($P<.01$) SRY. Although sex of lamb did not significantly affect SRW, female lambs had better survival than males (80 vs 78%). However, sex of lamb was an important component of variation on SRY, where ewe lambs had 6% higher SRY than ram lambs. The highly significant effect on SRY and the tendency for females had better SRW than males found in this study are in general agreement with the findings reported by other authors (Dickerson et al., 1975; Oltenacu and Boyland, 1981; Gonzalez, 1983; Fernandes, 1985; Kleemann et al., 1991). The better survival for ewe lambs may be due to factors associated with differences in birth weight, or from differences in body composition between female and male lambs. According to Oliver et al. (1967), carcasses of females contained more chemical fat and less protein and water than male lambs. Thus, this high fat percentage in females should be a favorable factor for surviving under the conditions of the NEB. Another possible explanation is the same described above for small differences on weights between male and female lambs, where ram lambs did not receive enough feed from native pastures to attain their nutritional requirements, and consequently they presented lower survival rates than ewe lambs. However, additional studies should be conducted to explain the causes and reasons for differences in survival between females and males under those NEB conditions.

The findings on the effects of type of birth/rearing on BWT, WWT, WT6, and YWT reported in this study are in agreement with results found by Galal and Awgichew (1981), Martinez (1983), Fernandes, (1985), Eltawil and Narendran (1990), Bennett et al. (1991a), Kabuga and Akowuah (1991), Kleemann et al. (1991), Molina et al. (1991) and, Olthoff and Boylan (1991). In general, it is expected that single born lambs (SS) grow faster than multiple born lambs, raised as twins (TT) or singles (TS), and that TS lambs grow better than TT lambs. This is due to competition for milk. The greater milk availability for SS and TS lambs has been reported to delay the time of those lambs start to graze in relation to TT animals. This early reliance on grazing for TT lambs may explain part of the disadvantage of those animals (Kilkenny, 1978).

One of the most striking factors contributing to survival rates (SRW and SRY) was the effect of type of birth, and these results were similar to those reported by other researchers (Shelton, 1963; Turner and Dolling, 1965; Magid et al., 1981a; Fernandes, 1985; Iniguez et al., 1991; Kleemann et al., 1991; Nawaz et al., 1992). The higher mortality of twins, at both ages, than singles, should be explained by an inadequate milk supply for the lambs from dams under range conditions, and probably, also, as a reflection of lighter birth weights of twins compared to single lambs. These factors have a marked influence prior to and after weaning since twin lambs are weaned on the average with a low and inadequate body weight for support and survive during the critical drought period following weaning where the forage disposability is low and normally does not meet the nutritional requirements of the animals raised under the range conditions of the NEB.

The significant effect of age of ewe at lambing on BWT, WWT and WT6 of their lambs in this research is in agreement with other results reported in the literature (Bodisco et al., 1973; Dickerson et al., 1975; Alrawi et al., 1982; Fernandes, 1985; Long et al., 1989; Kleemann et al,. 1990; Boujenane et al., 1991; Olthoff and Boylan, 1991; Buvanendran et al., 1992). This effect may be characterized as quadratic, that is, BWT, WWT and WT6 increased with age of ewe up to her maturity and then slowly decreased towards the end of her productive life. The quadratic effect of age of ewe agrees well with the reports of Barnico et al. (1956) and Boyazoglu (1963), in which maximum milk production for ewes was reported to occur between three and six years of age. Age of ewe did not influence YWT, and similar findings were described by Galal and Awgichew (1981) and Boujenane et al. (1991). This effect would appear to be a reflection of the lamb diet after weaning when lambs become independent of the influence of milk supply from their mothers, and also, because after weaning, lamb growth is more likely an expression of its own genetic potential and of the nutritional level under which it is raised.

Variation on SRW of lambs due to age of ewe found in this study is in close concordance with the results reported by Vesely et al., 1966, Dalton and Rae, 1978, Oltenacu and Boylan, 1981, Gonzalez, 1983, Hinch et al., 1985b, Atkins, 1986, Long et al., 1989, and Boujenane et al., 1991. The high mortality rate of lambs born to old ewes (≥ five-years of age) may be a combination of low birth weights of their lambs with a decrease in milk production from those old ewes raised under range conditions of the NEB. Age of ewe did not affect SRY, and this should express the lack of influence due to maternal effects on lamb performance after weaning. Similar results were found by Walker et al., 1979, Fernandes, 1985, Long et al., 1989, Kleemann et al., 1990, and Gama et al., 1991a.

A significant linear relationship was found between weight of ewes (WE) at lambing and lamb performance. Heavier ewes produced heavier lambs at birth, weaning, six-months, and at yearling. Equivalent findings were described in other studies (Bhasin and Desai, 1967; Chopra and Acharya, 1971; Singh et al., 1982; Iniguez et al., 1991). In relation to survival of lamb (SRW and SRY), the effect of weight of ewe was also highly significant and a linear relationship was described between WE and lamb survival rates in both phases. Lambs born to heavier ewes had higher SRW and SRY. Conversely, Laster et al., 1972, and Kleemann et al., 1991, found no significant variation on survival of lambs due to weight of ewe.

The interaction of year of birth x type of birth/rearing (YB*TB) effect was an important factor on BWT, WWT, WT6, YWT, SRW, and SRY. This indicated that the differences between singles and twins were not constant across years. It is expected that such differences in those traits would tend to increase in bad years and decrease in better years. In more extreme cases, where very bad years occur, multiple born lambs are expected to perform much poorer than singles. In fact many of the multiple lambs could die. However, the differences may be reduced in extremely good years. The interaction of YB*TB is what causes the argument about the desirability of multiple births. The controversies arise from comparisons in different kinds of conditions, which means that given the necessary conditions, multiple born lambs are more advantageous, but whenever the conditions are not appropriate, multiple born lambs become disadvantageous.

The interaction between age of ewe and type of birth/rearing (AE*TB) had a significant effect on WWT and WT6. The AE*TB may be one of the most important interactions found in this research. This type of interaction suggests that ewes of certain ages produce and raise singles and twins that are more similar than others and vice-versa.

Genetic Parameters

The proportion of variation due to additive gene effects is expressed by heritability estimates and the importance of those estimates is in their use for developing selection tools.

The heritabilities and, the genetic and phenotypic correlations estimated in this study are very important guides to design genetic programs to improve the growth performance of Morada Nova sheep. Fernandes (1985) estimated some of the genetic parameters for growth traits in Morada Nova breed. For instance, he reported heritability of .35±.10, .36±.11, and .29±.13, for BWT, WWT and YWT, respectively. At that time, the data set included fewer observations collected from two small flocks raised under different management conditions at the Iracema Farm. One of these flocks was the foundation of the Morada Nova herd from which this analysis is based. It is important to mention that the data set from this foundation flock also is included in this analysis. The estimates found in this study are smaller than the ones reported in the previous work (Fernandes, 1985) and, the present estimates have slightly smaller standard errors. Nevertheless, the heritabilities estimated for BWT, WWT, WT6, and YWT in this study are within the range of the estimates reported in the literature, some of which are listed in Table 1 (Chapter II).

The size and pattern of the genetic and phenotypic correlations between growth traits shown in Table 19 are in general agreement and comparable to published figures (Olson et al., 1976; Mavrogenis et al., 1980; Alwari et al., 1982; Atkins, 1986; Stobart et al., 1986; Bennett et al., 1991b). It is important to mention that the genetic and phenotypic correlations found in this study between those growth traits are in close agreement with estimates reported by Fernandes (1985) in Morada Nova sheep.

The positive and high genetic correlations between weights at various ages suggests that selection for any one weight would result in considerable positive change in weight all weights. In order to minimize the effect of selection for weight on birth weight and possible increased percentage of dystocia, selection would best be directed towards weights at later ages. However, selection for weights at later ages may be expected to lead to increased mature weights and greater maintenance requirements, which could be undesirable for the conditions of the NEB. Thus, it seems that direct selection for increased WWT or WT6 should be the preferable choices to improve growth performance of Morada Nova lambs.

Implications

Adjustment factors for type of birth/rearing, sex of lamb, and age of ewe need to be estimated and considered in selection programs to improve growth and survival performance of lambs.

Due to the fact that pasture condition (forage deterioration) is suspected to be major part of the effect of year of birth, it should be interesting to evaluate and minimize this component's influence with the goal to reduce differences on lamb performance (growth and survival) throughout years.

The low SRW and SRY of twin lambs suggest that management conditions should be improved to take advantage of multiple births as a way to increase lamb meat production at weaning and at one year of age. Selection to increase multiple births should be looked very carefully in those conditions of the NEB, principally if it is not feasible to improve management.

Despite the low heritability estimates for WWT and WT6, selection based on those weights seems to one of the best options to improve lamb performance, since those traits presented high and positive genetic correlations with BWT and YWT.

CHAPTER V

ANALYSIS OF REPRODUCTIVE PERFORMANCE AND LAMB PRODUCTION OF MORADA NOVA EWES IN NORTHEASTERN BRAZIL

ABSTRACT

Reproductive performance of Morada Nova ewes was analyzed using records from 806 different ewes during a 10-year period (1980-1990). Traits considered were mate rate (MAR), parturition rate (PAR), litter size at lambing (LSL) and at weaning (LSW), litter weight at lambing (LWL) and at weaning (LWW), and lamb survival rate up to weaning as a ewe trait (LSR=LSW/LSL). Effect of year of breeding (YB) or lambing (YL) was significant on MAR, PAR, LWL, LWW, LSW, and LSR. Age of ewe (AE) affected ($P<.05$) LWL and LSR. Type of parturition (TL) had a marked influence ($P<.01$) on LWL, LSW and LSR, and it tended ($P<.10$) to affect for LWW. Ewes with twin parturitions (TP) produced 64, 18 and 47% more LWL, LWW and LSR, respectively, than ewes with a single parturition (SP). However, ewes with TP presented lower LSR than ewes with SP (58 vs 84%, respectively). Ewe body condition (BC) was a highly significant factor affecting PAR, LSL, LWL, LSW, and LSR. Ewes in good condition (GC) presented PAR and LSL of 100% and 1.43 against 75% and 1.01, respectively, for ewes in poor condition (PC). Ewes in GC, also produced more kg of lamb at lambing (3.25 vs 2.79 kg) and at weaning (12.78 vs 7.56 kg) than ewes in PC, respectively. In addition, LSW

(0.80 vs 1.20 lambs) and LSR (46 vs 86%) were lower from ewes in PC than in ewes GC, respectively. The interaction YL*TL had a significant effect on LWL, LWW, LSW, and LSR; while AE*BC interaction was only important (P<.05) for PAR. Mate rate (MAR), LSL, LWL, and LWW were significantly affected by WE. A negative linear regression coefficient of -.01 was found for WE in relation to LSL. Adjustment factors for age of ewe, type of parturition and ewe body condition need to be estimated and considered in selection programs to improve reproductive performance of Morada Nova ewes. Estimates of heritability and repeatability were calculated for reproductive traits by half-sib analyses. Heritability and repeatability estimates of .06±.06 and .20±.03, .02±.05 and .07±.03, and .09±.03 and .24±.03, were found for LSL, LWL and LWW, respectively. In addition, estimates of repeatability and heritability were obtained for LSW (.13±.03 and .10±.07), and LSR (.18±.03 and .09±.03). The results suggest that direct selection based on LSW should be feasible to achieve genetic progress in reproductive performance of Morada Nova ewes expressed by LWW and(or) by LSR.

Key Words: Hair Sheep, Reproductive Traits, Lamb Survival, Environmental Factors, Lamb Production, Heritability, Repeatability, Morada Nova Sheep.

Introduction

Improvement of reproductive performance should be a major goal in any livestock enterprise as a way to improve efficiency and profitability of animal production. However, this objective normally is not easily achieved since reproductive performance is a complex characteristic.

Reproductive performance may be expressed in different ways such as parturition rate (PAR), litter size at lambing (LSL), litter weight at lambing (LWL), litter size at weaning (LSW), litter weight at weaning (LWW), or by lamb survival rate up to weaning as ewe trait (LSR).

Ewe productivity, defined as LSW and(or) LWW is dependent upon component traits of PAR, LSL, LWL, LSR, and lamb growth. An increase in biological and economic efficiency of lamb production is more dependent on LSW than on growth rate (Dickerson, 1978). In addition, LSR is one of main factors influencing LSW and LWW (Forgaty et al., 1985).

Selection for high reproductive performance, expressed through the mentioned reproductive traits, in hair sheep in the Northeast Brazil (NEB) should be of particular importance since those sheep have low reproductive efficiency compared with other sheep breeds in different regions. Morada Nova is one of most important breeds of hair sheep in NEB. It is used for meat production, with skins or hides as a secondary product.

The development of an efficient selection program for improving reproductive performance of sheep in this region depends on reliable estimates of genetic and phenotypic parameters, as well as knowledge of the effects of the environmental and genetic sources of variation influencing those reproductive traits.

Despite the importance of sheep production to NEB, little has been done and there is little information (genetic and phenotypic parameters) available about reproductive traits to develop a feasible selection program for improving reproductive performance of those hair sheep.

The present study was undertaken (1) to evaluate the genetic and environmental factors affecting reproductive performance of Morada Nova sheep, (2) to estimate heritability and repeatability for the component traits of reproductive efficiency of Morada Nova sheep, and (3) to define possible potential breeding programs to improve sheep productivity in the NEB, based on the results associated with the previous objectives.

Materials and Methods

Ewe Flock and Environment

The experimental sheep flock belongs to EPACE and it was housed at the Iracema Farm, Quixada, Ceara, Brazil. Details of the region, farm, flock and its management are given in Chapter III. The distribution of the Morada Nova ewe breeding flock per year at the different phases of productive cycle is presented in Table 20.

The breeding season lasted for sixty days each year during November to December with the subsequent lambing season in April to May. Breeding ewes were put together with vasectomized males to detect estrus. This was observed twice (early morning and late afternoon) each day and ewes standing in heat were mated by natural service in the corral by a previously selected sire. Weaning occured at 112 days of lamb age and normally happened from August to September. Dams and their lambs were raised together under native pasture (Caatinga) up to weaning. Ad-libitum access to mineral supplementation was provided throughout the year. In general, nutritional and health management practices were consistent between years, and variations in forage disposability (quantity and quality) were reflections of disturbances on climatic conditions major due to rainfall amount and distribution within and among years.

Data and Measurements

Data collected in this research covered the period from 1980/1981 to 1989/1990. Records were collected from 809 different breeding ewes during this experimental period.

Reproductive traits analyzed in this study were: mate rate (MAR) = number of ewes bred per ewe exposed; parturition rate (PAR) = number of ewes lambing per ewe bred; litter size at lambing (LSL) = number of lambs born per ewe lambing; litter weight at lambing (LWL) = total weight (kg) of lamb born per ewe lambing; litter size at weaning

TABLE 20. SUMMARY OF THE MORADA NOVA EWE BREEDING FLOCK THROUGHOUT THE EXPERIMENTAL PERIOD AT THE IRACEMA FARM, EPACE, QUIXADA, CEARA, BRAZIL

	NUMBER OF EWES			
YEAR (a/b)	EXPOSED	MATED	LAMBING	WEANING
1980/ 1981	121	94	85	77
1981/1982	203	200	194	177
1982/1983	271	246	228	211
1983/1984	302	302	283	260
1984/1985	302	302	265	219
1985/1986	309	309	292	257
1986/1987	260	260	176	151
1987/1988	313	312	286	251
1988/1989	249	245	232	219
1989/1990	197	195	185	171
TOTAL	**2527**	**2465**	**2226**	**1993**

(a/b) = (Year of Breeding/Year of Lambing)

(LSW) = number of lambs weaned per ewe lambing; and lamb survival rate up to weaning as ewe trait (LSR) = LSW/LSL.

Environmental factors considered for analyses of those reproductive traits in this research were: year of breeding (YB) or year of lambing (YL), ewe body condition (BC), age of ewe at breeding/lambing (AE), ewe coat color (CC), type of parturition (TP), and weight of ewe at breeding or lambing (WE).

Age of ewe (AE) was age at the beginning of breeding season. Six age categories ranging from 1 year of age to older than 6 years of age were used and classified as following: 1Y = one year to less than 2 yr of age; 2Y = 2 yr to less than 3 yr of age; 3Y = 3 yr to less than 4 yr of age; 4Y = 4 yr to less than 5 yr of age; 5Y = 5 yr to less than 6 yr of age; and 6Y = 6yr of age and older. Ewe body condition score (BC) also was recorded at the beginning of the mating season. Scores could vary from 1 (very thin = poor condition), 2 (moderate fat = regular condition) to 3 (fat = good condition). Ewe breeding weight was recorded on the day the ewe was bred. Litter weight and ewe lambing weight were registered within 12 hours of lambing. The red Morada Nova sheep present two major pattern of coat color: cream to clear brown and dark brown. These two categories were used to classify ewe breeding flock by coat color. Very few triplet lambings (less than 1%) occured and those were treated as twins. Nine triplet lambings were included and classified as twin type of parturition in the LSL, LWL, LSW, LWW, and LSR analyses.

In the analysis of mate rate (MAR), ewes that bred were recorded as 1 and those that did not were recorded as zero. Also, in the analysis of parturition rate (PAR), ewes that lambed were registered as 1 and those that did not were recorded as 0. For litter size at lambing (LSL), ewes not lambing were deleted from the analysis. In the analyses of litter size at weaning (LSW) and litter weight at weaning (LWW), lambs raised in the nursery were excluded, while in lamb survival rate (LSR) analysis those were considered as dead.

In calculating ewe productivity, measured throughout litter weight at weaning (LWW), individual adjusted LWW to a common period of time of 112 days, was calculated prior to analysis by extrapolation from lambing to weaning time, using the specific formula described in Chapter III.

Statistical Procedures

Data on mate rate (MAR), parturition rate (PAR), litter size at lambing (LSL), litter weight at lambing (LWL), litter size at weaning (LSW), litter weight at weaning (LWW), and lamb survival rate up to weaning as ewe trait (LSR) were analyzed by LSMLMW & MIXDML (Harvey, 1990).

The following general linear model (Model 1) was used to analyze environmental sources of variation on MAR and PAR, and to estimate repeatability of LSL:

Model 1:

$Y_{ijklmno} = \mu + E_i + P_j + A_k + B_l + C_m + (AB)_{kl} + W_n + \epsilon_{ijklmno}$, where:

$Y_{ijklmno}$ = the o^{th} record (MAR and Par) on the i^{th} ewe of k^{th} age class, l^{th} body condition score, m^{th} coat color class, and in the j^{th} year.

μ = overall mean.

E_i = effect of the ith ewe.

$P_j = j^{th}$ year of breeding or lambing effect.

$A_k = k^{th}$ age of dam class effect.

$B_l = l^{th}$ ewe body condition score effect.

C_m = effect of the m^{th} coat color class.

$(AB)_{kl}$ = effect of interaction between k^{th} age of ewe class and l^{th} ewe body condition.

$W_n = n^{th}$ effect of ewe breeding or lambing weight (covariate).

$\epsilon_{ijklmno}$ = random error effect, ϵ's assumed NID $(0, \sigma^2)$.

Records on ewe body condition (BC) were registered during seven years (1980/1981 to 1986/1987). Consequently, in the analyses of MAR, PAR, and LSL were used only 1768, 1713, and 1523 ewe records, respectively. Analyses covering all experimental periods are presented in Appendix A. These analyses did not include BC in the model (Model 2) and a total of 2527, 2465, and 2226 dam records were computed to evaluate environmental factors in MAR, PAR and LSL, respectively.

To estimate heritability of LSL and evaluate the environmental factors influencing this trait, the following model was considered:

Model 3:

$Y_{ijklmno} = \mu + S_i + P_j + A_k + B_l + C_m + (AB)_{kl} + W_n + \in_{ijklmno}$, where:

$Y_{ijklmno}$ = the o^{th} record (LSL) from one ewe of k^{th} age class, l^{th} body condition score, m^{th} coat color class, in the j^{th} year, and daughter of i^{th} sire.

S_i = effect of the i^{th} sire of dam.

P_j, A_k, B_l, C_m, $(AB)_{kl}$, W_n, and $\in_{ijklmno}$ = all terms retain the previous meaning.

Due to the fact BC information was available for just seven years and records were unavailable for the sires of breeding ewes used in 1980/1981 and 1981/1982, the LSL analysis based on Model 3 used only 789 ewe records. A different analysis of LSL using Model 4 (where BC was not fitted) based on 1476 dam records was computed to analyze environmental and genetic factors influencing LSL, and to estimate heritability of this reproductive trait.

The following general linear model (Model 5) was used for analysis of LSW, LWL, LWW, and LSR, and estimation of variance components for heritabilities and, genetic and phenotypic correlations through paternal half-sib families:

Model 5:

$$Y_{ijklmnop} = \mu + S_i + P_j + A_k + B_l + C_m + T_o + (AB)_{kl} + (AT)_{ko} + (PT)_{jo} + \\ + W_n + \in_{ijklmnop}, \text{ where:}$$

$Y_{ijklmnop}$ = observed values for LSW, LWL, LWW, and SRL measured on the p^{th} ewe daughter of i^{th} sire, k^{th} age class, l^{th} body condition score, m^{th} coat color class, and having o^{th} type of parturition in the j^{th} year.

S_i, P_j, A_k, B_l, C_m, $(AB)_{kl}$, and W_n = all the terms retain the previous meaning.

T_o = o^{th} type of parturition effect.

$(AT)_{ko}$ = effect of interaction between k^{th} age of ewe class and o^{th} type of parturition class.

$(PT)_{jo}$ = effect of interaction between j^{th} year effect and o^{th} type of parturition class.

To estimate repeatabilities of LSW, LWL, LWW, and LSR, the above model was used with only one modification: substitution of sire of dam effect by ewe effect. Tables of the least-squares analysis of variance from this model (Model 6) are presented in Appendix B.

Seven hundred and eighty-nine ewe records were computed in Model 5 to analyze environmental and genetic factors affecting LSW, LWL, LWW, and LSR, while Model 6 used 1523 records to estimate repeatabilities of those reproductive traits.

Two others models (Model 7 and Model 8) were run to analyze those reproductive traits. Model 7 did not include BC and it used 1476 ewe records to evaluate environmental and genetic sources of variation on LSW, LWL, LWW, and LSR. Model 8 did not also include BC and it computed 2,226 dam records to estimate repeatabilities of those reproductive characters. Tables of the least-squares analysis of variance from Model 7 and Model 8 are presented in Appendix C and Appendix D, respectively.

Differences on number of observations on those models were again due to the fact of BC records were not available for all years, and information on sire of breeding ewes used in 1980/1981 and 1981/1982 did not exist.

The analysis of paternal half-sib families provided the crossclassified "family" variance component, i.e., the sire of dam variance component (σ_s^2), and the within variance component (σ_ε^2) (Harvey, 1990). Sire of dam variance component (σ_s^2) multiplied by four and divided by the total phenotypic variance (σ_p^2) produced the heritability (h^2) from paternal half-sibs:

$$h^2 = \frac{4\hat{\sigma}_s^{\,2}}{\hat{\sigma}_p^{\,2}} = \frac{4\hat{\sigma}_s^{\,2}}{\hat{\sigma}_s^{\,2} + \hat{\sigma}_\varepsilon^{\,2}}\text{, where } \sigma_p^2 = \sigma_s^2 + \sigma_\varepsilon^2.$$

Ewe variance component (σ_d^2) divided by total phenotypic variance (σ_p^2) produced the repeatability estimates (Fisher, 1946):

$$r = \frac{\hat{\sigma}_d^{\,2}}{\hat{\sigma}_p^{\,2}} = \frac{\hat{\sigma}_d^{\,2}}{\hat{\sigma}_d^{\,2} + \hat{\sigma}_\varepsilon^{\,2}}\text{, where } \sigma_p^2 = \sigma_d^2 + \sigma_\varepsilon^2.$$

The approximate standard errors for parameter estimates are those given by the program (Harvey, 1990), which were developed from theory provided by Tallis (1959) and Swiger et al. (1964).

Results

Environmental Factors

The least-squares analyses of variance for mate rate (MAR) and parturition rate (PAR) are presented in Table 21. Overall means for MAR and PAR of this Morada Nova ewe flock were 0.97±.01 and 0.91±.01, respectively (Table 22). Mate rate (MAR) was affected by year of breeding ($P<.01$) and weight of ewe at mating ($P<.05$). Age of ewe (AE), ewe body condition (BC), ewe coat color (CC), and interaction AE*BC did not have influence ($P>.05$) on MAR. Least-squares means and standard errors for MAR are shown in Tables 22 and 23. Ewes mated in 1980/1981 had MAR of 81%, while in other years ewes presented MAR higher than 90% (Table 22). Weight of ewe at breeding (WE) significantly affected MAR, and a linear regression coefficient of .01±.0015 was estimated to WE in relation to MAR.

TABLE 21. ANALYSIS OF VARIANCE FOR MATE RATE (MAR), PARTURITION RATE (PAR) AND LITTER SIZE AT LAMBING (LSL) OF MORADA NOVA EWES USING EWE AS RANDOM EFFECT IN MODEL 1

SOURCE OF VARIATION	MAR[a]		PAR[b]		LSL[c]	
	DF	M.SQ.	DF	M.SQ.	DF	M.SQ.
Dam Effect	659	.019854	659	0.087080	628	.214715**
Year Effect	6	.396616**	6	0.537064**	6	1.197522**
Age of Ewe (AE)	5	.061180+	5	0.046431	5	.206423
Body Condition (BC)	2	.001828	2	2.127111**	2	1.493054**
Coat Color	1	.001012	1	0.001438	1	.290847
Interaction: AE*BC	10	.011213	10	0.182107*	10	.261012*
Weight of Ewe	1	.162686*	1	0.081608	1	2.091141**
Error	1083	.029942	1028	0.080918	869	.133914

+P < .10
*P < .05
**P < .01

$^{a}MAR = \frac{\text{No. of Ewes Mated}}{\text{No. of Ewes Exposed}}$

$^{b}PAR = \frac{\text{No. of Ewes Lambing}}{\text{No. of Ewes Mated}}$

$^{c}LSL = \frac{\text{No. of Lambs Born}}{\text{No. of Ewes Lambing}}$

TABLE 22. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR MATE RATE (MAR), PARTURITION RATE (PAR), AND LITTER SIZE AT LAMBING (LSL) BY MAJOR FACTORS IN MORADA NOVA EWES BASED ON MODEL 1

FACTORS	MAR		PAR		LSL	
	# Obs.	LSM±SE	# Obs.	LSM±SE	# Obs.	LSM±SE
Overall	**1768**	**0.97 ± .01**	**1713**	**0.91 ± .01**	**1523**	**1.45 ± .02**
Year Effect (a/b)						
1980/1981	121	0.81 ± .09	94	1.01 ± .15	85	1.49 ± .20
1981/1982	203	1.00 ± .06	200	1.00 ± .10	194	1.67 ± .14
1982/1983	271	0.93 ± .03	246	0.97 ± .05	228	1.67 ± .07
1983/1984	302	1.01 ± .01	302	0.94 ± .02	283	1.43 ± .03
1984/1985	302	1.02 ± .03	302	0.87 ± .05	265	1.33 ± .07
1985/1986	309	1.00 ± .06	309	0.89 ± .10	292	1.35 ± .13
1986/1987	260	0.99 ± .09	260	0.67 ± .15	176	1.20 ± .20
Age of Ewe (AE)						
1Y = 01 to < 02 yrs.	555	0.93 ± .07	511	0.86 ± .12	455	1.12 ± .17
2Y = 02 to < 03 yrs.	467	0.98 ± .05	463	0.87 ± .08	411	1.30 ± .11
3Y = 03 to < 04 yrs.	327	0.98 ± .02	323	0.88 ± .04	289	1.43 ± .05
4Y = 04 to < 05 yrs.	213	0.97 ± .02	211	0.93 ± .04	184	1.53 ± .05
5Y = 05 to < 06 yrs.	127	0.98 ± .05	127	0.90 ± .08	112	1.57 ± .11
6Y = older than 06 yrs.	79	0.95 ± .08	78	1.00 ± .14	72	1.76 ± .19
Body Condition (BC)						
Poor (PC)	275	0.97 ± .02	266	0.75 ± .03	179	1.36 ± .05
Regular (RC)	991	0.96 ± .01	954	0.94 ± .02	866	1.42 ± .03
Good (GC)	502	0.97 ± .01	493	1.04 ± .02	478	1.57 ± .03
Coat Color (CC)						
Cream/Brown	1402	0.95 ± .06	1362	0.89 ± .10	1197	1.26 ± .13
Dark Brown	366	0.98 ± .06	351	0.92 ± .10	326	1.64 ± .13

(a/b) = Year of mating/Year of lambing

TABLE 23. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR MATE RATE (MAR), PARTURITION RATE (PAR) AND LITTER SIZE AT LAMBING (LSL) BY AGE OF EWE VS BODY CONDITION (AE*BC) INTERACTION (AE*BC) IN MORADA NOVA EWES USING MODEL 1

FACTORS		MAR		PAR		LSL	
		# Obs.	LSM±SE	# Obs.	LSM±SE	# Obs.	LSM±SE
Interaction: AE*TB							
Age of Ewe	Body Condition						
1Y	PC	104	0.93 ± .08	99	0.79 ± .13	70	1.09 ± .18
1Y	RC	336	0.92 ± .08	304	0.87 ± .12	281	1.16 ± .17
1Y	GC	115	0.94 ± .08	108	0.91 ± .13	104	1.10 ± .18
2Y	PC	86	0.95 ± .05	84	0.74 ± .09	56	1.20 ± .12
2Y	RC	233	0.99 ± .05	233	0.90 ± .08	214	1.29 ± .11
2Y	GC	148	1.00 ± .05	146	1.00 ± .08	141	1.40 ± .11
3Y	PC	33	1.00 ± .04	33	0.66 ± .07	20	1.38 ± .11
3Y	RC	196	0.98 ± .02	192	0.91 ± .04	171	1.44 ± .05
3Y	GC	98	0.96 ± .03	98	1.04 ± .05	98	1.48 ± .06
4Y	PC	20	0.96 ± .05	19	0.90 ± .08	15	1.39 ± .12
4Y	RC	123	0.98 ± .02	122	0.89 ± .04	103	1.49 ± .05
4Y	GC	70	0.98 ± 03	70	1.00 ± .05	66	1.70 ± .06
5Y	PC	20	1.00 ± .06	20	0.63 ± .10	10	1.46 ± .16
5Y	RC	55	0.97 ± .05	55	1.00 ± .08	52	1.48 ± .11
5Y	GC	52	0.98 ± .05	52	1.06 ± .08	50	1.76 ± .12
6Y	PC	12	0.95 ± .10	11	0.83 ± .17	8	1.62 ± .24
6Y	RC	48	0.94 ± .08	48	1.03 ± .14	45	1.65 ± .19
6Y	GC	19	0.96 ± .09	19	1.15 ± .15	19	1.99 ± .21

Effects of year (YB), ewe body condition (BC), and interaction age of ewe vs ewe body condition (AE*BC) were significant sources of variation on parturition rate (PAR). Age of ewe and ewe coat color did not influence PAR (Table 21). All ewes bred in 1980 and 1981 lambed in 1981 and 1982, respectively (Table 22). Ewes bred in 1986 presented the lowest PAR (.67±.15).

Ewe body condition at breeding (BC) influenced ($P<.01$) PAR. Least-squares means were 0.75±.03, 0.94±.02, and 1.04±.02 for ewes in poor (PC), regular (RC), and good (GC) body condition, respectively. The linear orthogonal contrast was significant for the comparison of PAR of PC ewes vs the mean of PAR of RC and GC ewes; however, the comparison between PAR of RC and GC was not significant. Poor body condition (PC) was more critical factor for ewes of 3Y and 5Y age of ewe classes, where those ewes had PAR of only 0.66±.07 and 0.63±.10, respectively. Conversely, ewes of 4Y age class with PC showed high PAR of 0.90±.08 (Table 23).

Analyses of variance for litter size at lambing (LSL) using Models 3 and 4 are shown in Table 24. In Model 3, LSL was affected significantly by BC and WE. Effects of year of lambing (YL), age of ewe (AE), ewe coat color (CC), and AE*BC interaction were not significant on LSL. However, in Model 4 (without including BC in the model) AE and YL significantly affected LSL (Table 24).

Least-squares means for LSL are given in Tables 25 and 26. Overall means for LSL of Morada Nova ewes based on Model 3 (789 lambings) and Model 4 (1476 lambings) were 1.16±.04 and 1.21±.02, respectively (Table 25).

Ewes in good body condition (GC), had 36 and 42% larger LSL than ewes with RC and PC, respectively. The linear orthogonal contrast was significant for the comparison of LSL of GC vs the mean LSL of RC and PC ewes; however, LSL was similar for RC and PC ewes.

TABLE 24. ANALYSES OF VARIANCE FOR LITTER SIZE AT LAMBING (LSL)[a] USING SIRE OF DAM AS A RANDOM EFFECT

	MODEL 3[b]		MODEL 4[c]	
SOURCES OF VARIATION	DF	MEAN SQUARES	DF	MEAN SQUARES
Sire Effect	39	0.163134	59	0.155600
Year of Lambing (YL)	4	0.276713+	7	0.334978*
Age of Ewe (AE)	4	0.017434	5	0.371055*
Body Condition (BC)	2	3.851854**	-	-
Coat Color (CC)	1	0.074177	-	-
Interaction: AE * BC	8	0.243930+	-	-
Weight of Ewe Lambing	1	0.601121*	1	1.1676608**
Error	729	0.126932	1403	0.143200

+P < .10

*P < .05

**P < .01

[a]LSL = Number of Lambs Born/Ewe Lambing

[b]Model 3 = Ewe Body Condition is included

[c]Model 4 = Ewe Body Condition is not included

TABLE 25. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT LAMBING (LSL)[a] BY MAJOR FACTORS BASED ON MODEL 3 AND MODEL 4

	MODEL 3[b]		MODEL 4[c]	
FACTORS	No. OBS.	LSL LSM ± SE	No. OBS.	LSL LSM ± SE
Overall	**789**	**1.16±.04**	**1476**	**1.21±.02**
Year of Lambing (YL)				
1983	67	1.17±.09	67	1.31±.08
1984	134	1.06±.06	134	1.21±.06
1985	178	1.14±.05	178	1.20±.04
1986	245	1.21±.06	245	1.26±.03
1987	165	1.24±.08	165	1.18±.04
1988	-	-	273	1.24±.04
1989	-	-	229	1.17±.05
1990	-	-	185	1.09±.07
Age of Ewe (AE)				
1Y = One yr. to < two yrs.	347	1.18±.07	469	1.12±.05
2Y = Two yrs. to < three yrs.	258	1.16±.05	387	1.17±.04
3Y = Three yrs. to < four yrs.	119	1.19±.05	278	1.26±.03
4Y = Four yrs. to < five yrs.	49	1.17±.07	177	1.21±.03
5Y = Five yrs. to < six yrs.	16	1.12±.15	103	1.27±.05
6Y = Six yrs. and older	-	-	62	1.21±.07
Body Condition (BC)				
Poor (PC)	106	1.01±.09	-	-
Regular (RC)	465	1.05±.04	-	-
Good (GC)	218	1.43±.05	-	-
Coat Color (CC)				
Cream/Brown	694	1.15±.04	-	-
Dark Brown	95	1.18±.05	-	-

[a]LSL = Nunber of Lambs Born/Ewe Lambing

[b]Model 3 = Ewe Body Condition is included

[c]Model 4 = Ewe Body Condition is not Included

TABLE 26. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT LAMBING (LSL)[a] BY THE INTERACTION AGE OF EWE x BODY CONDITION (AE*BC) USING MODEL 3[b]

FACTORS		No. OBS.	LSL LSM ± SE
Interaction: AE * BC			
Age of Ewe	Body Condition		
1Y	PC	52	1.05±.09
1Y	RC	226	1.13±.07
1Y	GC	69	1.36±.08
2Y	PC	30	1.05±.08
2Y	RC	143	1.14±.06
2Y	GC	85	1.30±.06
3Y	PC	15	1.04±.10
3Y	RC	62	1.12±.06
3Y	GC	42	1.41±.07
4Y	PC	8	1.04±.14
4Y	RC	25	0.98±.09
4Y	GC	16	1.50±.10
5Y	PC	1	0.89±.36
5Y	RC	9	0.89±.14
5Y	GC	6	1.58±.16

[a]LSL = Number of Lambs Born/Ewe Lambing
[b]Model 3 = Ewe Body Condition is Included

Effect of weight of ewe at lambing (WE) was significant on LSL, and a negative linear regression coefficient of -.01±.00 was found for WE in relation to LSL.

Least-squares analyses of variance for LWL and LWW using Model 5 are presented in Table 27. Overall means for LWL and LWW based on 789 lambings of Morada Nova ewes were 3.01±.03 and 10.62±.70 kg, respectively (Table 28). Litter weight at lambing (LWL) was influenced by year of lambing (YL), age of ewe (AE), type of parturition (TL), ewe body condition (BC), weight of ewe at lambing (WE), and by YL*TL interaction (Table 27). Least-squares means for LWL by major effects and their two-level interactions are shown in Tables 28, 29 and 30.

Ewes lambing in 1983 and 1984 produced litters with weight at lambing higher than 3.00 kg. In 1985, ewes lambed the lightest litters (2.72±.08 kg). Yearling and older ewes (ewes of 1Y and 5Y age classes, respectively) presented lowest LWL (2.86±.10 and 2.80±.25 kg, respectively), while mature ewes (ewes of 3Y age of class) produced the heaviest litters at lambing (LWL=3.23±.08 kg).

Type of parturition (TL) was a highly significant factor explaining variation for LWL. Ewes having twins produced 64% more kg of lambs at lambing than ewes lambing singles (3.74±.10 vs 2.28±.06 kg) (Table 28).

There was significant effect of ewe body condition on LWL. Least-squares means for LWL of ewes in PC, RC and GC were respectively 2.79±.13, 2.98±.07, and 3.25±.07 kg. Ewes in GC produced 16 and 9% more kg of lamb at lambing than ewes in PC and RC, respectively.

The interaction YL*TL had a great (P<.01) influence on LWL. Ewes that lambed twins in 1983 had higher LWL (4.30±.20 kg) than ewes had twins in 1984, 1985, 1986, and 1987 (Table 29). Ewes that had SP (single parturition) in 1985 and 1986 produced lighter litters at lambing than ewes that had SP in 1983, 1984 and 1987 (Table 29).

TABLE 27. ANALYSIS OF VARIANCE FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] USING SIRE OF DAM AS A RANDOM EFFECT - MODEL 5

SOURCES OF VARIATION	DEGREES OF FREEDOM	LWL MEAN SQUARES	LWW MEAN SQUARES
Sire Effect	39	.277031	27.612899+
Year of Lambing (YL)	4	2.068777**	251.272454**
Age of Ewe (AE)	4	1.253290**	44.727468+
Type of Parturition (TL)	1	45.000119**	65.794965+
Body Condition (BC)	2	1.449914**	172.048346**
Coat Color (CC)	1	0.611351	4.451415
Interaction: YL * TL	4	0.831186*	131.567738**
Interaction: AE * TL	4	0.223889	11.842515
Interaction: AE * BC	8	0.220910	26.245142
Weight of Ewe Lambing	1	2.397199**	94.867347*
Error	720	0.257449	19.682358

+P < .10

*P < .05

**P < .01

aLWL = Total Weight (kg) of Lamb Born/Ewe Lambing

bLWW = Total Weight (kg) of Lamb Weaned/Ewe Lambing

TABLE 28. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY MAJOR FACTORS BASED ON MODEL 5

FACTORS	No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Overall	**789**	**3.01±.03**	**10.62±.70**
Year of Lambing (YL)			
1983	67	3.38±.14	12.19±1.28
1984	134	3.18±.10	8.54±0.99
1985	178	2.72±.08	8.32±0.84
1986	245	2.88±.09	10.49±0.87
1987	165	2.88±.12	13.55±1.09
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	347	2.86±.10	10.13±1.00
2Y = Two yrs. to < three yrs.	258	3.13±.08	11.54±0.79
3Y = Three yrs. to < four yrs.	119	3.23±.08	12.11±0.79
4Y = Four yrs. to < five yrs.	49	3.02±.12	11.05±1.11
5Y = Five yrs. to < six yrs.	16	2.80±.25	8.56±2.23
Type of Parturitiom (TL)			
Single (SP)	654	2.28±.06	9.74±.69
Twin (TP)	135	3.74±.10	11.50±.99
Body Condition (BC)			
Poor (PC)	106	2.79±.13	7.56±1.22
Regular (RC)	465	2.98±.07	11.51±0.77
Good (GC)	218	3.25±.07	12.78±.076
Coat Color (CC)			
Cream/Brown	694	3.06±.06	10.75±0.71
Dark Brown	95	2.96±.08	10.49±0.81

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 29. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY THE INTERACTIONS: YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TL) AND AGE OF EWE VS TYPE OF PATURITION (AE*TL) USING MODEL 5

FACTORS		No. OBS.	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: YL * TL				
Year of Lambing	Type of Parturition			
1983	SP	53	2.46±.13	11.45±1.22
1983	TP	14	4.30±.20	12.93±1.84
1984	SP	116	2.38±.09	9.35±0.90
1984	TP	18	3.99±.17	7.73±1.51
1985	SP	153	2.13±.08	8.21±0.78
1985	TP	25	3.32±.14	8.43±1.31
1986	SP	196	2.17±.08	9.12±0.85
1986	TP	49	3.58±.13	11.85±1.20
1987	SP	136	2.26±.11	10.55±1.08
1987	TP	29	3.49±.15	16.56±1.39
Interaction: AE * TL				
Age of Ewe	Type of Parturition			
1Y	SP	296	2.19±.10	8.63±1.00
1Y	TP	51	3.52±.12	11.63±1.15
2Y	SP	218	2.39±.07	10.12±0.74
2Y	TP	40	3.86±.11	12.96±1.03
3Y	SP	91	2.43±.07	11.38±0.77
3Y	TP	28	4.04±.12	12.85±1.14
4Y	SP	37	2.25±.12	10.66±1.10
4Y	TP	12	3.80±.19	11.44±1.71
5Y	SP	12	2.15±.24	7.90±2.14
5Y	TP	4	3.45±.42	8.61±3.66

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 30. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY AGE OF EWE x BODY CONDITION INTERACTION (AE*BC) USING MODEL 5

FACTORS		No. OBS.	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: AE * BC				
Age of Ewe	Body Condition			
1Y	PC	52	2.75±.13	7.69±1.25
1Y	RC	226	2.86±.10	11.14±1.01
1Y	GC	69	2.96±.11	11.57±1.07
2Y	PC	30	3.07±.12	10.43±1.11
2Y	RC	143	3.11±.08	12.25±0.83
2Y	GC	85	3.20±.09	11.95±0.88
3Y	PC	15	3.21±.15	11.03±1.37
3Y	RC	62	3.13±.09	11.97±0.86
3Y	GC	42	3.37±.10	13.45±0.94
4Y	PC	8	2.84±.21	8.51±1.88
4Y	RC	25	2.99±.15	11.55±1.35
4Y	GC	16	3.25±.15	13.09±1.38
5Y	PC	1	2.09±.56	7.12±2.95
5Y	RC	9	2.84±.30	10.66±2.65
5Y	GC	6	3.46±.24	13.98±2.18

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

Year of lambing (YL), ewe body condition (BC), YL*TL interaction, and weight of ewe at lambing (WE) were the major sources of explanation for variation in litter weight at weaning (LWW). Effects of AE and TL on LWW approached (P<.10) to be significant (Table 27).

Ewes lambing in 1984 and 1985 had low LWW (8.54±.99 and 8.32±.84 kg, respectively), while ewes in 1983 and 1987 produced LWW heavier than 12 kg. Although the AE effect was not significant for LWW, the results showed a tendency of young and old ewes (1Y and 5Y ewes, respectively) to have smaller LWW than ewes of intermediate age. Type of parturition (TL) tended (P<.10) to have a significant effect on LWW. Ewes with TP weaned 18% more kg of lambs than ewes with SP (Table 28). Also YL*TL interaction affected (P<.01) LWW. Ewes with TP produced 57% (16.56±1.39 vs 10.55±1.08 kg) more kg of lamb at weaning than ewes with SP in 1987. Conversely, the difference in LWW due to TL was not important (P>.05) in 1985 (SP=8.21±0.78 vs TP=8.43±1.31 kg) (Table 29).

There was a significant effect of BC on LWW (Table 27). Ewes in GC and RC weaned more 5.22 and 3.95 kg of lamb, respectively, than ewes in PC (Table 28). Weight of ewe at lambing (WE) had significant effect on LWL and LWW, and linear regression coefficients of .02±.01 and .14±.06 were estimated for WE in relation to LWL and LWW, respectively.

There were significant effects of year of lambing (YL), type of parturition (TL), ewe body condition (BC), and YL*TL interaction on litter size at weaning (LSW) and on lamb survival rate up to weaning as a ewe trait (LSR). Age of ewe (AE) only affected LSR. Ewe coat color, AE*TL interaction, AE*BC interaction, and weight of ewe at lambing, did not either influence LSW or LSR (Table 31).

Overall least-squares means for LSW and LSR were 1.05±06 and 0.71±.05, respectively (Table 32). Least-squares means for LSW and LSR were summarized in Tables 32, 33 and 34.

TABLE 31. ANALYSIS OF VARIANCE FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] USING SIRE OF DAM AS A RANDOM EFFECT - MODEL 5

SOURCES OF VARIATION	DEGREES OF FREEDOM	LSW MEAN SQUARES	LSR MEAN SQUARES
Sire Effect	39	0.223920*	0.150489+
Year of Lambing (YL)	4	0.926503**	0.254694*
Age of Ewe (AE)	4	0.261319	0.253642*
Type of Parturition (TL)	1	3.367200**	1.499314**
Body Condition (BC)	2	1.083113**	0.952642**
Coat Color (CC)	1	0.000631	0.034761
Interaction: YL * TL	4	1.486488**	0.381295**
Interaction: AE * TL	4	0.080351	0.023354
Interaction: AE * BC	8	0.127389	0.164452
Weight of Ewe Lambing	1	0.185215	0.031318
Error	720	0.153569	0.106287

+P < .10

*P < .05

**P < .01

[a]LSW = Number of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

TABLE 32. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] BY MAJOR FACTORS BASED ON MODEL 5

FACTORS	No. EWES	LSW LSM ± SE	LSR LMS ± SE
Overall	**789**	**1.05±.06**	**0.71±.05**
Year of Lambing (YL)			
1983	67	1.21±.11	0.83±.09
1984	134	0.92±.09	0.68±.07
1985	178	0.90±.07	0.62±.06
1986	245	1.11±.08	0.73±.06
1987	165	1.10±.10	0.70±.08
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	347	0.99±.09	0.65±.07
2Y = Two yrs. to < three yrs.	258	1.10±.07	0.77±.06
3Y = Three yrs. to < four yrs.	119	1.14±.07	0.81±.06
4Y = Four yrs. to < five yrs.	49	1.00±.10	0.72±.08
5Y = Five yrs. to < six yrs.	16	1.00±.20	0.61±.16
Type of Parturitiom (TL)			
Single (SP)	654	0.85±.06	0.84±.05
Twin (TP)	135	1.25±.09	0.58±.07
Body Condition (BC)			
Poor (PC)	106	0.80±.11	0.48±.09
Regular (RC)	465	1.14±.07	0.79±.06
Good (GC)	218	1.20±.01	0.86±.06
Coat Color (CC)			
Cream/Brown	694	1.05±.06	0.72±.05
Dark Brown	95	1.05±07	0.70±.06

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

TABLE 33. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] BY THE INTERACTIONS : YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TL) AND AGE OF EWE VS TYPE OF PATURITION (AE*TL) USING MODEL 5

FACTORS		No. OBS.	LSW LSM ± SE	LSR LSM ± SE
Interaction: YL * TL				
Year of Lambing	Type of Parturition			
1983	SP	53	0.97±.11	0.95±.09
1983	TP	14	1.44±.16	0.70±.14
1984	SP	116	0.93±.08	0.93±.07
1984	TP	18	0.91±.13	0.44±.11
1985	SP	153	0.79±.07	0.79±.06
1985	TP	25	1.02±.12	0.46±.09
1986	SP	196	0.82±.08	0.82±.06
1986	TP	49	1.40±.11	0.64±.09
1987	SP	136	0.73±.10	0.74±.08
1987	TP	29	1.47±.12	0.66±.10
Interaction: AE * TL				
Age of Ewe	Type of Parturition			
1Y	SP	296	0.78±.09	0.76±.07
1Y	TP	51	1.20±.10	0.53±.08
2Y	SP	218	0.88±.07	0.89±.06
2Y	TP	40	1.32±.09	0.64±.08
3Y	SP	91	0.96±.07	0.96±.06
3Y	TP	28	1.32±.10	0.67±.08
4Y	SP	37	0.89±.10	0.90±.08
4Y	TP	12	1.10±.15	0.55±.13
5Y	SP	12	0.72±.19	0.71±.16
5Y	TP	4	1.29±.32	0.51±.26

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

TABLE 34. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] BY AGE OF EWE x BODY CONDITION INTERACTION (AE*BC) USING MODEL 5

FACTORS		No. OBS.	LSW LSM ± SE	LSR LSM ± SE
Interaction: AE * BC				
Age of Ewe	Body Condition			
1Y	PC	52	0.77±.11	0.42±.09
1Y	RC	226	1.09±.09	0.75±.07
1Y	GC	69	1.10±.10	0.77±.08
2Y	PC	30	1.00±.10	0.68±.08
2Y	RC	143	1.16±.08	0.81±.06
2Y	GC	85	1.15±.08	0.82±.06
3Y	PC	15	1.04±.12	0.74±.10
3Y	RC	62	1.16±.08	0.82±.06
3Y	GC	42	1.22±.08	0.89±.07
4Y	PC	8	0.77±.17	0.56±.14
4Y	RC	25	1.07±.12	0.75±.10
4Y	GC	16	1.15±.12	0.86±.10
5Y	PC	1	0.43±.43	0.36±.02
5Y	RC	9	1.22±.23	0.82±.19
5Y	GC	6	1.36±.19	0.98±.16

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

Ewes that lambed in 1983 and 1986 had better performance than ewes lambed in 1984, 1985 and 1987, based on their LSW and LSR (Table 32). Lambs born to ewes of 3Y age class had 16 and 20% superior LSR than lambs born to ewes of 1Y and 5Y age classes, respectively (Table 32).

Effects of ewe body condition were important ($P<.01$) for both LSW and LSR. Ewes in PC had very poor performance in comparison of ewes in RC and GC considering LSW and LSR traits. Least-squares means ± se for LSW of ewes in PC, RC and GC were respectively, 0.80±.11, 1.14±.07 and 1.20±.01. Lambs born to ewes in PC had 31 and 38% lower LSR than lambs born to ewes in RC and GC, respectively (Table 32).

Ewes lambing twins (TP) produced 100% more LSW than ewes with SP in 1987; however, LSW for TP and SP did not differ in 1984 (0.93±.08 vs 0.91±.13, respectively). Lambs born from SP had similar LSR to lambs born to TP in 1987 (0.74±.08 vs 0.66±.10, respectively). Conversely, lambs born from SP presented superior LSR than lambs born from TP in 1983, 1984, 1985, and 1986 (Table 33).

Genetic Parameters

Heritability (h^2) and repeatability (r) estimates for reproductive traits are presented in Table 35. Those figures were estimated considering the environmental effect of ewe body condition (BC) in the statistical models. Different estimates of h^2 and r are listed in Appendix E (Table 71) where BC factor was not included in the statistical models.

Heritability of litter size at lambing (LSL) estimated in this research was low (.06±.06), but LSL was found to be moderately repeatable ($r = .20\pm.03$).

Both heritability and repeatability of litter weight at lambing were low (.02±.05 and .07±.03, respectively). The heritability of litter weight at weaning (LWW) was also low (.09±.07), but repeatability for this trait was found moderate (.24±.03).

Litter size at weaning had moderately low estimate values of heritability (.10±.07) and repeatability (.13±.03).

Lamb survival rate up to weaning as ewe trait (LSR) had a low estimate of heritability (.09±.07) and a more moderate estimate of repeatability (.18±.03).

TABLE 35. NUMBER OF SIRES, K_h VALUES, HERITABILITIES (h^2), NUMBER OF EWES, K_r VALUES, AND REPEATABILITIES FOR REPRODUCTIVE TRAITS OF MORADA NOVA EWES CONSIDERING EWE BODY CONDITION SCORE IN THE STATISTICAL MODEL

TRAITS	No. SIRES	K_h[a]	$h^2 \pm$ se	No. EWES	K_r[b]	r ± se
LSL[c]	40	18.2	.06 ± .06	629	2.4	.20 ± .03
LWB[d]	40	18.2	.02 ± .05	629	2.4	.07 ± .03
LWW[e]	40	18.2	.09 ± .07	629	2.4	.24 ± .03
LSW[f]	40	18.2	.10 ± .07	629	2.4	.13 ± .03
LSR[g]	40	18.2	.09 ± .07	629	2.4	.18 ± .03

[a]K_h = Average Number of Offspring per Sire

[b]K_r = Average Number of Repeated Records per Ewe

[c]LSL = Litter Size at Lambing

[d]LWL = Litter Weight at Lambing

[e]LWW = Litter Weight at Weaning

[f]LSW = Litter Size at Weaning

[g]LSR = Lamb Survival Rate as Ewe Trait

Discussion

Environmental Factors

A significant effect of year of breeding or lambing was found on MAR, PAR, LSL, LWL, LWW, LSW, and LSR. The year effects on all ewe reproductive traits were expected, based on literature reports and from the unique climatic pattern of the NEB. Findings in this study are in general agreement with most of the published results. For instance, Vakil et al. (1968), Levine and Hohenboken (1978), Fogarty et al. (1984b), Fernandes (1985), Younis et al. (1990), Kabuga and Akowuak (1991), Kleemann et al. (1991), Bedier et al. (1992), and Nawaz and Meyer (1992) also reported significant effects of year on those reproductive characters. However, there are some reports that yielded no significant year effect on reproductive traits (Mavrogenis, 1982; Iniguez et al., 1991). Explanations for the year effect on those reproductive traits, are similar to those given for year on growth traits presented in Chapter IV. The unique climatic pattern of the NEB, amount and distribution of rainfall within and among years, combined with its effects on forage production and deterioration, should be considered major points to explain differences on reproductive performance, expressed by those reproductive traits, due to year effects.

The significant effect of age of ewe (AE) on LWL and LSR reported in this research is in agreement with other results found in the literature (Purser and Young, 1964; Oltenacu and Boylan, 1981; Gonzalez, 1983; Peterson and Danell, 1985; Atkins, 1986; Long et al., 1989; Younis et al., 1990). Nevertheless, the non-significant effects of AE on MAR, PAR, LSL, LSW, and LWW reported in this research are in disagreement with the majority of published literature (Coop, 1962; Turner and Dolling, 1965; Dickerson and Glimp, 1975; Atkins, 1986; Long et al., 1989; Gates, 1990; Younis et al., 1990). Conversely, results found in this study are in agreement with data from Bedier et al. (1992). They reported that AE found did not affect LSL, LSW and LWW in Barki sheep.

According to what was found in this Morada Nova sheep study, it could be stated whenever the ewe had reached minimum weight and(or) adequate body condition, age of ewe (AE) was not an important factor on ewe reproductive performance, i.e., it seems that weight and ewe body condition of ewe to be more important than age of ewe its reproductive performance.

Ewe body condition (BC) was one of the most striking factor affecting reproductive performance of Morada Nova ewes expressed by LSL, LWL, LSW, LWW, and LSR. These findings are in concordance with other results described in the literature (Allen and Lamming, 1961; Gunn et al., 1969; Bastimam, 1972; Ducker and Boyd, 1977; Molina et al., 1991).

Effect of BC on LSL could be explained as reflection of higher ovulation rate associated with better capacity to carry on at term multiple pregnancy of ewes in good BC than ewes in poor BC. In addition, it could also indicate that effects of BC on LWL, LSW, and LSR were direct reflection and due to higher LSL of ewes in good BC in relation to ewes in poor BC.

Weight of ewe (WE) at breeding or lambing significantly influenced on MAR, LSL, LWL, and LWW. The negative correlation found between WE at lambing and LSL in this study is in agreement with the result of Iniguez et al. (1991) in Sumatran ewes. Positive linear correlations between WE and each of the other reproductive traits (MAR, LWL and LWW) described in this research are in general concordance with other results reported in the literature (Coop, 1962; Cumming et al., 1975; Cochram et al., 1984; Bedier et al., 1992). Ewes that are too heavy or too light tend toward lower reproductive performance with a nearly linear relationship between productivity and ewe weight in the middle of the range.

Effect of type of parturition (TL) was also one of the most important environmental factors affecting reproductive performance. Its effect was strongly ($P<.01$) evident on LWL, LSW, and LSR, and it approached ($P<.10$) significance for LWW. The positive effect of TL on LWL, LSW and LWW would apparently support the need to increase reproductive performance of Morada Nova ewes through a selection program for increasing twin parturition. However, the strong negative effect of TL on lamb survival rate up to weaning as ewe trait (LSR) needs to be considered in the NEB sheep production system. Based on the results found in this study, it could be seen that Morada Nova ewes have feasible rearing ability to support an increment of twin lambing rate; however, lamb survival rate as a lamb and(or) a ewe trait must be improved to take complete advantage of multiple births as an effective way to make progress on total lamb production. It seems clear that management conditions, principally nutrition level, need to become better to give reasonable opportunities for ewes to raise their litters for high LSW and LSR, and consequently increase in final lamb production expressed by LWW.

Significant effects (P<.01) of YL*TL interaction were found on LWL, LWW, LSW, and LSR. The YL*TL interaction is an important factor and means that differences between years were not the same in the two type of parturitions, and vice-versa. It is expected that such differences on LWL, LSW and LWW would tend to reduce, and in relation to those differences on LSR would tend to increase in bad years, and consequently should take off the possible advantage of multiple parturition. Conversely, in extremely good years the differences on LWL, LSW and LWW may become very large, and differences on LSR may almost disappear, and consequently, in this situation, twin parturitions would become very desirable. This interaction (YL*TL), such as mentioned previously in Chapter IV, is what causes the discussion about the desirability or not of multiple parturition. It seems clear, as cited before, that some improvement on management conditions should be applied to reduce the negative effects of YL*TL interaction on those productive traits in bad years, and consequently to take complete advantage of multiple lambings to improve sheep production in the NEB.

Genetic Parameters

The heritabilities and repeatabilities estimated in this research are very important guides for developing possible genetic programs to improve reproductive performance of Morada Nova sheep in the NEB.

The accessible literature, on a variety of different breeds suggests that heritability estimates are normally low for the component traits of ewe reproductive performance. Estimates of heritability for litter size at lambing (LSL), as reported in the literature and summarized in Table 3 (Chapter II) range from -.01 (Lal, 1968) to .35 (Abdulkhaliq et al., 1989). The estimates found in this research (.06±.06) is in general agreement with those published in the literature and it seems to indicate that additive genetic effects on LSL in this Morada Nova sheep flock are not too important and measurable genetic progress can not be achieved by selecting for LSL. Similar findings were described by Ch'ang and Rae (1961) in Romney (h^2=.03), Basuthakur et al. (1973) in Columbia (h^2=.05±.11), and Forrest and Bichard (1974) in Clun Forest sheep (h^2=.08±.05).

The heritability estimate for LWL found in this study (.02±.05) is lower than previous estimates of .24±.09 (Martin et al., 1981) and .12 (Abdulkhaliq et al., 1989).

Litter size at weaning (LSW) had a moderately low heritability estimate (.10±.07) in this study. This estimate is higher than the estimates of .00±.03 (Clark and Hohenboken, 1983), .02±.07 (Martin et al., 1981) and .05±.04 (Purser, 1965), similar to the estimates .09±.09 (Young et al., 1963), .13±.10 (Basuthakur et al., 1973), and .10±.05 (Fogarty et al., 1985), but less than the estimates .25 (More O'Ferrall, 1976) and .26 (Abdulkhaliq et al., 1989).

Heritability estimates published in the literature for litter weight at weaning (LWW) ranged between -.05±.02 (Clark and Hohenboken, 1983) and .50±.18 (Basuthakur et al., 1973). For instance, the estimate found in this research (.09±.07) falls inside of the limits of this parameter estimate. Very similar results were reported by Fogarty et al. (1985) in crossbred sheep (.11±.07) and Abdulkhaliq et al. (1989) in Targhee sheep (.13).

Compared with other reproductive traits, heritability estimates for litter size and weight at weaning have not received much consideration in past investigations. Both traits were found in this study to be moderately heritable and hence, probably direct selection on one or both traits would promote some genetic progress in improving total litter weight weaned in Morada Nova sheep.

Heritability estimates for lamb survival rate up to weaning as a ewe trait (LSR) found in the literature average about .07 (Cundiff et al., 1982; Fogarty et al., 1985; Atkins, 1986; Baker and Steine, 1986; Abdulkhaliq et al., 1989). Thus, it will be noticed that there is close agreement between the estimate (.09±.07) obtained in this research and those reported in the literature. Further, it can be stated that LSR in the Morada Nova sheep is influenced, at least to some extent, by additive gene effects, and that some genetic progress on LSR may be achieved throughout selection program. Also, it could be added that, since LSR is highly affected by the ewe rearing ability expressed by LSW and given that rearing ability showed as a low moderately heritable trait (h^2=.09±.07), it should be possible to improve LSR in Morada Nova breed by selection for increased rearing ability of the ewe, i.e., selection for improving LSW.

The repeatability estimates reported in Table 35 for the reproductive characters considered in this study are within the range of the estimates reported in the literature. It is also important to note that the repeatability estimates found in this research for LSL and LWW may very well represent the upper limit of the heritability for those traits, respectively, in Morada Nova sheep.

Repeatability of litter size at lambing (LSL) was estimated to be .20±.03. This estimate is similar to the figure found by Fernandes (1985) in Morada Nova sheep. In addition, similar findings were reported by Purser (1965), More O'Ferrall (1976), Clark and Hohenboken (1983), Atkins (1986), and Davis and Kinghorn (1986).

The estimate of repeatability for LWL was found to be lower (.07±.03) than figures of .17, .18 and .21 in Targhee, Suffolk and Columbia sheep reported by Abdulkhaliq et al.

(1989). In addition, repeatability estimate (.24±.03) for LWW found in this study was higher than the values described by Eikje (1975), Clark and Hohenboken (1983) and Fogarty et al. (1985), but similar to the estimates of .21 and .22 found by Gjedrem (1967) and Abdulkhaliq et al. (1989), respectively.

Litter size at weaning (LSW) was found to be moderately to lowly repeatable (.13±.03) in Morada Nova sheep. This result is similar to the results reported by Inskeep et al. (1967) in Hampshire sheep (.13) and Abdulkhaliq et al. (1989) in Suffolk, Targhee and Columbia sheep (.10, .13 and .15, respectively). In relation to the repeatability estimate for LSR observed in this research (.18±.03) is in general agreement with other figures cited in literature. This estimate is higher than the figures of .06 and .08 (Shelton and Menzies, 1970) and .02 and .05 (Fogarty et al., 1985), but similar to .15 and .16 (Piper et al., 1982) in two flocks of Merino, and .17, .21 and .17 (Abdulkhaliq et al., 1989) for Targhee, Columbia and Suffolk breeds, respectively.

The moderately higher estimates of repeatability for the reproductive traits considered in this study, especially in relation to each respective heritability, suggest the possible existence of sizable permanent environmental effects or non-additive genetic effects. These findings would partly reflect consistent behavioral response of ewes to similar environmental conditions provided to them each year during mating, lambing and up to weaning periods on the experimental farm. Further, it would be state that repeatability estimates for LSL and LSW support the current practice used in this Morada Nova flock of culling ewes which do not lamb or rear any lamb in two consecutive years after the first opportunity.

Implications

Adjustment factors for ewe body condition, age of ewe and type of parturition need to be estimated and considered in selection programs to improve reproductive performance of Morada Nova ewes.

As previously mentioned in Chapter IV, it should be interesting to evaluate and minimize the influence of pasture condition (forage deterioration), that is suspected to be one of the primary causes of the year effect, with the aim to reduce differences in ewe reproductive performance throughout years.

Although there was a negative effect of twinning parturition on lamb survival rate, ewes that dropped twins produced higher LWL, LSW and LWW (64, 47 and 18%, respectively) than ewes with a single lamb. However, these results suggest that management conditions should be improved to take complete advantage of multiple parturition as a way to increase reproductive performance of Morada Nova sheep, principally expressed by LSW, LWW and LSR.

Despite the fairly low heritability estimate of LSW, it seems feasible that direct selection based on this trait should be more effective to achieve some genetic progress on reproductive performance of this Morada Nova flock measured as LWW and(or) LSR than direct selection for LSL or LSR.

CHAPTER VI

ADDITIVE AND MULTIPLICATIVE CORRECTION FACTORS FOR SEX, BIRTH-REARING CLASS, AND AGE OF EWE IN MORADA NOVA HAIR LAMB WEIGHTS IN BRAZIL

ABSTRACT

Records on 2755, 2267, 1968, and 1451 Morada Nova lambs at birth, weaning, six-month, and yearling, respectively, were used to evaluate the influence of sexof lamb (SL), age of ewe (AE) and type of birth-rearing (TB) to derive additive (AF) and multiplicative (MF) correction factors for these environmental influences on birth weight (BWT), weaning weight (WWT), six-month weight (WT6), and yearling weight (YWT). Year of birth (YB) differences were also evaluated. The effects of YB, SL and TB were important (P<.01) sources of variation to explain differences on BWT, WWT and YWT. Sex of lamb (P<.01) and YB (P<.05) effects also were significant on WT6. Age of ewe at lambing (AE) had a marked effect on BWT, WWT, WT6 (P<.01) and on YWT (P<.05). The interaction of YB*TB had a marked influence (P<.01) on WWT, WT6 and YWT; while the AE*TB interaction was important for BWT (P<.01) and WWT and YWT (P<.05). Separate additive (AF) correction factors of .08, .36, .42, and .51 kg for SL (ewe lambs lighter than ram lambs) were calculated for BWT, WWT, WT6, and YWT, respectively. The highest separate AF adjustment factor for AE was for ewes of 1Y age class in WT6 (.71 kg lighter than 3Y ewes), while for TB was for twin-twin (TT) lambs in

WWT, where TT lambs were 2.26 kg lighter than SS lambs. Multiplicative (MF) correction factors for sex of lamb (SL), type of birth-rearing (TB) and age of ewe (AE) together (SL*TB*AE) were highest for TT ewe lambs born to 1Y ewes at birth (1.40), weaning (1.34), and at six-months (1.27). Additive or multiplicative correction factors for SL, TB and AE need to be considered in a selection program to improve growth performance of hair sheep in the Northeastern Brazil.

Key Words: Hair Sheep, Growth Traits, Correction Factors, Sex, Birth-Rearing Class, Ewe Age, Morada Nova Sheep.

Introduction

Lamb growth is one of the major components in profitability and efficiency of sheep production, and should be an important objective in selection (Dickerson, 1970; Bradford, 1985). According to Anderson and Wilham (1978) environmental differences that may not be controlled, such as sex of lamb, age of dam and type of birth-rearing, should be statistically adjusted. Thus, to accurately estimate breeding values for lamb growth traits, records must be adjusted for various environmental factors such as age of dam, sex and birth-rearing class.

Considering the results found in relation of those environmental factors on growth traits (Chapter IV), they cleary indicate that correction factors for sex, birth-rearing class and age of ewe in Morada Nova lamb pre- and post-weaning weights need to be considered in selection programs. Adjustment factors, in addition, for those environmental variables in hair sheep weights are not found in the published literature.

With the above background, the objectives of this study were to estimate age of ewe, sex and type of birth-rearing effects and to calculate additive and multiplicative correction factors for those environmental effects on birth (BWT), weaning (WWT), six-month (WT6), and yearling (YWT) weights of Morada Nova lambs.

Materials and Methods

Sheep Flock and Environment

The experimental sheep flock was housed at the Iracema Farm, Quixada, Ceara, Brazil and it is property of the Agency of Agricultural Research of the Ceara State - EPACE. Details of the region, farm, sheep breed and its management are presented in Chapters III and IV.

Description of Data

Data from a purebred unselected flock of Morada Nova hair sheep were recorded from 1981 to 1991. Growth traits considered in this study were: birth weight (BWT), weaning weight (WWT), six-month weight (WT6), and yearling weight (YWT). Individual adjusted WWT, WT6 and YWT to a common age of 112, 180 and 365 days, respectively, were calculated prior to analyses using the specific equation for each weight as presented in Chapter III. The distribution of the number of records per year at different phases is showed in Table 5, Chapter III. The analyses of BWT, WWT, WT6, and YWT were based on 2755, 2267, 1968, and 1452 records, respectively (Table 5, Chapter III).

Environmental factors considered for analyses of those growth traits in this research were: year of birth (YB), age of ewe (AE), sex of lamb (SL), and type of birth-rearing (TB). Age of ewe (AE) was age at lambing. Preliminary analyses indicated that lamb growth from ewes of 2 yr, 3 yr and 4 yr of age was not significantly different. Therefore, ewes two to four years of age were grouped into one age class (3Y). In addition, those preliminary analyses indicated that lambs born to ewes with 5 yr, 6 yr and older had similar performance. Thus, those ewes were grouped into a common age of ewe class (6Y). Therefore, three age categories were used and classified as follows: 1Y = one year to less than 2 yr of age; 3Y = 2 yr to 4 yr of age; and 6Y = 5 yr of age and older.

Additive and multiplicative correction factors for AE, SL and TB were estimated in all Morada Nova lamb weights considered in this study.

Statistical Procedures

Analyses of data on BWT, WWT, WT6, and YWT were performed using the GLM procedure described in SAS/STAT User's Guide (SAS, 1988). The following general linear model was used:

$$\mathbf{Y_{ijklmn}} = \mu + P_i + S_j + T_k + A_l + (PT)_{ik} + (ST)_{jk} + (AT)_{lk} + (STA)_{jkl} + \epsilon_{ijklmn},$$

where:

$\mathbf{Y_{ijklmn}}$ = observed value for BWT, WWT, WT6, and YWT on the n^{th} lamb born to ewe of the l^{th} age class, k^{th} type of birth-rearing class, j^{th} sex class in the i^{th} year.

μ = overall mean.

P_i = i^{th} year of birth effect.

S_j = j^{th} sex class of lamb effect.

T_k = k^{th} type of birth-rearing effect.

A_l = l^{th} age of dam class effect.

$(PT)_{ik}$ = effect of interaction between the i^{th} year of birth and the k^{th} type of birth-rearing class.

$(ST)_{jk}$ = effect of interaction between the j^{th} sex class of lamb and the k^{th} type of birth-rearing class.

$(AT)_{lk}$ = effect of interaction between the l^{th} age of dam class and the k^{th} type of birth-rearing class.

$(STA)_{jkl}$ = effect of interaction among the j^{th} sex class of lamb, the k^{th} type of birth-rearing and the l^{th} age of dam class.

ϵ_{ijklmn} = random error effect, ϵ's assumed NID $(0, \sigma^2)$.

Correction factors were calculated on basis of the least-squares means provided for AE, SL and TB classes in each weight analysis. Least-squares means for male single lambs born to ewe of 3Y class were considered the base values for estimating additive and multiplicative adjustment correction factors for the other different class combinations of those environmental factors in BWT, WWT, WT6, and YWT.

Results

Environmental Factors

The analyses of variance for BWT and YWT are presented in Table 36. Birth weight (BWT) and YWT were significant (P<.01) affected by year of birth (YB), sex of lamb (SL) and type of birth/rearing (TB). Age of ewe (AE) and the interaction AE*TB had very strong influence (P<.01) on BWT, while they were only significant (P<.01) on YWT. The interaction YB*TB did not influence (P>.05) BWT, but it was a highly significant factor on YWT. The interactions SL*TB and SL*TB*AE did not affect (P>.05) BWT and YWT (Table 36). Least-squares means and standard errors for BWT and YWT are shown in Tables 37, 38 and 39. Morada Nova lambs weighed on average 2.25±.01 and 18.78±.07 kg at birth and yearling, respectively (Table 37).

Weaning weight (WWT) and six-month weight (WT6) were highly influenced (P<.01) by year of birth (YB), type of birth/rearing (TB), age of ewe (AE), and interaction YB*TB. In addition, sex of lamb(SL) (P<.01) and interaction AE*TB (P<.05) influenced WWT. Six-month weight (WT6) was also affected by SL (P<.05) and the interaction AE*TB tended (P<.10) to affect WT6. The interactions SL*TB and SL*TB*AE were not significant (P>.05) sources of variation for WWT and WT6 (Table 40). Least-squares means for WWT and WT6 by SL, AE, TB and their interactions are listed in Tables 41, 42 and 43. The overal means for WWT and WT6 were 11.38±.04 and 13.26±.05 kg, respectively (Table 41).

TABLE 36. ANALYSIS OF VARIANCE FOR BIRTH AND YEARLING WEIGHTS OF MORADA NOVA LAMBS

SOURCE OF VARIATION	BIRTH WEIGHT DF	BIRTH WEIGHT MEAN SQUARES	YEARLING WEIGHT DF	YEARLING WEIGHT MEAN SQUARES
Year of Birth (YB)	9	4.655432**	9	43.005328**
Sex of Lamb (SL)	1	2.667406**	1	24.917000**
Type Birth/Rearing (TB)	1	69.367832**	2	154.572684**
Age of Ewe (AE)	2	9.730059**	2	19.620479*
YB * TB	9	0.180623	18	14.116885**
SL * TB	1	0.509895	2	1.809183
AE * TB	2	0.716072**	4	16.009509*
SL * TB * AE	4	0.190064	6	5.737816
Error	2725	0.196523	1406	6.398770

*P< .05
**P < .01

TABLE 37. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH AND YEARLING WEIGHTS OF MORADA NOVA LAMBS BY YEAR OF BIRTH, SEX OF LAMB, TYPE OF BIRTH-REARING, AND AGE OF EWE

	BIRTH WEIGHT (kg)		YEARLING WEIGHT (kg)	
FACTORS	No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Overall	**2755**	**2.25 ± .01**	**1451**	**18.78 ± .07**
Year of Birth (YB)				
1981	96	2.24±.05	79	20.34±.58
1982	26	2.37±.03	184	17.95±.27
1983	305	2.38±.03	222	17.26±.28
1984	357	2.24±.02	223	17.77±.26
1985	320	2.03±.03	178	18.93±.29
1986	359	2.02±.02	192	17.74±.30
1987	206	2.05±.03	87	19.89±.56
1988	367	2.13±.02	87	19.19±.39
1989	274	2.13±.03	120	19.22±.51
1990	211	2.22±.04	79	17.55±.69
Sex of Lamb (SL)				
Male (ML)	1416	2.22±.02	676	18.84±.20
Female (FL)	1339	2.14±.02	775	18.33±.21
Type of Birth/Rearing (TB)				
Single as Single (SS)	1708	2.40±.01	1074	19.47±.10
Twin as Twin (TT)	1047	1.96±.02	265	17.81±.23
Twin as Single (TS)	-	-	112	18.47±.41
Age of Ewe (AE)				
One yr. to < two yrs. (1Y)	661	2.03±.02	383	18.19±.26
Two yrs to < five yrs. (3Y)	1650	2.26±.01	886	18.86±.15
Five yrs. and older (6Y)	444	2.25±.02	182	18.70±.29

TABLE 38. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH (BWT) AND YEARLING (YWT) WEIGHTS OF MORADA NOVA LAMBS BY THE INTERACTIONS AGE OF EWE*TYPE OF BIRTH (AE*TB) AND SEX OF LAMB*TYPE OF BIRTH (SL*TB)

FACTORS		BWT (kg)		YWT (kg)	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: AE * TB					
Age of Ewe	Type of Birth				
1Y	SS	495	2.22±.02	319	18.68±.15
3Y	SS	969	2.50±.01	629	19.86±.11
6Y	SS	244	2.47±.03	126	19.88±.23
1Y	TT	166	1.85±.04	44	18.07±.42
3Y	TT	681	2.02±.02	180	17.89±.23
6Y	TT	200	2.02±.03	41	17.47±.41
1Y	TS	-	-	20	17.81±.66
3Y	TS	-	-	77	18.84±.37
6Y	TS	-	-	15	18.74±.74
Interaction: SL * TB					
Sex of Lamb	Type of Birth				
Male	SS	878	2.45±.02	496	19.75±0.15
Male	TT	538	1.99±.02	125	17.94±.32
Male	TS	-	-	55	18.81±.49
Female	SS	830	2.34±.02	578	19.19±.13
Female	TT	509	1.94±.03	140	17.68±.29
Female	TS	-	-	57	18.12±.54

TABLE 39. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR BIRTH (BWT) AND YEARLING (YWT) WEIGTHS OF MORADA NOVA LAMBS IN RELATION THE INTERACTION SEX OF LAMB*TYPE OF BIRTH*AGE OF EWE (SL*TB*AE)

FACTORS			BIRTH WEIGHT (kg)		YEARLING WEIGHT (kg)	
SEX OF LAMB	TYPE OF BIRTH	AGE OF EWE	No. OF LAMBS	LSM ± SE	No. OF LAMBS	LSM ± SE
RAM	SS	1Y	254	2.27±.03	142	18.97±0.21
		3Y	494	2.55±.03	293	20.07±0.15
		6Y	130	2.53±.04	58	20.06±0.34
	TT	1Y	81	1.88±.05	18	17.78±0.63
		3Y	350	2.07±.02	89	18.49±0.30
		6Y	107	2.00±.04	18	17.55±0.62
	TS	1Y	-	-	10	17.87±0.88
		3Y	-	-	36	19.35±0.48
		6Y	-	-	9	19.22±0.91
EWE	SS	1Y	241	2.16±.02	177	18.39±0.20
		3Y	475	2.45±.02	333	19.64±0.14
		6Y	114	2.42±.04	68	19.53±0.31
	TT	1Y	85	1.82±.05	26	18.36±0.52
		3Y	331	2.04±.03	91	17.39±0.31
		6Y	93	2.04±.05	23	17.39±0.54
	TS	1Y	-	-	10	17.76±0.88
		3Y	-	-	41	18.34±0.48
		6Y	-	-	6	18.26±1.09

TABLE 40. ANALYSIS OF VARIANCE FOR WEANING AND SIX-MONTH WEIGHTS OF MORADA NOVA LAMBS

SOURCE OF VARIATION	WEANING WEIGHT DF	WEANING WEIGHT MEAN SQUARES	SIX-MONTH WEIGHT DF	SIX-MONTH WEIGHT MEAN SQUARES
Year of Birth (YB)	9	152.35434**	9	49.028233**
Sex of Lamb (SL)	1	24.30599**	1	25.790854*
Type Birth/Rearing (TB)	2	583.81760**	2	425.736888**
Age of Ewe (AE)	2	25.94575**	2	31.398704**
YB * TB	18	19.17698**	18	23.214291**
SL * TB	2	2.97138	2	0.692915
AE * TB	4	7.74182*	4	8.509328+
SL * TB * AE	6	1.19665	6	1.270957
Error	2222	3.11535	1923	3.98603

+P< .10

*P< .05

**P < .01

TABLE 41. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR WEANING AND SIX-MONTH WEIGHTS OF MORADA NOVA LAMBS BY YEAR OF BIRTH, SEX OF LAMB, TYPE OF BIRTH-REARING AND AGE OF EWE

	WEANING WEIGHT (kg)		SIX-MONTH WEIGHT (kg)	
FACTORS	No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Overall	**2267**	**11.38 ± .04**	**1968**	**13.26 ± .05**
Year of Birth (YB)				
1981	82	11.69±.36	81	13.87±.41
1982	214	12.43±.17	196	13.43±.20
1983	262	10.63±.17	240	12.99±.21
1984	283	9.38±.14	243	11.54±.18
1985	237	9.20±.16	209	11.77±.22
1986	291	10.01±.15	251	12.25±.19
1987	172	12.72±.25	150	13.84±.31
1988	290	11.35±.14	261	12.93±.18
1989	248	10.34±.22	223	12.57±.27
1990	188	11.82±.32	114	13.20±.39
Sex of Lamb (SL)				
Male (ML)	1151	11.14±.10	968	13.05±.13
Female (FL)	1116	10.78±.11	1000	12.63±.13
Type of Birth/Rearing (TB)				
Single as Single (SS)	1530	12.21±.06	1378	13.98±.07
Twin as Twin (TT)	546	9.95±.11	441	11.81±.14
Twin as Single (TS)	191	10.70±.21	149	12.73±.26
Age of Ewe (AE)				
One yr. to < two yrs. (1Y)	545	10.59±.14	483	12.44±.17
Two yrs to < five yrs. (3Y)	1379	11.18±.08	1211	13.15±.09
Five yrs. and older (6Y)	343	11.09±.14	274	12.94±.19

TABLE 42. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR WEANING (WWT) AND SIX-MONTH (WT6) WEIGTHS OF MORADA NOVA LAMBS BY THE INTERACTIONS AGE OF EWE*TYPE OF BIRTH (AE*TB) AND SEX OF LAMB*TYPE OF BIRTH (SL*TB)

FACTORS		WWT (kg)		WT6 (kg)	
		No. LAMBS	LSM ± SE	No. LAMBS	LSM ± SE
Interaction: AE * TB					
Age of Ewe	Type of Birth				
1Y	SS	427	11.61±.09	388	13.25±.10
3Y	SS	887	12.63±.06	810	14.46±.07
6Y	SS	216	12.41±.12	180	14.22±.15
1Y	TT	86	9.75±.20	68	11.62±.25
3Y	TT	370	10.07±.11	302	12.12±.14
6Y	TT	90	10.04±.20	71	11.69±.25
1Y	TS	32	10.41±.36	27	12.43±.44
3Y	TS	122	10.86±.19	99	12.88±.23
6Y	TS	37	10.83±.34	23	12.89±.47
Interaction: SL * TB					
Sex of Lamb	Type of Birth				
Male	SS	780	12.48±.08	676	14.23±.10
Male	TT	272	10.09±.15	219	11.98±.19
Male	TS	99	10.84±.25	73	12.96±.31
Female	SS	750	11.94±.08	702	13.73±.09
Female	TT	274	9.82±.14	222	11.64±.17
Female	TS	92	10.56±.27	76	12.51±.35

TABLE 43. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR WEANING (WWT) AND SIX-MONTH (WT6) WEIGTHS OF MORADA NOVA LAMBS BY THE INTERACTION SEX OF LAMB*TYPE OF BIRTH*AGE OF EWE (SL*TB*AE)

FACTORS			WEANING WEIGHT (kg)		SIX-MONTH WEIGHT (kg)	
SEX OF LAMB	TYPE OF BIRTH	AGE OF EWE	No. OF LAMBS	LSM ± SE	No. OF LAMBS	LSM ± SE
RAM	SS	1Y	210	11.84±.12	184	13.40±.15
		3Y	456	12.93±.08	405	14.70±.10
		6Y	114	12.67±.17	87	14.57±.22
	TT	1Y	39	9.84±.29	30	11.68±.37
		3Y	192	10.24±.14	159	12.38±.18
		6Y	41	10.18±.28	30	11.87±.38
	TS	1Y	16	10.84±.47	13	12.73±.59
		3Y	60	10.85±.26	45	13.14±.33
		6Y	23	10.84±.40	15	13.00±.55
EWE	SS	1Y	217	11.37±.12	204	13.10±.14
		3Y	431	12.32±.09	405	14.21±.10
		6Y	102	12.14±.18	93	13.87±.21
	TT	1Y	47	9.67±.27	38	11.56±.34
		3Y	178	9.89±.14	143	11.86±.18
		6Y	49	9.90±.26	41	11.51±.32
	TS	1Y	16	9.98±.48	14	12.14±.59
		3Y	62	10.88±.25	54	12.68±.29
		6Y	14	10.83±.51	8	12.68±.74

<u>Correction Factors</u>

Separate additive adjustment factors for the effects of sex of lamb (SL), age of ewe (AE) and type of birth-rearing (TB) on birth (BWT), weaning (WWT), six-month (WT6), and yearling (YWT) lamb weights are presented in Table 44. Correction factors for SL, in relation to male lamb weights, ranged from 0.08 to 0.51 kg in BWT and YWT of ewe lambs, respectively. Ewes of 1Y age class required higher adjustment factors than ewes of 6Y age class in all weights. However, both classes(1Y and 6Y) presented the same pattern to increase correction factors in BWT up to WT6 and to decrease in YWT. Large adjustment factors were calculated for TB in all weights, considering single-single lamb weights as base values. Correction factors for TB in WWT were 1.51 and 2.26 kg for twin-single lambs (TS) and twin-twin lambs (TT), respectively. Adjustment factors for TB decreased by 17 and 34% in WT6 and YWT of TS lambs, and by 4 and 27% in WT6 and YWT of TT lambs, in relation to the figures in WWT (Table 44).

Additive (AF) and multiplicative (MF) correction factors for the effects of the three environmental factors (SL*TB*AE) on BWT ,YWT, WWT, and WT6 of Morada Nova lambs are presented in Tables 45, 46 , 47 and 48, respectively. Correction factors were calculated based on the least-squares means of each weight for single-single (SS) ram lambs born to ewes of 3Y age class. Twin-twin (TT) ewe lambs born to ewes of 1Y age class had the highest AF and MF correction factors in BWT (0.73 and 1.40, respectively). However, single-single (SS) ram lambs born to ewes of 6Y age class showed the lowest AF and MF adjustment factors (0.02 and 1.01, respectively) (Tables 45 and 46). All MF correction factors for SL*TB*AE in YWT were smaller than in BWT (Table 46). Twin-twin (TT) ewe lambs born to ewes of 3Y and 6Y age class presented similar AF and MF adjustment factors for SL*TB*AE in BWT (0.51 and 1.25) and in YWT (2.68 and 1.15) (Tables 45 and 46). At weaning, TT ewe lambs born to 1Y ewe had the highest AF (3.26) and MF (1.34) adjustment factors, while SS male lambs born to 6Y presented the lowest (0.26 and 1.02 for AF and MF, respectively) . Twin-single (TS)

TABLE 44. ADDITIVE CORRECTION FACTORS (kg) FOR BIRTH (BWT), WEANING (WWT), SIX-MONTH (WT6), AND YEARLING (YWT) WEIGHTS BY SEX (SL), AGE OF EWE (AE), AND TYPE OF BIRTH-REARING (TB)

FACTOR		WEIGHTS			
		BWT	WWT	WT6	YWT
Sex (SL)	Ram	(2.22)*	(11.14)*	(13.05)*	(18.84)*
	Ewe	0.08	0.36	0.42	0.51
Age of Ewe (AE)	1Y	0.23	0.59	0.71	0.67
	3Y	(2.26)*	(11.18)*	(13.15)*	(18.86)*
	6Y	0.01	0.09	0.21	0.16
Type of Birth/ Rearing (TB)	SS	(2.40)*	(12.21)*	(13.98)*	(19.47)*
	TS	-	1.51	1.25	1.00
	TT	0.44	2.26	2.17	1.66

*Figures between paratenhesis are the base least-squares means used to estimate adjustments for weights by the specific class of environmental factor.

TABLE 45. ADDITIVE CORRECTION FACTORS (kg) FOR BIRTH (BWT) AND YEARLING (YWT) WEIGHTS BY COMMON SEX, AGE OF EWE, AND TYPE OF BIRTH-REARING

FACTOR		BIRTH WEIGHT		YEARLING WEIGHT		
		TYPE OF BIRTH/REARING		TYPE OF BIRTH/REARING		
SEX	AGE OF EWE	SS	TT	SS	TS	TT
EWE	1Y	0.39	0.73	1.68	2.31	1.71
	3Y	0.10	0.51	0.43	1.73	2.68
	6Y	0.13	0.51	0.54	1.81	2.68
RAM	1Y	0.28	0.67	1.10	2.20	2.29
	3Y	**(2.55)***	0.48	**(20.07)***	0.72	1.58
	6Y	0.02	0.55	0.01	0.85	2.52

*Figures between parenthesis are the base least-squares means used to estimate adjustments for weights by that specific environmental factor.

TABLE 46. MULTIPLICATIVE CORRECTION FACTORS FOR BIRTH (BWT) AND YEARLING (YWT) WEIGHTS BY COMMON SEX, TYPE OF BIRTH-REARING, AND AGE OF EWE

FACTOR		BIRTH WEIGHT		YEARLING WEIGHT		
		TYPE OF BIRTH/REARING		TYPE OF BIRTH/REARING		
SEX	AGE OF EWE	SS	TT	SS	TS	TT
EWE	1Y	1.18	1.40	1.09	1.13	1.09
	3Y	1.04	1.25	1.02	1.09	1.15
	6Y	1.05	1.25	1.03	1.10	1.15
RAM	1Y	1.12	1.36	1.06	1.12	1.13
	3Y	**1.00**	1.23	**1.00**	1.04	1.09
	6Y	1.01	1.28	1.00	1.04	1.14

TABLE 47. ADDITIVE CORRECTION FACTORS (kg) FOR WEANING (WWT) AND SIX-MONTH (WT6) WEIGHTS BY COMMON SEX, TYPE OF BIRTH-REARING, AND AGE OF EWE

FACTOR		WEANING WEIGHT			SIX-MONTH WEIGHT		
	AGE OF	TYPE OF BIRTH-REARING			TYPE OF BIRTH-REARING		
SEX	EWE	SS	TS	TT	SS	TS	TT
EWE	1Y	1.56	2.95	3.26	1.60	2.56	3.14
	3Y	0.61	2.05	3.04	0.49	2.02	2.84
	6Y	0.79	2.10	3.03	0.83	2.02	3.19
RAM	1Y	1.09	2.09	3.09	1.30	1.97	3.02
	3Y	**(12.93)***	2.08	2.69	**(14.70)***	1.56	2.32
	6Y	0.26	2.09	2.75	0.13	1.70	2.83

*Figures between parenthesis are the base least-squares means used to estimate adjustments for weights by that specific environmental factor.

TABLE 48 . MULTIPLICATIVE CORRECTION FACTORS FOR WEANING (WWT) AND SIX-MONTH (WT6) WEIGHTS BY COMMON SEX, TYPE OF BIRTH-REARING, AND AGE OF EWE

FACTOR		WEANING WEIGHT			SIX-MONTH WEIGHT		
	AGE OF	TYPE OF BIRTH-REARING			TYPE OF BIRTH-REARING		
SEX	EWE	SS	TS	TT	SS	TS	TT
EWE	1Y	1.14	1.30	1.34	1.12	1.21	1.27
	3Y	1.05	1.19	1.31	1.03	1.16	1.24
	6Y	1.07	1.19	1.31	1.06	1.16	1.28
RAM	1Y	1.09	1.19	1.31	1.10	1.15	1.26
	3Y	**1.00**	1.19	1.26	**1.00**	1.12	1.19
	6Y	1.02	1.19	1.27	1.01	1.13	1.24

male lambs born to 1Y, 3Y and 6Y had very similar MF correction factors in WWT and WT6 (Table 48). At six-month of age TT ewe lambs born to 1Y and 6Y ewes presented the highest AF (3.14 and 3.19) MF (1.27 and 1.28) adjustment factors. However, SS ewe lambs from 3Y ewes and SS ram lambs from 6Y had the lowest correction factors, i.e., AF (0.49 and 0.13) and MF (1.03 and 1.01), respectively (Tables 47 and 48).

Discussion

Environmental Factors

The effect of year of birth was an important factor for all growth traits (BWT, WWT, WT6, and YWT). Similar findings have been cited in the literature (Dickerson et al., 1975; Kaushish et al., 1990; Nawaz and Meyer, 1992).

Differences in weights of lambs at different ages due to sex of lamb are in general agreement with other results published (Galal and Awgichew, 1981; Bennett et al., 1991a; Kleemann et al., 1991; Buvanendran et al., 1992).

The findings on the effects of type of birth-rearing on BWT, WWT, WT6, and YWT reported in this study are in complete agreement with results found by Galal and Awgichew (1981), Eltawil and Narendran (1990), Molina et al. (1991) and, Olthoff and Boylan (1991).

The significant effect of age of ewe at lambing on BWT, WWT and WT6 of their lambs in this research is in agreement with other results reported in the literature (Dickerson et al., 1975; Long et al., 1989; Boujenane et al., 1991; Buvanendran et al., 1992). In addition, similar results of the significant effect of AE on YWT found in this study were described by Price et al. (1962), Dickerson and Laster (1975), and Alwari et al. (1982).

Further discussion on the effects of those environmental factors on BWT, WWT, WT6, and YWT of Morada Nova lambs is presented in Chapter IV.

Correction Factors

Estimates of additive (AF) and multiplicative correction factors for sex (SL), type of birth-rearing (TB) and age of ewe (AE) in growth traits found in this study are the first figures reported in hair sheep.

Observing the results found here, they tend to show that TB represents the major contributor to define the value of those AF and MF adjustment factors, although SL and AE are also important factors. One of the possible explanations of the small to medium contribution of SL on these correction factors could be that male lambs did not receive appropriate nutritient requirements in the range conditions of Northeastern Brazil (NEB) to express their total growth potential and to increase the difference between them and ewe lambs at the same conditions at different ages, principally after weaning. In addition, the results seem to imply that the carry over significant effect of AE after weaning on lamb growth and consequently on the magnitude of AF and MF correction factors, it should be also a consequence of the range nutritional system those lambs were raised which did not give opportunity for lambs born to ewes of different age classes to minimize and(or) eliminate AE effect on their post-weaning performance.

Despite not having similar studies with hair sheep to estimate AF and MF for SL, TB and AE, it is possible to observe that the MF correction factors for SL*TB*AE in WWT found in this study are in general agreement and follow the same pattern of the figures recognized by the Sheep Industry Development Program (1987) in the USA.

Implications

Additive or multiplicative correction factors for sex of lamb, age of ewe and type of birth-rearing in growth traits should be considered and used by sheep breeders in NEB in selection programs to improve growth performance of hair sheep. However, more research needs to be conducted to define the possible differences and desirability between additive and multiplicative correction factors for these environmental factors in BWT, WWT, WT6,and YWT of hair sheep in the NEB conditions.

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APPENDIXES

APPENDIX A

MATE AND PARTURITION RATES, AND LITTER SIZE AT LAMBING OF MORADA NOVA EWES ANALYZED BY STATISTICAL MODEL 2

TABLE 49. ANALYSIS OF VARIANCE FOR MATE RATE (MAR), PARTURITION RATE (PAR) AND LITTER SIZE AT LAMBING (LSL) OF MORADA NOVA EWES USING EWE AS RANDOM EFFECT IN MODEL 2

SOURCE OF VARIATION	MAR[a] D.F.	MAR[a] M.SQ.	PAR[b] D.F.	PAR[b] M.SQ.	LSL[c] D.F.	LSL[c] M.SQ.
Dam Effect	808	.019838	807	.070658	805	.214462**
Year Effect	9	.459705**	9	1.273663**	9	.733692**
Age of Ewe	5	.057541*	5	.034956	5	.292916+
Weight of Ewe	1	.146958**	1	2.772239**	1	.328720
Error	1703	.021624	1642	.086312	1405	.140354

+P < .10
*P < .05
**P < .01

[a] $MAR = \frac{\text{No. of Ewes Mated}}{\text{No. of Ewes Exposed}}$

[b] $PAR = \frac{\text{No. of Ewes Lambing}}{\text{No. of Ewes Mated}}$

[c] $LSL = \frac{\text{No. of Lambs Born}}{\text{No. of Ewes Lambing}}$.

TABLE 50. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR MATE RATE (MAR), PARTURITION RATE (PAR) AND LITTER SIZE AT LAMBING (LSL) OF MORADA NOVA EWES BY MAJOR FACTORS BASED ON MODEL 2

FACTORS	MAR[a]		PAR[b]		LSL[c]	
	# Obs.	LSM ± SE	# Obs.	LSM ± SE	# Obs.	LSM ± SE
Overall	**2527**	**0.95 ± .00**	**2465**	**0.91 ± .01**	**2226**	**1.27 ± .01**
Year Effect (d/e)						
1980/1981	121	0.70 ± .07	94	0.96 ± .14	85	1.25 ± .20
1981/1982	203	0.91 ± .06	200	0.98 ± .11	194	1.46 ± .15
1982/1983	271	0.86 ± .04	246	0.94 ± .08	228	1.45 ± .11
1983/1984	302	0.97 ± .03	302	0.96 ± .05	283	1.31 ± .07
1984/1985	302	0.99 ± .01	302	0.88 ± .03	265	1.25 ± .04
1985/1986	309	1.00 ± .01	309	0.93 ± .03	292	1.30 ± .04
1986/1987	260	1.00 ± .03	260	0.68 ± .05	176	1.18 ± .07
1987/1988	313	1.00 ± .04	312	0.89 ± .08	286	1.27 ± .11
1988/1989	249	1.02 ± .05	245	0.94 ± .11	232	1.15 ± .15
1989/1990	197	1.02 ± .07	195	0.92 ± .14	185	1.08 ± .19
Age of Ewe						
1Y=01 to < 02 yrs.	684	0.96 ± .04	639	0.92 ± .08	577	1.07 ± .11
2Y=02 to < 03 yrs.	612	0.98 ± .03	603	0.91 ± .05	540	1.18 ± .07
3Y=03 to < 04 yrs.	501	0.97 ± .01	497	0.90 ± .02	448	1.28 ± .03
4Y=04 to < 05 yrs	348	0.95 ± .01	346	0.88 ± .02	312	1.30 ± .03
5Y=05 to < 06 yrs.	217	0.93 ± .02	217	0.91 ± .05	199	1.35 ± .07
6Y=06 yrs. and older	165	0.90 ± .05	163	0.91 ± .09	150	1.42 ± .13

[a]MAR = $\frac{\text{No. of Ewes Mated}}{\text{No. of Ewes Exposed}}$

[b]PAR = $\frac{\text{No. of Ewes Lambing}}{\text{No. of Ewes Mated}}$

[c]LSL = $\frac{\text{No. of Lambs Born}}{\text{No. of Ewes Lambing}}$

(d/e) = (Year of mating/Year of lambing)

APPENDIX B

STATISTICAL ANALYSES USING MODEL 6 TO ESTIMATE REPEATABILITIES OF REPRODUCTIVE TRAITS IN MORADA NOVA EWES

TABLE 51. ANALYSIS OF VARIANCE FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] USING EWE AS A RANDOM EFFECT BASED ON MODEL 6

SOURCES OF VARIATION	DEGREES OF FREEDOM	LWL MEAN SQUARES	LWW MEAN SQUARES
Dam Effect	628	0.336952*	29.392557**
Year of Lambing (YL)	6	1.262205**	307.297876**
Age of Ewe (AE)	5	0.948348**	71.147968**
Type of Parturition (TP)	1	184.956605**	476.403157**
Body Condition (BC)	2	0.077720	123.040384**
Coat Color	1	0.606994	0.912324
Interaction: YL * TP	6	1.020208**	36.605113*
Interaction: AE * TP	5	0.293862	28.568897
Interaction: AE * BC	10	0.194843	19.172777
Weight of Ewe Lambing	1	1.808054*	127.815630**
Error	857	0.288977	16.944758

+P < .10

*P < .05

**P < .01

[a]LWL = Total Weight (kg) of Lamb Born/Ewe Lambing

[b]LWW = Total Weight (kg) of Lamb Weaned/Ewe Lambing

TABLE 52. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY MAJOR FACTORS BASED ON MODEL 6

FACTORS	No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Overall	**1523**	**3.29 ± .03**	**13.55 ± .30**
Year of Lambing (YL)			
1981	85	3.06 ± .30	16.79 ± 2.34
1982	194	3.44 ± .20	18.15 ± 1.56
1983	228	3.46 ± .11	14.95 ± 0.87
1984	283	3.31 ± .05	11.48 ± 0.43
1985	265	3.15 ± .11	9.75 ± 0.86
1986	292	3.28 ± .20	10.80 ± 1.54
1987	176	3.37 ± .30	12.90 ± 2.33
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	455	3.27 ± .25	11.02 ± 1.96
2Y = Two yrs. to < three yrs.	411	3.44 ± .16	13.04 ± 1.22
3Y = Three yrs. to < four yrs.	289	3.50 ± .08	14.72 ± 0.65
4Y = Four yrs. to < five yrs.	184	3.25 ± .08	14.16 ± 0.65
5Y = Five yrs. to < six yrs.	112	3.22 ± .16	13.01 ± 1.23
6Y = Older than six yrs.	72	3.08 ± .29	15.32 ± 2.20
Type of Parturitiom (TP)			
Single (SP)	1154	2.48 ± .04	12.23 ± .35
Twin (TP)	369	4.11 ± .05	14.86 ± .42
Body Condition (BC)			
Poor (PC)	179	3.27 ± .07	12.58 ± 0.55
Regular (RC)	866	3.29 ± .04	13.33 ± 0.35
Good (GC)	478	3.32 ± .05	14.73 ± 0.40
Coat Color			
Cream/Brown	1197	3.02 ± .19	13.21 ± 1.48
Dark Brown	326	3.57 ± .19	13.89 ± 1.49

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 53. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY THE INTERACTIONS: YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TP) AND AGE OF EWE VS TYPE OF PATURITION (AE*TP) USING MODEL 6

FACTORS		No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: YL * TP				
Year of Lambing	Type of Parturition			
1981	SP	74	2.41 ± .30	16.74 ± 2.31
1981	TP	11	3.71 ± .35	16.84 ± 2.66
1982	SP	131	2.44 ± .21	16.83 ± 1.61
1982	TP	63	4.43 ± .21	19.46 ± 1.64
1983	SP	152	2.52 ± .12	13.53 ± 0.94
1983	TP	76	4.39 ± .12	16.37 ± 0.96
1984	SP	212	2.57 ± .06	10.41 ± 0.47
1984	TP	71	4.05 ± .08	12.56 ± 0.66
1985	SP	211	2.37 ± .11	9.17 ± 0.87
1985	TP	54	3.92 ± .14	10.33 ± 1.05
1986	SP	228	2.45 ± .20	8.91 ± 1.53
1986	TP	64	4.11 ± .21	12.70 ± 1.64
1987	SP	146	2.57 ± .30	10.07 ± 2.28
1987	TP	30	4.16 ± .34	15.74 ± 2.59
Interaction: AE * TP				
Age of Ewe	Type of Parturition			
1Y	SP	389	2.45 ± .25	8.88 ± 1.95
1Y	TP	66	4.09 ± .27	13.17 ± 2.07
2Y	SP	319	2.70 ± .16	11.39 ± 1.23
2Y	TP	92	4.18 ± .17	14.70 ± 1.32
3Y	SP	204	2.65 ± .08	13.04 ± 0.67
3Y	TP	85	4.35 ± .10	16.41 ± 0.81
4Y	SP	122	2.46 ± .09	12.60 ± 0.69
4Y	TP	62	4.04 ± .11	15.72 ± 0.86
5Y	SP	77	2.33 ± .16	12.38 ± 1.28
5Y	TP	35	4.11 ± .18	13.65 ± 1.42
6Y	SP	43	2.28 ± .30	15.14 ± 2.34
6Y	TP	29	3.89 ± .29	15.51 ± 2.27

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 54. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY AGE OF EWE VS BODY CONDITION INTERACTION (AE*BC) USING MODEL 6

FACTORS		No. OBS.	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: AE * BC				
Age of Ewe	Body Condition			
1Y	PC	70	3.19 ± .28	9.55 ± 2.12
1Y	RC	281	3.35 ± .26	11.29 ± 1.98
1Y	GC	104	3.27 ± .26	12.23 ± 2.01
2Y	PC	56	3.48 ± .18	12.23 ± 1.40
2Y	RC	214	3.42 ± .16	13.26 ± 1.24
2Y	GC	141	3.43 ± .16	13.63 ± 1.28
3Y	PC	20	3.49 ± .16	15.25 ± 1.27
3Y	RC	171	3.41 ± .08	13.78 ± 0.63
3Y	GC	98	3.60 ± .09	15.14 ± 0.73
4Y	PC	15	3.24 ± .18	13.29 ± 1.37
4Y	RC	103	3.26 ± .08	14.24 ± 0.66
4Y	GC	66	3.25 ± .09	14.94 ± 0.74
5Y	PC	10	3.19 ± .23	10.43 ± 1.81
5Y	RC	52	3.21 ± .17	13.17 ± 1.30
5Y	GC	50	3.26 ± .17	15.44 ± 1.32
6Y	PC	8	3.01 ± .36	14.71 ± 2.73
6Y	RC	45	3.11 ± .28	14.25 ± 2.12
6Y	GC	19	3.12 ± .31	17.02 ± 2.40

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 55. ANALYSIS OF VARIANCE FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] USING EWE AS A RANDOM EFFECT BASED ON MODEL 6

SOURCES OF VARIATION	DEGREES OF FREEDOM	LSW MEAN SQUARES	LSR MEAN SQUARES
Dam Effect	628	0.211473**	0.124268**
Year of Lambing (YL)	6	0.635741**	0.178469*
Age of Ewe (AE)	5	0.456961*	0.297675**
Type of Parturition (TP)	1	13.865827**	3.079299**
Body Condition (BC)	2	1.032621**	0.505018**
Coat Color	1	0.002508	0.001812
Interaction: YL * TP	6	0.575577**	0.132739
Interaction: AE * TP	5	0.310640+	0.023354
Interaction: AE * BC	10	0.240750	0.082177
Weight of Ewe Lambing	1	0.882628*	0.548344**
Error	857	0.157490	0.081827

+P < .10
*P < .05
**P < .01
[a]LSW = Number of Lambs Weaned/Ewe Lambing
[b]LSR = (LSW/LSL[c])
[c]LSL = Number of Lambs Born/Ewe Lambing

TABLE 56. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b], BY MAJOR FACTORS BASED ON MODEL 6

FACTORS	No. EWES	LSW LSM ± SE	LSR LSM ± SE
Overall	**1523**	**1.21 ± .02**	**0.83 ± .02**
Year of Lambing (YL)			
1981	85	1.44 ± .22	1.02 ± .16
1982	194	1.47 ± .15	0.99 ± .11
1983	228	1.42 ± .08	0.95 ± .06
1984	283	1.15 ± .04	0.81 ± .03
1985	265	1.00 ± .08	0.70 ± .06
1986	292	1.03 ± .15	0.71 ± .11
1987	176	0.94 ± .22	0.66 ± .16
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	455	0.98 ± .19	0.67 ± .13
2Y = Two yrs. to < three yrs.	411	1.12 ± .12	0.79 ± .08
3Y = Three yrs. to < four yrs.	289	1.29 ± .06	0.89 ± .04
4Y = Four yrs. to < five yrs.	184	1.26 ± .06	0.86 ± .04
5Y = Five yrs. to < six yrs.	112	1.17 ± .12	0.80 ± .08
6Y = Older than six yrs.	72	1.42 ± .21	0.99 ± .15
Type of Parturitiom (TP)			
Single (SP)	1154	0.98 ± .03	0.93 ± .02
Twin (TP)	369	1.43 ± .04	0.74 ± .03
Body Condition (BC)			
Poor (PC)	179	1.10 ± .05	0.75 ± .04
Regular (RC)	866	1.20 ± .03	0.85 ± .02
Good (GC)	478	1.32 ± .04	0.91 ± .03
Coat Color			
Cream/Brown	1197	1.23 ± .14	0.85 ± .10
Dark Brown	326	1.19 ± .14	0.82 ± .10

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL[c])

[c]LSL = No. of Lambs Born/Ewe Lambing

TABLE 57. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a], AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] BY THE INTERACTIONS: YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TP) AND AGE OF EWE VS TYPE OF PATURITION (AE*TP) USING MODEL 6

FACTORS		No. EWES	LSW LSM ± SE	LSR LSM ± SE
Interaction: YL * TP				
Year of Lambing	Type of Parturition			
1981	SP	74	1.33 ± .22	1.16 ± .16
1981	TP	11	1.54 ± .26	0.87 ± .18
1982	SP	131	1.18 ± .15	1.07 ± .11
1982	TP	63	1.77 ± .16	0.92 ± .11
1983	SP	152	1.11 ± .09	1.01 ± .06
1983	TP	76	1.73 ± .09	0.89 ± .07
1984	SP	212	1.00 ± .04	0.94 ± .03
1984	TP	71	1.31 ± .06	0.67 ± .04
1985	SP	211	0.86 ± .08	0.83 ± .06
1985	TP	54	1.14 ± .10	0.57 ± .07
1986	SP	228	0.78 ± .15	0.78 ± .11
1986	TP	64	1.28 ± .16	0.64 ± .11
1987	SP	146	0.63 ± .22	0.69 ± .12
1987	TP	30	1.25 ± .25	0.63 ± .18
Interaction: AE * TP				
Age of Ewe	Type of Parturition			
1Y	SP	389	0.70 ± .18	0.73 ± .06
1Y	TP	66	1.26 ± .20	0.52 ± .07
2Y	SP	319	0.88 ± .12	0.90 ± .08
2Y	TP	92	1.36 ± .13	0.65 ± .07
3Y	SP	204	1.00 ± .06	0.94 ± .09
3Y	TP	85	1.58 ± .08	0.65 ± .06
4Y	SP	122	1.00 ± .06	0.92 ± .09
4Y	TP	62	1.52 ± .08	0.57 ± .11
5Y	SP	77	0.99 ± .12	0.73 ± .14
5Y	TP	35	1.35 ± .14	0.53 ± .22
6Y	SP	43	1.32 ± .23	0.85 ± .07
6Y	TP	29	1.51 ± .22	0.58 ± .12

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL[c])

[c]LSL = No. of Lambs Born/Ewe Lambing

TABLE 58. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] BY AGE OF EWE VS BODY CONDITION INTERACTION (AE*BC) USING MODEL 6

FACTORS		No. OBS.	LSW LSM ± SE	LSR LSM ± SE
Interaction: AE * BC				
Age of Ewe	Body Condition			
1Y	PC	70	0.89 ± .20	0.56 ± .15
1Y	RC	281	1.03 ± .19	0.70 ± .14
1Y	GC	104	1.02 ± .19	0.75 ± .14
2Y	PC	56	1.06 ± .13	0.74 ± .10
2Y	RC	214	1.14 ± .12	0.81 ± .08
2Y	GC	141	1.16 ± .12	0.83 ± .09
3Y	PC	20	1.31 ± .12	0.90 ± .09
3Y	RC	171	1.22 ± .06	0.84 ± .04
3Y	GC	98	1.35 ± .07	0.93 ± .05
4Y	PC	15	1.16 ± .13	0.77 ± .09
4Y	RC	103	1.30 ± .06	0.89 ± .04
4Y	GC	66	1.32 ± .07	0.92 ± .05
5Y	PC	10	0.89 ± .17	0.58 ± .12
5Y	RC	52	1.18 ± .12	0.85 ± .09
5Y	GC	50	1.44 ± .13	0.98 ± .09
6Y	PC	8	1.32 ± .26	0.95 ± .19
6Y	RC	45	1.33 ± .20	0.98 ± .15
6Y	GC	19	1.61 ± .23	1.03 ± .16

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL[c])

[c]LSL = No. of Lambs Born/Ewe Lambing

APPENDIX C

ANALYSIS OF REPRODUCTIVE PERFORMANCE IN MORADA NOVA SHEEP CONSIDERING THE STATISTICAL MODEL 7

TABLE 59. ANALYSIS OF VARIANCE FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] USING SIRE OF DAM AS A RANDOM EFFECT BASED ON MODEL 7

SOURCES OF VARIATION	DEGREES OF FREEDOM	LWL MEAN SQUARES	LWW MEAN SQUARES
Sire Effect	59	0.267133	25.368951
Year of Lambing (YL)	7	2.342905**	183.697934**
Age of Ewe (AE)	5	2.147155**	20.216297
Type of Parturition (TP)	1	222.415895**	653.748224**
Interaction: YL * TP	7	0.472466+	149.362386**
Interaction: AE * TP	5	0.434002	56.936184*
Weight of Ewe at Lambing	1	14.995942**	989.593548**
Error	1390	0.248381	20.891117

+P < .10

*P < .05

**P < .01

[a]LWL = Total Weight (kg) of Lamb Born/Ewe Lambing

[b]LWW = Total Weight (kg) of Lamb Weaned/Ewe Lambing

TABLE 60. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY MAJOR FACTORS BASED ON MODEL 7

FACTORS	No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Overall	**1476**	**3.08±.03**	**11.96±.02**
Year of Lambing (YL)			
1983	67	3.34±.12	11.89±1.12
1984	134	3.15±.09	8.93±.087
1985	178	2.76±.07	9.17±0.65
1986	245	2.95±.05	11.88±0.46
1987	165	2.88±.06	14.71±.055
1988	273	3.12±.05	12.43±.052
1989	229	3.16±.08	13.23±0.70
1990	185	3.24±.10	13.48±.089
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	469	2.97±.07	12.54±0.66
2Y = Two yrs. to < three yrs.	387	3.25±.05	12.91±0.50
3Y = Three yrs. to < four yrs.	278	3.21±.04	12.27±0.41
4Y = Four yrs. to < five yrs.	177	3.11±.05	11.56±0.51
5Y = Five yrs. to < six yrs.	103	3.05±.07	11.77±0.68
6Y = Six yrs and older	62	2.86±.11	10.74±1.02
Type of Parturitiom (TP)			
Single (SP)	1211	2.33±.02	10.69±0.25
Twin (TP)	265	3.82±.05	13.24±0.44

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 61. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY THE INTERACTIONS: YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TP) AND AGE OF EWE VS TYPE OF PATURITION (AE*TP) USING MODEL 7

FACTORS		No. OBS.	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: YL * TP				
Year of Lambing	Type of Parturition			
1983	SP	53	2.39±.11	11.67±1.04
1983	TP	14	4.28±.18	12.12±1.65
1984	SP	116	2.37±.08	10.23±0.75
1984	TP	18	3.92±.15	7.62±1.34
1985	SP	153	2.13±.06	8.98±0.54
1985	TP	25	3.39±.12	9.36±1.07
1986	SP	196	2.19±.05	10.26±0.43
1986	TP	49	3.72±.08	13.50±0.77
1987	SP	136	2.22±.05	11.41±0.48
1987	TP	29	3.54±.10	18.01±0.93
1988	SP	209	2.42±.05	10.70±0.50
1988	TP	64	3.82±.08	14.15±0.73
1989	SP	189	2.41±.07	10.43±0.64
1989	TP	40	3.92±.10	16.03±0.97
1990	SP	159	2.53±.09	11.82±0.82
1990	TP	26	3.95±.13	15.13±1.21
Interaction: AE * TP				
Age of Ewe	Type of Parturition			
1Y	SP	410	2.32±.06	10.22±0.60
1Y	TP	59	3.62±.09	14.87±0.87
2Y	SP	323	2.46±.05	10.83±0.46
2Y	TP	64	4.05±.08	14.99±0.72
3Y	SP	207	2.43±.04	11.09±0.40
3Y	TP	71	3.99±.07	13.44±0.66
4Y	SP	141	2.33±.05	11.11±0.46
4Y	TP	36	3.90±.09	12.01±0.87
5Y	SP	79	2.28±.07	10.82±0.65
5Y	TP	24	3.82±.12	12.71±1.09
6Y	SP	51	2.17±.10	10.06±0.93
6Y	TP	11	3.54±.17	11.42±1.59

[a]LWL = Total Weight of Lamb Born/Ewe Lambing

[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 62. ANALYSIS OF VARIANCE FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] USING SIRE OF DAM AS A RANDOM EFFECT BASED ON MODEL 7

SOURCES OF VARIATION	DEGREES OF FREEDOM	LSW MEAN SQUARES	LSR MEAN SQUARES
Sire Effect	59	0.194294+	0.124908
Year of Lambing (YL)	7	0.940927**	0.280777**
Age of Ewe (AE)	5	0.255332	0.097632
Type of Parturition (TP)	1	18.502516**	5.358957**
Interaction: YL * TP	7	1.485785**	0.398552**
Interaction: AE * TP	5	0.404034*	0.097429
Weight of Ewe at Lambing	1	3.019720**	2.125043**
Error	1390	0.155475	0.103597

+P < .10

*P < .05

**P < .01

[a]LSW = Number of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL)

TABLE 63. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR) BY MAJOR FACTORS BASED ON MODEL 7

FACTORS	No. EWES	LSW LSM ± SE	LSR LMS ± SE
Overall	**1476**	**1.11±.02**	**0.76±.02**
Year of Lambing (YL)			
1983	67	1.13±.10	0.76±.08
1984	134	0.91±.08	0.67±.06
1985	178	0.92±.06	0.65±.05
1986	245	1.18±.04	0.80±.03
1987	165	1.18±.05	0.79±.04
1988	273	1.11±.04	0.76±.04
1989	229	1.28±.06	0.88±.05
1990	185	1.15±.08	0.81±.06
Age of Ewe (AE)			
1Y = One yr. to < two yrs.	469	1.18±.06	0.82±.05
2Y = Two yrs. to < three yrs.	387	1.19±.04	0.82±.04
3Y = Three yrs. to < four yrs.	278	1.14±.04	0.79±.03
4Y = Four yrs. to < five yrs.	177	1.02±.04	0.72±.04
5Y = Five yrs. to < six yrs.	103	1.09±.06	0.74±.05
6Y = Six yrs. and older	62	1.03±.09	0.70±.07
Type of Parturitiom (TP)			
Single (SP)	1211	0.89±.02	0.88±.02
Twin (TP)	265	1.32±.04	0.65±.03

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

TABLE 64. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE AS EWE TRAIT (LSR)[b] BY THE INTERACTIONS: YEAR OF LAMBING VS TYPE OF PARTURITION (YL*TP) AND AGE OF EWE VS TYPE OF PATURITION (AE*TP) USING MODEL 7

FACTORS		No. OBS.	LSW LSM ± SE	LSR LSM ± SE
Interaction: YL * TP				
Year of Lambing	Type of Parturition			
1983	SP	53	0.96±.09	0.92±.07
1983	TP	14	1.31±.14	0.60±.12
1984	SP	116	0.99±.06	0.94±.05
1984	TP	18	0.84±.12	0.40±.09
1985	SP	153	0.83±.05	0.80±.04
1985	TP	25	1.02±.09	0.50±.08
1986	SP	196	0.90±.04	0.87±.03
1986	TP	49	1.46±.07	0.73±.05
1987	SP	136	0.81±.04	0.80±.03
1987	TP	29	1.56±.08	0.77±.07
1988	SP	209	0.86±.04	0.87±.04
1988	TP	64	1.36±.06	0.66±.05
1989	SP	189	0.92±.06	0.93±.05
1989	TP	40	1.64±.08	0.82±.07
1990	SP	159	0.89±.07	0.91±.06
1990	TP	26	1.41±.10	0.70±.08
Interaction: AE * TP				
Age of Ewe	Type of Parturition			
1Y	SP	410	0.90±.05	0.90±.04
1Y	TP	59	1.47±.07	0.74±.06
2Y	SP	323	0.91±.04	0.92±.03
2Y	TP	64	1.47±.06	0.74±.05
3Y	SP	207	0.90±.03	0.90±.03
3Y	TP	71	1.37±.06	0.68±.05
4Y	SP	141	0.90±.04	0.89±.03
4Y	TP	36	1.15±.07	0.55±.06
5Y	SP	79	0.88±.06	0.85±.05
5Y	TP	24	1.30±.09	0.63±.08
6Y	SP	51	0.87±.08	0.83±.07
6Y	TP	11	1.18±.14	0.57±.11

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSL/LSW)

APPENDIX D

ANALYSIS OF MORADA NOVA EWE PRODUCTIVITY TRAITS UNDER MODEL 8

TABLE 65. ANALYSIS OF VARIANCE FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] USING EWE AS A RANDOM EFFECT BASED ON MODEL 8

SOURCES OF VARIATION	DEGREES OF FREEDOM	LWL MEAN SQUARES	LWW MEAN SQUARES
Dam Effect	805	0.337169**	28.851567**
Year of Lambing (YL)	9	1.567690**	269.796917**
Age of Ewe (AE)	5	1.758897**	40.744806+
Type of Parturition (TP)	1	365.727901**	2084.186875**
Interaction: YL * TP	9	0.650821**	73.436097**
Interaction: AE * TP	5	0.117980	24.764889
Weight of Ewe Lambing	1	5.697228**	805.073909**
Error	1390	0.259184	18.640504

+P < .10

**P < .01

[a]LWL = Total Weight (kg) of Lamb Born/Ewe Lambing

[b]LWW = Total Weight (kg) of Lamb Weaned/Ewe Lambing

TABLE 66. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY MAJOR EFFECTS BASED ON MODEL 8

FACTORS	No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Overall	**2226**	**3.22 ± .02**	**12.92 ± .18**
Year of Lambing (YL)			
1981	85	3.24 ± .28	13.98 ± 2.35
1982	194	3.53 ± .21	15.77 ± 1.77
1983	228	3.47 ± .15	12.96 ± 1.27
1984	283	3.28 ± .10	10.87 ± 0.81
1985	265	3.04 ± .06	10.13 ± 0.50
1986	292	3.09 ± .05	11.92 ± 0.50
1987	176	3.06 ± .11	15.36 ± 0.93
1988	286	3.17 ± .15	12.50 ± 1.27
1989	232	3.15 ± .20	12.52 ± 1.73
1990	185	3.19 ± .27	13.17 ± 2.27
Age of Ewe (AE)			
1Y= One yr. to < two yrs.	577	3.04 ± .16	12.93 ± 1.32
2Y= Two yrs. to < three yrs.	540	3.28 ± .10	13.78 ± 0.83
3Y= Three yrs. to < four yrs.	448	3.33 ± .05	13.53 ± 0.41
4Y= Four yrs. to < five yrs.	312	3.25 ± .05	13.16 ± 0.40
5Y= Five yrs. to < six yrs.	199	3.26 ± .09	12.27 ± 0.80
6Y= Older than six yrs.	150	3.17 ± .18	11.85 ± 1.49
Type of Parturitiom (TP)			
Single (SP)	1719	2.42 ± .02	11.00 ± .21
Twin (TP)	507	4.03 ± .03	14.84 ± .29
Interaction : TP * AE			
SP * 1Y	503	2.28 ± .15	10.40 ± 1.30
TP * 1Y	74	3.80 ± .17	15.45 ± 1.45
SP * 2Y	424	2.49 ± .10	11.45 ± 0.83
TP * 2Y	116	4.07 ± .11	16.11 ± 0.94
SP * 3Y	320	2.51 ± .05	11.55 ± 0.43
TP * 3Y	128	4.16 ± .07	15.52 ± 0.57
SP * 4Y	226	2.45 ± .05	11.20 ± 0.42
TP * 4Y	86	4.06 ± .07	15.12 ± 0.61
SP * 5Y	144	2.42 ± .10	10.77 ± 0.82
TP * 5Y	55	4.10 ± .12	13.77 ± 0.98
SP * 6Y	102	2.37 ± .18	10.62 ± 1.54
TP * 6Y	48	3.97 ± .19	13.07 ± 1.59

[a]LWL = Total Weight of Lamb Born/Ewe Lambing
[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 67. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER WEIGHT AT LAMBING (LWL)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] BY THE INTERACTION YEAR OF LAMBING AND TYPE OF PARTURITION (YL*TP) USING MODEL 8

FACTORS		No. EWES	LWL (kg) LSM ± SE	LWW (kg) LSM ± SE
Interaction: YL*TP				
Year of Lambing	Type of Parturition			
1981	SP	74	2.59 ± .27	13.61 ± 2.29
1981	TP	11	3.90 ± .32	14.36 ± 2.70
1982	SP	131	2.56 ± .21	14.29 ± 1.80
1982	TP	63	4.51 ± .22	17.26 ± 1.85
1983	SP	152	2.55 ± .15	11.48 ± 1.31
1983	TP	76	4.40 ± .16	14.45 ± 1.35
1984	SP	212	2.53 ± .10	9.67 ± 0.84
1984	TP	71	4.03 ± .11	12.06 ± 0.95
1985	SP	211	2.26 ± .05	9.24 ± 0.47
1985	TP	54	3.82 ± .09	11.03 ± 0.80
1986	SP	228	2.27 ± .05	9.99 ± 0.47
1986	TP	64	3.91 ± .08	13.85 ± 0.69
1987	SP	146	2.26 ± .10	11.03 ± 0.86
1987	TP	30	3.86 ± .15	19.69 ± 1.27
1988	SP	216	2.40 ± .15	10.08 ± 1.27
1988	TP	70	3.94 ± .16	14.92 ± 1.38
1989	SP	190	2.36 ± .21	9.82 ± 1.75
1989	TP	42	3.94 ± .22	15.21 ± 1.83
1990	SP	159	2.41 ± .26	10.77 ± 2.23
1990	TP	26	3.97 ± .29	15.58 ± 2.45

[a]LWL = Total Weight of Lamb Born/Ewe Lambing
[b]LWW = Total Weight of Lamb Weaned/Ewe Lambing

TABLE 68. ANALYSIS OF VARIANCE FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] USING EWE AS A RANDOM EFFECT BASED ON MODEL 8

SOURCES OF VARIATION	DEGREES OF FREEDOM	LSW MEAN SQUARES	LSR MEAN SQUARES
Dam Effect	805	0.207757**	0.123254**
Year of Lambing (YL)	9	0.431659**	0.103609
Age of Ewe (AE)	5	0.138337	0.070687
Type of Parturition (TP)	1	42.572240**	3.789649**
Interaction: YL * TP	9	0.586393**	0.163762*
Interaction: AE * TP	5	0.229658	0.084579
Weight of Ewe Lambing	1	4.871910**	3.299849**
Error	1390	0.155306	0.085906

+P < .10

**P < .01

[a]LSW = Number of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL)

TABLE 69. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] BY MAJOR EFFECTS BASED ON MODEL 8

FACTORS	No. EWES	LSW LSM ± SE	LSR LSM ± SE
Overall	**2226**	**1.16 ± .02**	**0.79 ± .01**
Year of Lambing (YL)			
1981	85	1.15 ± .21	0.74±.16
1982	194	1.24 ± .16	0.78±.12
1983	228	1.24 ± .12	0.79±.09
1984	283	1.11 ± .07	0.76±.05
1985	265	1.06 ± .04	0.74±.03
1986	292	1.17 ± .04	0.80±.03
1987	176	1.22 ± .08	0.83±.06
1988	286	1.10 ± .12	0.78±.09
1989	232	1.22 ± .16	0.87±.12
1990	185	1.10 ± .21	0.82±.15
Age of Ewe (AE)			
1Y= One yr. to < two yrs.	577	1.20 ± .12	0.86±.09
2Y= Two yrs. to < three yrs.	540	1.22 ± .08	0.85±.06
3Y= Three yrs. to < four yrs.	448	1.21 ± .04	0.84±.03
4Y= Four yrs. to < five yrs.	312	1.16 ± .04	0.79±.03
5Y= Five yrs. to < six yrs.	199	1.10 ± .07	0.73±.05
6Y= Older than six yrs.	150	1.08 ± .14	0.69±.10
Type of Parturitiom (TP)			
Single (SP)	1719	0.89 ± .02	0.87±.01
Twin (TP)	507	1.44 ± .03	0.71±.02
Interaction : TP * AE			
SP * 1Y	503	0.89 ± .12	0.91±.09
TP * 1Y	74	1.50 ± .13	0.81±.10
SP * 2Y	424	0.92 ± .08	0.93±.06
TP * 2Y	116	1.51 ± .09	0.77±.06
SP * 3Y	320	0.90 ± .04	0.90±.03
TP * 3Y	128	1.53 ± .05	0.77±.04
SP * 4Y	226	0.88 ± .04	0.87±.03
TP * 4Y	86	1.44 ± .06	0.71±.04
SP * 5Y	144	0.84 ± .08	0.80±.06
TP * 5Y	55	1.37 ± .09	0.65±.07
SP * 6Y	102	0.89 ± .14	0.82±.10
TP * 6Y	48	1.27 ± .14	0.55±.11

[a]LSW = No. of Lambs Weaned/Ewe Lambing
[b]LSR = (LSW/LSL)

TABLE 70. LEAST-SQUARES MEANS ± STANDARD ERRORS (LSM ± SE) FOR LITTER SIZE AT WEANING (LSW)[a] AND LAMB SURVIVAL RATE UP TO WEANING AS EWE TRAIT (LSR)[b] BY THE INTERACTION YEAR OF LAMBING AND TYPE OF PARTURITION (YL*TP) USING MODEL 8

FACTORS		No. EWES	LSW LSM ± SE	LSR LSM ± SE
Interaction: YB*TP				
Year of Lambing	Type of Parturition			
1981	SP	74	1.01 ± .21	0.90±.16
1981	TP	11	1.29 ± .25	0.57±.18
1982	SP	131	0.93 ± .16	0.86±.12
1982	TP	63	1.55 ± .17	0.70±.13
1983	SP	152	0.93 ± .12	0.87±.09
1983	TP	76	1.56 ± .12	0.71±.09
1984	SP	212	0.94 ± .08	0.90±.06
1984	TP	71	1.29 ± .09	0.62±.06
1985	SP	211	0.89 ± .04	0.85±.03
1985	TP	54	1.24 ± .07	0.63±.05
1986	SP	228	0.90 ± .04	0.88±.03
1986	TP	64	1.43 ± .06	0.72±.05
1987	SP	146	0.78 ± .08	0.80±.06
1987	TP	30	1.67 ± .12	0.86±.09
1988	SP	216	0.82 ± .12	0.86±.09
1988	TP	70	1.38 ± .13	0.71±.09
1989	SP	190	0.88 ± .16	0.94±.12
1989	TP	42	1.56 ± .17	0.81±.12
1990	SP	159	0.79 ± .20	0.88±.15
1990	TP	26	1.40 ± .22	0.76±.17

[a]LSW = No. of Lambs Weaned/Ewe Lambing

[b]LSR = (LSW/LSL[c])

[c]LSL = No. of Lambs Born/Ewe Lambing

APPENDIX E

HERITABILITY AND REPEATABILITY ESTIMATES OF REPRODUCTIVE TRAITS IN MORADA NOVA SHEEP

TABLE 71. NUMBER OF SIRES USED, K_h VALUES, HERITABILITIES (h^2), NUMBER OF EWES USED, K_r VALUES, AND REPEATABILITIES FOR REPRODUCTION TRAITS OF MORADA NOVA EWES WITHOUT CONSIDERING EWE BODY CONDITION SCORE IN THE MODEL

TRAITS	No. SIRES	K_h[a]	$h^2 \pm$ se	No. EWES	K_r[b]	r ± se
LSL[c]	60	23.2	.02 ± .03	806	2.7	.16 ± .02
LWL[d]	60	23.2	.01 ± .03	806	2.7	.10 ± .02
LWW[e]	60	23.2	.04 ± .04	806	2.7	.17 ± .03
LSW[f]	60	23.2	.04 ± .04	806	2.7	.11 ± .02
LSR[g]	60	23.2	.04 ± .04	806	2.7	.14 ± .03

[a]K_h = Average Number of Offspring per Sire

[b]K_r = Average Number of Repeated Records per Ewe

[c]LSL = Litter Size at Lambing

[d]LWL = Litter Weight at Lambing

[e]LWW = Litter Weight at Weaning

[f]LSW = Litter Size at Weaning

[g]LSR = Lamb Survival Rate as Ewe Trait

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