ESTIMATION OF REPRODUCTIVE, PRODUCTION, AND PROGENY GROWTH DIFFERENCES AMONG F_1 BOER-SPANISH AND SPANISH FEMALES

A Thesis

by

JEFFREY ANDREW RHONE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Animal Breeding

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ABSTRACT

Estimation of Reproductive, Production, and Progeny Growth Differences among F_1 Boer-Spanish and Spanish Females. (May 2005)

Jeffrey Andrew Rhone, B.S., Texas Tech Univeristy

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Dr. Dan Waldron

The study was performed in the Edwards Plateau region of West Texas from the years of 1994 through 2004 and involved data collected on 291 F_1 Boer-Spanish and Spanish does and their 1,941 kids. Differences were estimated between dam types for growth traits, fertility traits, prolificacy, kid growth traits, survivability, longevity, and progeny growth. The mixed model analysis of variance procedure was used for all traits, except doe survivability where chi-square analysis was used.

The F_1 Boer-Spanish does were significantly heavier at birth than Spanish does, but there was no significant difference between the F_1 Boer-Spanish and Spanish does for weaning weight. The F_1 Boer-Spanish does had a significantly heavier body weight at breeding than the Spanish does (46 vs. 43 kg). No significant differences were found between breed types for fertility traits. Age of doe was a significant source of variation for fertility. There was no significant difference between the two doe breed types for number of kids born or number of kids weaned. Age of doe significantly affected both number of kids born and number of kids weaned. There was no significant difference

between breed for total litter weight at weaning. For kid birth weight there was no significant difference between dam breed types. Kid weaning weight and pre-weaning average daily gain were not significantly different between dam breed types. Age at time of leaving the herd for all causes was 6.15 years for F_1 Boer-Spanish does and 5.56 years for Spanish does ($P = 0.06$). There was no significant difference between breeds for proportions of does leaving the herd for the three main reasons.

Although F_1 Boer-Spanish does were significantly heavier for birth weight and body weight at breeding, there were no significant differences for weaning weights, reproduction, production, and progeny growth differences at weaning between F_1 Boer-Spanish and Spanish does. When kid production was measured at weaning there was no difference between breeds. However the greater body weight of the F_1 Boer-Spanish does at breeding suggests that if kid production was measured at a later endpoint, a significant difference may be realized.

DEDICATION

I dedicate this project and paper to my late mother, Theresa Louise Rhone, a very strong and Godly woman who instilled in me the values that make up the person I am today.

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Most of all I would like to thank my Father in heaven and my Lord and Savoir Jesus Christ who has given me the strength, wisdom, and ability to accomplish this task. To Him I give all the honor and glory for He is worthy of my praise.

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I would also like to thank Dr. Jim Sanders, whom I have a great deal of respect for and consider being a great leader in the animal breeding field. It is clearly seen that you have a great deal of care for your students and I appreciate the time you have taken to invest in my life. I would also like to thank Dr. Jeff Hart for his willingness to serve on my committee and for his part in helping me learn the concepts of statistics.

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INTRODUCTION

Goats are a very valuable and important livestock species used for meat production around the world. With goat meat being the most consumed meat in the world, and goats being among the oldest domesticated animals, the goat continues to be valued as a meat producing livestock species (Penn State, 2000). In the United States goat meat is still gaining acceptance and popularity among consumers. However, as immigration continues to rise and the culture of the United States becomes more diverse, the demand and consumption of goat meat will most likely increase.

With the introduction of South African Boer in the 1990s, and the continued use of several established breeds, U.S. meat goat producers have a choice of breeds to select from in order to maximize profits in their production systems. Crossbreeding in goats has allowed an opportunity for goat producers to blend desirable traits of individual breeds to improve production efficiency and use them towards producing an animal that has the ability to increase profits for producers. Using different crosses in order to improve growth and carcass traits in progeny is only one way crossbreeding can be beneficial. Producers in the industry should also look at how crossbreeding can improve the reproductive efficiency, prolificacy, and longevity of production in females through the utilization of heterosis and breed differences.

This thesis follows the style and format of *The Journal of Animal Science.*

With a large portion of research projects focusing on either progeny performance or female reproduction, researching both aspects in a single crossbreeding trial could prove to be valuable for goat producers. Although the Boer and Spanish goats are both classified as meat goat types, they are two distinctly different types of goats. Since the introduction of the Boer goat, no other breed has stimulated the level of interest concerning its potential influence on the U.S. meat goat industry. Additionally, with the Spanish goat being one of the primary meat goats in the United States that is known for its hardiness and adaptability to many different environments, there is just as much interest in knowing how breeders can improve Spanish goats through crossbreeding. This research project aims to study two genetic types of does in regard to overall productivity, in the western part of Texas.

Three objectives were outlined for this study. The first objective was to estimate the differences between F_1 Boer-Spanish and Spanish does for birth and growth rates, fertility, prolificacy (number of kids born), total litter weight at birth, number of kids weaned, and total litter weight at weaning. The second objective was to estimate differences between kids of F_1 Boer-Spanish and Spanish dams for birth weight, weaning weight, and pre-weaning gain. Finally, the third objective was to predict the difference between F_1 Boer-Spanish and Spanish dams for longevity and survivability.

LITERATURE REVIEW

History and background of the U.S. goat industry

The goat industry has developed in many different ways over the past few decades. With the phase out of the wool and mohair incentive act beginning in 1993 and finally ending in 1995, Angora goat producers liquidated 80 percent of their goat herds in the 1990's in response to declining revenues as a direct result of policy changes and other influences such as drought and foreign economics (Anderson, 2001). Nonetheless, in the midst of a troubling mohair and wool market, goat meat production and consumption has steadily increased over the past several years. Current statistics show that there are approximately 2.5 million goats in the U.S., of which 2.1 million are breeding goats and the remaining 0.4 million market goats (USDA, 2005). From 1991 to 2001 the goat slaughter rate at United States inspected facilities rose from 207,893 goats to 560,300 goats (Stanton, 2003). In addition imports from Australia rose from approximately 1.4 million kilograms in 1990 to 5.7 million kilograms in 2001 (Stanton, 2003). With estimates showing the total goat market in the United States growing at a rate of 10 to 15 percent annually, there is a great opportunity for goat producers to take advantage of the meat goat market in the United States. With the rise in U.S. meat goat consumption, other meat goat breeds such as the Boer goat have sparked a new interest in meat goat production throughout the country. It is understood from most South African literature that Boer goats have high growth rates, large frame size and substantial amounts of muscling that could prove very valuable for producers wanting to improve in overall meat goat production (Shelton, 1986; Erasmus, 2000). However, in the midst of the interest in Boer goats for improving meat goat genetics is a lack of comparative data concerning the crossbreeding of Boer goats with other meat goat breeds in the United States. As a result, research considered in this paper will include research work done in the United States as well as in the international community.

History and background of Boer and Spanish goats. Boer and Spanish goats are two different and distinct types of meat goats that have been selected and developed in different ways over the course of history. The origin of the Boer goat is not exactly known, although researchers say that the Boer goat was probably rooted in ancestors kept by migrating tribes in Africa (Casey and Van Niekerk, 1988). The most commonly kept goat in rural areas of South Africa is the unimproved "Boer" goat, where Boer means "farm" in Dutch (Casey and Van Niekerk, 1988). These unimproved Boer goats are typical of the kind of goats found in many parts of Africa and Asia, being long-legged lean type goats with a mixed array of color patterns. One unique characteristic of Boer goat breeding history is that the breed was not created from two or more purebred breeds, but was established from selecting from all the existing types of goats in South Africa, with the end result being the improved Boer goat that we see today (Malan, 2000). The original work in the development of the "improved" Boer goat was first initiated by a group of farmers in the Eastern Cape region of South Africa (Malan, 2000). These farmers began to breed for more distinct characteristics using the unimproved

Boer goats of the region, and eventually these goats evolved into the compact, well proportioned, short haired goat that exists today (Casey and Van Niekerk, 1988).

The history of the Spanish goat is somewhat different from that of the Boer goat. Spanish type goats were originally brought to America by Spanish explorers. History shows that over a period of time these goats either escaped or were released when other sources of meat were discovered, and as a result these goats roamed wild and became a type of "feral" goat for a period of over 400 years before any kind of re-domestication of them took place (Yoakum and Waldron, 1996). Today, the Spanish goat refers to goats produced in the Southwestern U.S., mainly in south and southwestern areas of Texas (Shelton, 1978). Over the past several decades some producers have practiced selection for size, conformation, and occasionally color for Spanish goats, but most Spanish goats have developed through the process of natural selection (Shelton, 1978). Although Spanish goats are highly variable in appearance and performance, producers have used these goats not only for brush control, but also for the purpose of meat production (Shelton, 1978).

Spanish and Boer goat traits

The majority of Spanish goats used in meat goat production are located in the Southwestern part of the United States. Therefore most of the research evaluated will come from research trials performed in Southern U.S. states such as Texas. The Spanish goat is a breed that is known for its hardiness and ability to adapt to challenging environments as well as its meat production ability. In many areas the Spanish goat is used as a dual purpose animal in that they are not only used for meat production, but also for the purposes of brush control. Although not nearly as heavily muscled or large as the Boer goat (Blackburn, 1995), the Spanish goat has many other positive characteristics such as hardiness, moderate frame size and muscling, and the ability to adapt to harsher environments that should prove to be beneficial when using Spanish goats in a crossbreeding program (Coffey, 2002). The improved Boer goat is best known for its larger mature size coupled with its high degree of muscling that result in fast growth rates and higher yielding, heavier muscled carcasses (Erasmus, 2000). However, the Boer goat is also very fertile with females having the ability to stay in production for long periods of time (Greyling, 2000; Malan, 2000).

Reproductive traits. The Boer and Spanish goat are different in many reproductive traits. In the 1980's research trials were performed to evaluate the reproductive and growth performance of Spanish females and their progeny. In a trial involving over 650 Spanish does and 1,730 kids raised in the Edward's Plateau area of West Texas, Bogui (1986) reported that females managed in a 60-day fall breeding season, averaged 1.70 live kids/doe/year with 52% of kids born singles, 46% twins, and 1.9% triplets. In a similar experiment in West Texas, Lawson and Shelton (1982) reported that Spanish nannies averaged 1.32 kids born/ doe/year, which was noted as slightly below average for Spanish goats. Lawson and Shelton (1982) also reported that the Spanish females recorded over a 10 month period averaged a 1.57 ovulation rate. Finally, Lawson et al. (1984) reported Spanish does with a 1.87 kids/doe/year average.

It is important to note that the Lawson et al. (1984) publication may have higher results due to a sucking manipulation response on does in the project. Nonetheless, it is reasonable to conclude litter sizes among the three different trials have shown Spanish does averaging approximately 1.6 kids/doe/year, with the ability to reach 1.8 kids/doe/year.

Casey and Van Niekerk (1988) reported mean litter sizes for Boer females of 1.93 kids per parturition. Greyling (2000) stated that Boers have a mean ovulation rate of 1.72 per estrous which is much higher than other known African breeds such as the Malawain goat (1.68), Boer x Small East African Does (1.39), and the Angora (1.15-1.58). Greyling (2000) also stated that Boer goats are reported as averaging 24.5, 59.2, 15.3, and 1% for singles, twins, triplets, and quadruplets, respectively, per parturition. In another study involving 826 Boer does, ages 1.5 to 6.5 years, 7.6 % of the kids were born as singles, 56.5% as twins, and 33.2 % as triplets (Erasmus et al., 1985). Furthermore, in an additional trial Erasmus (2000) reported that Boer females averaged litters of 15.2% kids born as singles, 67.5% born as twins, and 16.3% born as triplets.

Although prolificacy is important and useful when looking at maternal ability of the doe, the number of kids weaned per doe is of more practical importance when measuring true reproductive efficiency. Bogui (1986) reported that the Spanish does averaged 4.10 kg and 24.74 kg for litter weight at birth and weaning. In addition, Lawson and Shelton (1982) showed that over a nine year period kid crop weaned averaged 1.16 kids/doe, which was noted as somewhat below expectations and may be below that of flocks given a higher level of management. Conversely, according to the

South African Department of Agriculture, Boer females on natural pasture with an annual rainfall of 295 cm, have averaged conception rates of 90%, kidding rates of 189% , fecundity (kids born/does kidded) of 210%, and weaning rate (kids weaned/does mated) at 149% over a twenty year period (Malan, 2000). In a similar report by Campbell (1984), 100 Boer females averaged weaning rates of 1.42 per doe/per year.

Growth traits. Traits such as birth weight and weaning weight are important when considering growth potential and muscle development in meat goats. Spanish and Boer goats differ substantially in many of these production traits. Birth weight of Boer kids typically range from 3 to 4 kg with male kids weighing approximately 0.5 kg heavier than females, while typical weaning weights range from 20 to 25 kg depending upon weaning times and methods (Lu and Potchoiba, 1988). Additionally, mature Boer goat weights average from 80-100 kg for does and 90-130 kg for bucks (Lu and Potchoiba, 1988). Spanish kid birth and weaning weights are somewhat lighter due mainly to smaller mature sizes. According to information from Bogui (1986), Spanish kids have an approximate 2.7 kg birth weight, and 17.8 kg weaning weight when weaned at 120 days. Another important trait to consider when analyzing a kid's growing potential is his/her ability to gain weight from birth to weaning. One point to consider is that daily weight gain averages have a substantial amount of variability due to differences in litter sizes and type of rearing. Information from trials involving Spanish kids have revealed daily gain averages of 132 g/day from birth to weaning, when weaning at 120 days (Bogui, 1986). Boer goats had higher daily gain with an average of

227 g/day kept under intensive conditions with free access to a high quality feed ration (Naudé and Hofmeyr, 1981 as cited by Van Niekerk and Casey, 1988). Results more comparable to Southwestern U.S. conditions were seen in Africa, which involved Boer goats managed under extensive conditions in sub-tropical grass-bush settings, showed average kid crop daily gain of 163 g/day from birth to weaning when weaned 100 days after birth (Aucamp and Venter, 1981 as cited by Van Niekerk and Casey, 1988).

Crossbreeding and heterosis

Crossbreeding can be defined as the mating of males to females of different breeds. The majority of commercial livestock producers use some aspect of crossbreeding and crossbreeding systems in their production systems. The main advantages in crossbreeding are an increase of performance due to hybrid vigor, the blending of traits resulting from breeds, and the potential to use specialized sire and dam types. In typical crossbreeding programs breeds are selected for their ability to complement each other in certain genotypic and phenotypic traits. For example, a dam breed may be selected that exhibits high merit for reproductive and maternal traits, while the sire breed may show superior genetics in muscling and growth traits. Environmental considerations can also play an important role in choosing different breeds for different environments. Breeds that are smaller in mature size and have lower nutritional requirements may blend well with moderate framed high growth trait breeds. Hybrid vigor or heterosis is the increased performance of crossbreds over that of the mean of their purebred counterparts.

Heterosis components and estimation. Heterosis can be classified in three different components, individual or direct, maternal, and paternal. The direct component of a trait is the effect of an individual's genes on its performance (Bourdon, 1997). The maternal component is the effect of genes in the dam of an individual that influence the performance of the individual through the environment provided by the dam (Bourdon, 1997). Although rare and usually not measured, the paternal component is much like the maternal component in that it is the effect of the genes in the sire of an individual that influence the performance of the individual through the environment provided by the sire (Bourdon, 1997). Much research has been performed on estimating hybrid vigor for different types of livestock species. Typical hybrid vigor estimates for traits in sheep can be found in Table 1, which shows the benefits of increased fertility and growth due to hybrid vigor. Although in this study hybrid vigor estimates are not measured, knowing to what extent hybrid vigor impacts certain traits is valuable when using crossbreeding.

Genotype × environment interaction considerations

Blackburn (1995) reported the results of a simulation study that was performed to compare the performance of Boer and Spanish Goats run on three different types of

Table 1. Typical individual (I), maternal (M), and paternal (P) hybrid vigor estimates for sheep (Bourdon, 1997)

Species	Trait	$\%HV^{I}$	$\%HV^{M}$	$\%HV^{P}$
Sheep	Conception rate (trait of ewe)	8.0	-	6.0
	Lambing rate (trait of ewe)	3.0	-	8.0
	Number born	3.0	8.0	-
	60-day weaning weight	5.0	9.0	-
	Lambs weaned / ewe exposed	8.0	17.0	6.0
	Mature ewe weight	5.0	-	-

nutritional forage conditions, high, medium, and low forage in two different environments and at two different geographical locations, West Texas and Oklahoma. Results from the Oklahoma location showed that when looking at yearling weights, Spanish goat performance did not vary and remained constant indicating that changes in forage conditions and year round breeding conditions had no impact on yearling weight (Blackburn, 1995). As nutritional resources were lowered, reproductive productivity for both breeds was lowered, but Spanish does were able to have higher levels of total births per doe under lower forage conditions (Blackburn, 1995). Results from the Texas location showed, at the low forage level, reproductive performance in Spanish females was expected to be 12% higher than that of Boer females (Blackburn, 1995). Predicted biological efficiency (total weight of kids and cull does sold divided by flock dry matter consumption) among the two breeds showed Boer does, at the Oklahoma location, under high forage conditions were .6% more efficient that Spanish does, but at the low forage level, Spanish does had a 21% advantage over that of Boers (Blackburn, 1995). Results of the Blackburn (1995) simulation study show a genotype × environment interaction between the two breeds. At the lowest forage and nutritional level, Boer females were predicted to be less productive, while Spanish have the ability to maintain better reproductive efficiency.

In a study primarily looking at how environmental conditions affected performance, several different goat breeds in Mexico managed under extensive range conditions were measured for factors that affect reproductive and production traits. Results from the study showed that does with a body condition score (BCS) of less than 1.5 (scale from 1-5) were three times less likely to kid, compared to goats with a higher BCS (Mellado et al., 2004). Furthermore, Mellado et al. (2004) reported that does with a BCS score of greater than 2.5 had less than half of the risk of having an abortion as compared with all other goats. Conclusions from Mellado et al. (2004) suggested that low BCS scores do not affect the ability of does to come into estrous and conceive, but rather after conception the low BCS scores increase the risk of abortions and as a result lower kidding rates.

Crossbreeding among different breeds of meat goats

There has been interest over the past several years concerning Boer goats and how their genetic potential could be used to impact the U.S. meat goat industry. Crossbreeding is a valuable tool that can be used by meat goat producers to improve production efficiency by taking advantage of genetic differences amongst breeds and using heterosis.

Crossbreeding in Boer and Spanish goats. In preliminary results from a study using Boer and Kiko does as dams bred to Spanish bucks in the humid subtropical southeastern part of the United States, Browning et al. (2004) reported Boer does as having an average litter size of 1.92 kids/doe, a litter birth weight of 6.05 kg, and an average kid birth weight of 3.21 kg, but not different ($P > 0.05$) than Kiko females with an average litter size of 1.82 kids/doe, litter birth weight of 5.9 kg, and an average kid birth weight of 3.29 kg. Further results indicated that pre-weaning growth rates and weaning weights were greater ($P < 0.05$) for F_1 Kiko-Spanish kids compared with 32 F_1 Boer-Spanish kids (Browning et al., 2004). Moreover, measurements for litter size, litter weight, and litter weight to doe weight ratio, respectively, was significantly greater for Kiko (1.85 kids/doe, 31.73 kg, 78.1%) than Boer dams (1.58 kids/doe, 26.48 kg, 63.9%) at weaning. Results from this study seem to show a possible lack of adaptation of the Boer goats to the local environment, which may be related to nutrition and the lack of adaptation to the humid environment in the southeastern U.S. (Browning et al., 2004).

In a trial involving two local goat breeds of China (Huai and Haimen) crossed with Boer bucks, Haimen-Boer F_1 does averaged 1.80 kids per litter, while Huai-Boer F_1 females averaged 2.10 kids per litter, which are both considerably lower than the Haimen and Huai purebred averages for litter size of 2.70 and 2.44 respectively (Yonghong et al. 2001). Additionally, Boer cross F_1 kids were much heaver at birth

(2.50 kg F_1 Boer-Haimen vs. 1.14 kg Haimen, and 2.75 F_1 Boer-Huai vs. 1.44 kg Huai) as compared to the purebred Huai and Haimen goats (Yonghong et al., 2001).

Progeny performance and growth traits are important considerations when using Spanish and Boer goats in a crossbreeding system. With the large mature size and heavy muscling of the Boer goat, one might conclude that, given the proper plane of nutrition, the Boer goat and its crosses may have the genetic potential to out grow and out gain other crossbred and purebred goats. Luo et al. (2000) reported that, in a study involving purebred Spanish, Spanish-Boer, and Boer-Angora kids fed milk replacer over a pre-weaning period, significant growth differences were seen between the three groups. Boer crosses were heavier than Spanish kids at 2, 6, and 8, weeks of age, with no body weight differences between the Boer crosses (Luo et al., 2000). Furthermore, from weeks 3 to 8, Boer crosses gained body weight more rapidly than the Spanish kids with a 60 g/day gain for Spanish kids, 71g/day for Boer-Angora, and 77 g/day for Boer-Spanish goat crosses (Luo et al., 2000). In a similar trial conducted in China using Boer goats to cross with Taihang Da Qing goats, the crossbred Boer-Qing kids grew faster and performed better than the Taihang Da Qing purebreds (Chunxiang et al, 2001). In this study Boer-Qing goats grew and developed faster before the age of 3 months than the Qing purebreds with a daily gain of 149 g/day compared to 130 g/day. Research studies with similar results as Luo et al. (2000) reflect that crossbreeding has the potential to improve the growth rate of kids and as a result have the potential to bring added economic benefits to goat producers.

Crossbreeding in other meat goat breeds. In addition to research specifically directed towards Boer and Spanish goats, there has also been a fair amount of research involving other meat goat breeds. As previously mentioned, increasing reproductive performance through the use of crossbreeding in meat goats could be economically beneficial to goat producers. Anous and Mourad (1993) reported a study comparing purebred Alpine and Rove does with Alpine × Rove crossbred does; no difference was found between crossbreds and purebreds on fertility, but crossbred females were significantly ($P < 0.01$) higher for number of kids born/fecund does as compared to the purebred does. Heterosis for prolificacy and fertility for the Alpine × Rove does was 24.2 and 4.2 percent, respectively (Anous and Mourad, 1993). Heterosis for growth traits in Alpine × Rove crossbred kids of this study also was significant ($P < 0.05$) with a 22.4% weight gain advantage for males and a 16.4% weight gain advantage for females between the ages of 30 and 90 days over that of the purebred kids (Anous and Mourad, 1993).

Longevity and survivability in goats

Measuring lifetime production. Lifetime production is an important measure of efficiency of all livestock species, and is a function of fertility, maternal ability, prolificacy, and the ability of females and their offspring to survive. Lasley (1978) stated that, in beef cattle, cows with a long productive lifetime will be genetically superior for traits such as longevity and reproductive performance. Iman and Slyter

(1996) also stated that, in sheep, lifetime production is a good tool for measuring the total production and efficiency of females. In a study involving cattle, Martinez et al. (2004) when evaluating lifetime production for Hereford cows, used number of calves born, number of calves weaned, and total weaning weight of calves by age of cow for ages 2 through 8. In a study involving sheep, Iman and Slyter (1996) used cumulative number of lambs born, number of lambs weaned, and total lamb weight for each ewe as a tool to evaluate individual lifetime production, and to compare differences amongst breeds. Another aspect of longevity in livestock is the influence of crossbreeding on longevity and total production. Riley et al. (2001), in a study evaluating the longevity and lifetime production of F_1 *Bos indicus* × Hereford cows, found that survival rates of F_1 cows to 14 years of age were from 43 to 80 percent. Furthermore, on average *Bos indicus* × *Bos taurus* F_1 cows had longer longevity than *Bos taurus* × *Bos taurus* F_1 cows, indicating that crossing more genetically diverse animals increases the longevity of production in females (Riley et al., 2001)

Survivability in goats. Most research studying survivability in goats has primarily been focused on the pre-weaning survivability of kids. Analyses of survivability usually involve classification of death to separated specific causes. For example, mortality can be identified as dam related, disease related, or environment related. In a study of kid pre-weaning survivability, Perez-Razo et al. (1998) reported kids weighing more than 3 kg at birth had a higher survival rate than those weighing 2 kg or less, and also that year and period of birth affected all survival rates. Kids born from October to January had a higher survival rate than those born from April to July

(Perez-Razo et al., 1998). Southey et al. (2004), when analyzing mortality in lambs, grouped cause of mortality into the four different groups of dam related, pneumonia, disease, and other. The authors reported that 3.7 percent of kids died due to a dam related cause, 2.1 percent due to disease, 4.3 percent due to pneumonia, and 4.5 percent due other causes.

Despite all the research performed on the survivability of kids, the amount of information on survivability of does is much more limited. Causes for the culling or mortality of does are similar to kids in regards to management and possibly disease, but further effort should be put forth in studying causes associated with doe survivability and longevity. Mastitis and bad udders are one problem that affect the longevity of does. Larsgard and Vaabenoe (1993) reported, in a study involving six different sheep breeds and including 920 ewes with 2364 records, overall mastitis in ewes was at a 6.8% level. Furthermore, according to udder scores given to ewes at lambing, ewes that had a bad udder conformation had a much higher incidence of mastitis. Another problem that affects goats is the disease Caseous Lymphadenitis. Caseous Lymphadenitis is a chronic, contagious disease of goats that is caused by the gram-positive bacterium *Corynebacterium pseudotuberculosis* (Gall, 1981). Natural infections from Caseous Lymphadenitis in goats, have been reported from the USA, India, Pakistan, Egypt, Venezuela and Sicily and has also been associated with 70% of the superficial abscesses in goats in the United States (Gall, 1981). Although there seems to be a higher incidence of the disease in older goats, there is no difference in the sex or breed distribution of the disease (Gall, 1981). Of the known causes of mortality or causes of does leaving the herd, mastitis/udder problems and Caseous Lymphadenitis seem to be common among meat goats in the United States.

Summary of literature review

With increased U.S. immigration and broadening of diets by Americans, the consumption of goat meat will most likely continue to steadily increase in the future. As a result, U.S. goat producers will have opportunities to take advantage of this growing market by improving and increasing production and efficiency in their operations. With the introduction and use of new meat goat types, such as the Boer goat, and the continued effort to genetically improve existing goat populations, goat breeders are increasingly having more breed choices from which to choose. Through the use of crossbreeding, goat breeders not only are able to able to take advantage of breed complementarity, but also the added performance in crossbreds over purebreds due to heterosis. Using genetically diverse animals in crossbreeding systems has been shown to increase growth traits, prolificacy, total production, and longevity in production females. Nonetheless, it is important to realize that, when utilizing crossbreeding, the possibility of having genotype × environment interactions may occur and, therefore, selection and how nutrition of the animal affects reproductive efficiency should be taken into account. Measurements, such as total lifetime production, are valuable for evaluating production operations and comparing individual performance levels. Knowing how to use this information, coupled with learning how diseases, such as mastitis, udders related problems, and Caseous Lymphadenitis affect the longevity of does, goat producers should be able to increase reproductive efficiency and overall productivity in their herds.

MATERIALS AND METHODS

The data for this study were collected from 1994 to 2004 on goats born at the Winters Ranch located in McCulloch County, Texas. In 1999, the goats were transferred to the Hill Ranch located in Edwards County, Texas. Records were taken from 291 (160 F_1 Boer-Spanish, 131 Spanish) does sired by 24 different Boer and Spanish bucks. These does were in turn bred to 39 Boer and Boer-cross sires, and produced 1,941 kids over the course of their production lifetime.

Experimental material

Geographical location. McCulloch County is located at 31° north latitude and 99° west longitude on the Edwards Plateau, in the central western part of Texas. McCulloch County has a range of elevation from 411 to 609 m above sea level and has rolling hill topography. Average temperatures range from a high of 35°C in July to a low of -1° C in January with an annual average rainfall of 63 cm per year. The growing season in McCulloch County is 226 days with typical vegetation in the region consisting of both warm and cool season grasses, live oak, and juniper. Located approximately 160 kilometers southwest of McCulloch County, Edwards County is at 29° north latitude and 100° west longitude on the southwestern part of the Edward's Plateau. The climate is considered a dry climate with average annual rainfall of 53 centimeters and temperatures that range from a low of 3° C in January and a high of 34° C in July. Edwards County has an altitude of 762 m above sea level and typically has a 250 day growing season. Common vegetation within the county consists of various grasses, yucca, cacti, juniper, shrub oaks, and lechugilla. Table 2 contains the total precipitation and mean temperature for the production years of the project.

Description of foundation females. The 291 foundation does in the study resulted from the mating of 24 Boer (n = 16) and Spanish (n = 8) bucks to 196 Spanish females. The foundation does were born in 1994 (n = 175) and 1995 (n = 116) for a total of 160 F_1 Boer-Spanish and 131 Spanish making up the 291 foundation females. Most of the Boer bucks were used via artificial insemination with frozen-thawed semen. The Boer bucks were a representative sample of those available in the US at the time. Bucks were chosen to be as unrelated as possible. The semen had been imported into the U.S. from New Zealand. Spanish sires were donated to Texas A&M University from different herds in west-central Texas and came from breeders who had a reputation for selecting for growth rate. Spanish bucks were used via natural mating in single-sire breeding pastures. Spanish does showed typical Spanish goat color markings, while the F_1 Boer-Spanish does were a mix of Spanish goat colors with others having the typical red head and white body of Boer goats. Most does were horned, but a few were polled. No records were kept on animals for horned or polled status. The dams of the foundation females were Spanish goats with a wide variety of color patterns and were property of the Texas A&M Research and Extension Center in San Angelo, Texas. The foundation females were bred to 39 different purebred Boer or percentage Boer bucks over the course of their lifetime.

Table 2. Total precipitation and mean temperatures between 1994 and 2003 for McCulloch and Edwards Counties

Item	McCulloch County (Brady, TX)			Edwards County (Rocksprings, TX)		
	Precipitation, cm.	Mean temp., C	Num. of days temp. > 32°C	Precipitation, cm.	Mean temp., C	Num. of days temp. >32°C
Year						
1994	70.1	18.3	106	70.4[c]	19.1[c]	82[c]
1995	72.4	18.5	96	48.1	18.4	78
1996	83.3	18.5	112	70.1	18.7	98
1997	80.0	17.5	107	77.5	17.6	80
1998	37.6[a]	18.2[a]	95[a]	82.0	19.2	97
1999	55.4	19.4	105	51.6	19.2	62
2000	81.8	19.4	121	98.9	19.0	98
2001	69.1	18.3	95	47.4	18.6	92
2002	68.8	18.0	96	NA	NA	NA
2003	56.6	18.5	96	61.1	16.5[b]	37
Average						
1971-2000	70.1	18.2	104	63.0	17.9	81.1

a - Month of July rainfall data not complete
b - Month of May, June, and July rainfall data not complete
c - Month of November rainfall data not complete

Flock management. The does in the study were managed for once a year kidding. At the start of the breeding season, does were weighed and randomly assigned to single-sire breeding pastures with 25 to 40 does with one buck. In 1995 does were randomly assigned to different dates for breeding. In 1996, as a consequence of not having enough time to get all goats divided into pastures on the same day, breeding dates for some goats were two days apart. In each subsequent year, all does went into breeding pastures on the same day within a year. Breeding seasons typically lasted one to two months. In most years the original service sires were removed from the does, and at a point later in time a cleanup buck was placed with the does.

Prior to kidding, does were taken from pasture and placed in small pens so that kidding records could be obtained. Assistance was rarely if at all given to the does during kidding because dystocia problems were few. While kidding, does were given supplement that varied from year to year with one typical feed consisting of 30% sorghum grain, 40% peanut hulls, 16.5% cottonseed meal and 8% molasses. Kids were tagged and identified with their dam within 18 hours of birth. Birth weight, sex, and type of birth were also recorded at kidding. Sire of kid was determined based on the assumption that a doe would kid approximately 150 days after conception. The goats were returned to pasture anywhere from 3 to 14 days after kidding depending on the weather, pen space, and strength of kids. Vaccinations for sore mouth (contagious ecthyma) were given to kids at less than one month of age. Does were given an anthelmintic wormer as needed. Kids were vaccinated for overeating disease at weaning. The goats in the study were maintained on native pasture and run as one flock throughout the year, except during the breeding season. Diets of the goats consisted of shrubs, trees, and different grasses found in the two geographical regions. Salt was provided ad libitum, and water sources mainly came from water wells. Supplemental feed was provided in the winter, depending upon range conditions. When given, supplemental feed consisted of a salt limited ration made up of 60% sorghum, 20% cottonseed meal, and 16% salt. In other years, supplement was in the form of cottonseed. Kids were typically weaned in groups once or twice a year from the months of May through July. Because of differences in breeding season and date of conception, kids were sometimes weaned at three separate times of the year. No castration was performed on the male kids.

Dams were culled when kids were weaned. Major reasons for culling were old age, mastitis, bad udder, and Caseous lymphadenitis. Goats were culled for other, less frequent, health problems if the problem was serious enough to affect production.

Record summary. Records on the does included breed of sire, identification number, birth date, birth year, type of birth, type of rearing, birth weight, dam of doe, sire of doe, weaning weight, weaning date, day doe left the herd, and cause of doe leaving the herd. Annual production records on does include production year, date of sires introduced in the breeding pastures, body weight of doe at the start of the breeding season, kidding date, number of kids born, number of kids weaned, and sire exposed to doe during initial breeding season. Records for each kid include identification number, birth date, type of birth, type of weaning, sex, sire, dam, birth weight, weaning weight, weaning date, and date kid left the herd.

In addition to these records, additional variables were also created. Age of dam was created by taking the year of production minus the birth year. Two fertility variables were created to measure fertility of the does. The first fertility variable (FERT1) was created by assigning a value of 1 to does with a number of kids born of 1 or greater and assigning a zero to does with a value of zero for number of kids born. Therefore the FERT1 variable measured whether the doe kidded or did not kid in a given production year. The second measure of fertility was created to distinguish those does that kidded as a result of conceiving during the first 30 days of the breeding season from those that kidded later. A variable (FERT2) was created by first creating a kidding day variable (KDAYS):

KDAYS = kidding date – date of start of breeding season

If the KDAYS variable was less than 180 days (150 day gestation + first 30 days of kidding season) then the FERT2 variable was assigned a value of 1. If the KDAYS variable was greater than 180 days then the FERT2 variable was assigned a value of zero. Thus the FERT2 variable measured whether the doe kidded within the first 30 days of the kidding season. A weaning age variable was calculated for each kid as the difference between the weaning date and the birth date of the kid. Weaning weights were adjusted to 120 days for does and 90 days for kids of the does by the following formula:

AWW= ((((weaning weight - birth weight) / (weaning age)) × 90/120) + birth weight)

After weaning weights were adjusted to a common age, an across-animal regression for weaning age was used to account for additional variation due to age.

An average daily gain variable (ADG) was also created to measure kids pre-weaning average daily gain (grams) as:

$$\text{ADG (g)} = \frac{\text{weaning weight} - \text{birth weight}}{\text{weaning age}} \times 1000 \text{ (1kg = 1000g)}$$

An age of doe when culled from the herd variable was calculated for each doe as the difference between the date the doe was culled from the herd and the birth date of the doe. Causes of doe culled from the herd were grouped into the four categories of old age, udder related (udder), Caseous Lymphadenitis (caseous), and other (other). Udder related causes include mastitis and bad udder. Causes of doe leaving the herd grouped into the other category include cancer of the vulva, lameness, blindness, overeating disease, sick and thin or sick, ruptured organ, and hung in fence. The cause, old age, was for does culled at 9 years of age.

Statistical analysis

All traits, except for doe survivability, were analyzed using the Proc Mixed procedure of SAS as outlined by Ott and Longnecker (2001), with least squares means used to determine differences within a class as described by Harvey (1982). Chi-square goodness of fit analysis was used to analyze the doe survivability trait as described by Ott and Longnecker (2001). Least squares means tests within classes and chi-square tests were said to be significant at the $\alpha = 0.05$ level.

Traits of the doe. Models for traits recorded on the does included birth weight, weaning weight and body weight of the doe at the start of the breeding season. The birth weight (BWT) and weaning weight (WWT) models included fixed effects for breed, type of birth, month of birth nested within year of birth, and random effects of the dam of the doe and the sire of the doe nested within breed. In the weaning weight model, weaning weights of the does were adjusted to 120 days, and age at weaning was used as a covariate for WWT analysis. The dam of the doe, sire of the doe, and error term were assumed to be normally distributed in both BWT and WWT models.

The model for doe birth weight was:

$$Y_{ijklmn} = \mu + B_i + Y_j + M_{k(j)} + T_l + s_{m(i)} + d_n + e_{ijklmn}$$

Where:

Y_{ijklmn} = observed value for the ijklmnth trait measured,

μ = overall mean for birth weight,

B_i = the fixed effect of the ith breed,

Y_j = the fixed effect of the jth birth year,

$M_{k(j)}$ = the fixed effect of the kth birth month nested within the jth birth year

T_l = the fixed effect of the lth type of birth,

$s_{m(i)}$ = the random effect of the mth sire of the doe nested within the ith breed,

d_n = the random effect of the nth dam of the doe,

e_{ijklmn} = the random error associated with the ijklmnth observation.

The model for doe weaning weight was:

$$Y_{ijklmno} = \mu + B_i + Y_j + M_{k(j)} + T_l + W_m + s_{n(i)} + d_o + e_{ijklmno}$$

Where:

$Y_{ijklmno}$ = observed value for the ijklmnoth trait measured,

μ = overall mean for weaning weight,

B_i = the fixed effect of the ith breed,

Y_j = the fixed effect of the jth birth year,

$M_{k(j)}$ = the fixed effect of the kth birth month nested within the jth birth year,

T_l = the fixed effect of the lth type of birth,

W_m = the average linear regression coefficient for age at weaning,

$s_{n(i)}$ = the random effect of the nth sire of the doe nested within the ith breed,

d_o = the random effect of the oth dam of the doe,

$e_{ijklmno}$ = the random error associated with the ijklmnoth observation.

Interactions in the doe birth and weaning weight models were not significant. Simple means and standard deviations for doe birth weight and weaning weight by breed, type of birth and year of birth are found in Table 3.

The body weight at the start of breeding season model included fixed effects for breed of doe, age of doe, production year, date the weight was obtained nested within year of production, and random effects for sire of doe nested within breed and doe nested within sire of doe and breed. The doe, sire of the doe, and error term were assumed to be normally distributed.

The model for body weight of the doe at breeding was:

$Y_{ijklmn} = \mu + B_i + Y_j + A_k + G_{l(j)} + s_{m(i)} + d_{n(m\ i)} + e_{ijklmn}$

Where:

Y_{ijklmn} = observed value for the ijklmnth trait measured,

μ = overall mean for body weight,

B_i = the fixed effect of the ith breed,

, Y_j = the fixed effect of the jth production year,

A_k = the fixed effect of the kth age of doe,

$G_{l(j)}$ = the fixed effect of the lth breeding date nested within the jth production year,

$s_{m(i)}$ = the random effect of the mth sire of the doe nested within the ith breed,

$d_{n(m\ i)}$ = the random effect of the nth doe nested within the mth sire of the doe and the ith breed,

e_{ijklmn} = the random error associated with the ijklmnth observation.

Although an age of doe by breed interaction in the body weight at breeding model was found to be significant, the interaction was chosen to be left out of the model on the basis that there were only a few comparisons within the interaction that caused the interaction effect to be significant. Therefore a subjective decision was made to exclude the interaction effect because the impact on the estimation of the breed effect was negligible.

Table 3. Means and standard deviations for birth weights and non-adjusted weaning weights of F1 Boer-Spanish and Spanish does by breed, type of birth, and year of birth

Item	Breed									
	F_1 Boer-Spanish					Spanish				
		BWT, kg		WWT, kg			BWT, kg		WWT, kg	
	n	Mean	Std	Mean	Std	n	Mean	Std	Mean	Std
Type of birth										
Single	41	3.2	.52	18.5	3.7	46	2.9	.32	17.4	3.2
Twin	103	2.8	.34	15.7	3.7	77	2.8	.34	15.5	3.0
Triplet	16[a]	2.5	.46	13.2	3.8	8	2.4	.14	14.5	2.4
Year of birth										
1994	103	2.9	.44	16.4	4.0	72	2.8	.40	17.0	3.3
1995	57	2.8	.47	15.7	4.1	59	2.8	.29	15.2	2.7
Overall	160	2.9	.45	16.1	4.0	131	2.8	.35	16.1	3.2

[a] 3 quadruplets have been grouped with the triplets.
[b] Weaning weights have not been adjusted to a certain age

Simple means and standard deviations for doe body weight at breeding by breed, and age of doe are found in Table 4.

Fertility traits. Fertility was coded as 1 or 0, for kidding or not kidding respectively, in a production year (FERT1). A second analysis of fertility (FERT2) was coded as 1 or 0 for kidding or not kidding respectively, within 180 days of the start of the breeding season. The Fertility models FERT1 and FERT2 included fixed effects for breed, production year, age of doe in years, breeding date of doe nested within the production year, and random effects for service sire, sire of the doe nested within breed, and doe nested within sire of doe and breed. The doe, sire of the doe, service sire and error term were assumed to be normally distributed in both fertility models. A second model for NKB and NKW also included body weight at breeding as a linear covariate.

The model for FERT1 and FERT2 was:

$$Y_{ijklmno} = \mu + B_i + Y_j + A_k + G_{l(j)} + v_m + s_{n(i)} + d_{o(n\ i)} + e_{ijklmno}$$

Where:

$Y_{ijklmno}$ = the observed value for the ijklmnoth trait measured,

μ = the overall mean for FERT1 or FERT2,

B_i = the fixed effect of the ith breed,

Y_j = the fixed effect of the jth production year,

A_k = the fixed effect of the kth age of the doe,

$G_{l(j)}$ = the fixed effect of the lth breeding date of the doe nested within the jth production year,

Table 4. Means and standard deviations for body weight at breeding of F_1 Boer-Spanish and Spanish does by breed and age of doe

Item	Breed					
	F_1 Boer-Spanish			Spanish		
	Body weight, kg			Body weight, kg		
	n	Mean	Std	n	Mean	Std
Age of doe, yr						
2	152	34.08	5.51	120	32.14	5.22
3	145	37.85	5.03	115	35.14	4.54
4	134	41.47	5.37	103	38.29	5.00
5	116	45.17	6.85	80	41.29	5.75
6	96	46.46	6.66	65	41.53	5.58
7	72	52.41	9.15	50	48.33	6.24
8	62	56.48	7.35	41	52.37	6.37
9	49	57.40	7.81	31	51.84	5.21
Overall	826	43.60	9.80	605	39.69	8.32

vm = the random effect of the mth service sire,

$s_{n(i)}$ = the random effect of the n^{th} sire of the doe nested within the i^{th} breed,

$d_{o(n\ i)}$ = the random effect of the o^{th} doe nested within the n^{th} sire of the doe and the i^{th} breed,

$e_{ijklmno}$ = the random error associated with the $ijklmno^{th}$ observation.

The second set of models for FERT1 and FERT2 included the same fixed and random effects as the first set except including the covariate body weight at breeding in the model. Body weight at breeding was included to account for differences in weight among animals. Estimates of breed differences from a model that included body weight are not unbiased when a breed difference exists for the covariate, because some of the breed effect is accounted for by the regression.

The model for FERT1 and FERT2 including body weight was:

$$Y_{ijklmnop} = \mu + B_i + Y_j + A_k + G_{l(j)} + W_m + v_n + s_{o(i)} + d_{p(o\ i)} + e_{ijklmnop}$$

Where:

W_m = the linear regression coefficient for body weight at breeding.

Interactions in the doe fertility models were not found to be significant. Simple means and standard deviations for percentage of does that had at least one kid in a production year (FERT1) and percentage of does that kidded within the first thirty days of the kidding season (FERT2) by breed and age of doe are found in Table 5.

Table 5. Means and standard deviations for percentages of F_1 Boer-Spanish and Spanish does that kidded (FERT1) and that kidded within the first thirty days of kidding season (FERT2) by breed and age of doe

Item	Breed									
	F_1 Boer-Spanish					Spanish				
		FERT1		FERT2			FERT1		FERT2	
	n	Mean	Std	Mean	Std	n	Mean	Std	Mean	Std
Age of doe, yr										
2	152	0.84	0.37	0.47	0.50	122	0.75	0.43	0.35	0.48
3	145	0.87	0.34	0.54	0.50	116	0.85	0.36	0.46	0.50
4	135	0.83	0.38	0.42	0.50	104	0.74	0.44	0.34	0.47
5	117	0.87	0.34	0.57	0.50	81	0.94	0.24	0.59	0.49
6	96	0.84	0.36	0.55	0.50	65	0.86	0.35	0.48	0.50
7	72	0.93	0.26	0.46	0.50	50	0.92	0.27	0.58	0.50
8	62	0.87	0.34	0.55	0.50	41	0.73	0.45	0.34	0.48
9	49	0.82	0.39	0.33	0.47	31	0.77	0.43	0.35	0.49
Overall	828	0.86	0.35	0.50	0.50	610	0.82	0.38	0.43	0.50

Prolificacy traits. For analysis of prolificacy and kid production traits of the doe, a variable for accounting for differences in kidding dates (SEASON) was created by forming contemporary groups. A separate SEASON was created when there was a 10 day break between a given kidding date and the subsequent kidding date. Additionally, if there were no breaks of 10 or more days between kidding dates, the maximum range of kidding dates for a single SEASON was 45 days (i.e. if the kidding dates for the year spanned more than 45 days, a new SEASON was created so that the maximum range of dates for a SEASON contemporary group was 45 days) There were 26 different SEASON contemporary groups in the data set season.

Measures of prolificacy included number of kids born (NKB) and number of kids weaned (NKW). The NKB and NKW models included fixed effects for breed, age of doe in years, production year, season of kidding nested within production year, breeding date nested within year, and random effects for sire of the kid, sire of the doe nested within breed, and doe nested within sire of doe and breed. The sire of doe, doe, and error terms for the NKB and NKW doe models were assumed to be normally distributed. A second model for NKB and NKW also included body weight at breeding as a linear covariate

The model for NKB and NKW was:

$$Y_{ijklmno} = \mu + B_i + Y_j + A_k + T_{l(j)} + G_{m(j)} + s_{n(i)} + d_{o(n\ i)} + e_{ijklmno}$$

Where:

$Y_{ijklmno}$ = observed value for the ijklmnoth trait measured,

μ = overall mean for number of kids born or weaned,

B_i = the fixed effect of the ith breed,

Y_j = the fixed effect of the j^{th} production year,

A_k = the fixed effect of the k^{th} age of doe,

$T_{l(j)}$ = the fixed effect of the l^{th} season of kidding nested within the j^{th} production year,

$G_{m(j)}$ = the fixed effect of the m^{th} breeding date nested within the j^{th} production year,

$s_{n(i)}$ = the random effect of the n^{th} sire of the doe nested within the i^{th} breed,

$d_{o(n\ i)}$ = the random effect of the o^{th} doe nested within the n^{th} sire of the doe and the i^{th} breed,

$e_{ijklmno}$ = the random error associated with the $ijklmno^{th}$ observation .

The second set of models for NKB and NKW including the covariate body weight at breeding included the same fixed and random effects as the first model.

The model for NKB and NKW including body weight was:

$$Y_{ijklmnop} = \mu + B_i + Y_j + A_k + T_{l(j)} + G_{m(j)} + W_n + s_{o(i)} + d_{p(o\ i)} + e_{ijklmnop}$$

Where:

W_n = the linear regression coefficient for body weight at breeding.

Interactions in the NKB and NKW models were not found to be significant. Simple means and standard deviations for number of kids born and number of kids weaned by breed and age of doe are found in Table 6.

Table 6. Means and standard deviations for number of kids born and number of kids weaned from F_1 Boer-Spanish and Spanish does by breed and age of doe

	Breed											
	F_1 Boer-Spanish						Spanish					
	NKB			NKW			NKB			NKW		
Item	n	Mean	Std	n	Mean	Std	n	Mean	Std	n	Mean	Std
Age of doe, yr												
2	127	1.53	0.52	126	1.16	0.64	92	1.52	0.64	92	1.34	0.63
3	126	1.50	0.55	126	1.37	0.63	99	1.44	0.56	99	1.34	0.57
4	112	1.49	0.52	112	1.22	0.65	77	1.45	0.50	77	1.22	0.64
5	102	1.70	0.54	102	1.34	0.71	76	1.49	0.50	76	1.32	0.62
6	81	1.90	0.58	81	1.48	0.69	56	1.71	0.56	56	1.41	0.68
7	67	1.91	0.62	67	1.54	0.86	46	1.70	0.55	46	1.41	0.75
8	54	1.94	0.66	54	1.54	0.72	30	1.70	0.60	30	1.50	0.73
9	40	1.88	0.56	40	1.53	0.68	24	1.83	0.64	24	1.58	0.72
Overall	709	1.67	0.59	708	1.35	0.70	500	1.55	0.57	500	1.35	0.65

Kid production traits. Kid production traits included total litter weight at birth (TLBW) and total litter weight at weaning (TLWW). The traits TLBW and TLWW were analyzed with a model that included fixed effects for breed, production year, age of doe in years, a contemporary group for SEASON nested with year, breeding date nested within year, and random effects for sire of kids, sire of doe nested with breed, and doe nested within sire of doe and breed. The sire of kid, sire of doe, doe, and error term were assumed to be normally distributed. A second analysis for TLBW and TLWW included body weight at breeding as a linear covariate.

The model for TLBW and TLWW was: $Y_{ijklmnop} = \mu + B_i + Y_j + A_k + T_{l(j)} + G_{m(j)} + k_n + s_{o(i)} + d_{p(o\ i)} + e_{ijklmnop}$

Where:

$Y_{ijklmnop}$ = observed value for the ijklmnopth trait measured,

μ = overall mean for TLBW or TLWW,

B_i = the fixed effect of the ith breed,

Y_j = the fixed effect of the jth production year,

A_k = the fixed effect of the kth age of doe,

$T_{l(j)}$ = the fixed effect of the lth kidding season nested within the jth production year,

$G_{m(j)}$ = is the fixed effect of the mth breeding date nested within the jth production year,

k_n = the random effect of the nth sire of the kid,

$S_{o(i)}$ = the random effect of the oth sire of the doe nested within the ith breed,

$d_{p(o\ i)}$ = the random effect of the pth doe nested within the oth sire of the doe and the ith breed,

$e_{ijklmnop}$ = the random error associated with the ijklmnopth observation.

The second set of models for TLBW and TLWW included the same fixed and random effects of the previous models except including the covariate body weight at breeding in the model.

The model for TLBW and TLWW including body weight was:

$Y_{ijklmnopq} = \mu + B_i + Y_j + A_k + T_{l(j)} + G_{m(j)} + W_n + k_o + s_{p(i)} + d_{q(p\ i)} + e_{ijklmnopq}$

Interactions in the TLBW and TLWW models were found not to be significant. Simple means and standard deviations for total litter birth weight and total litter weaning weight by breed and age of doe are found in Table 7.

Kid growth traits. The traits analyzed as a trait of the kid included birth weight of the kid, weaning weight of the kid, and pre-weaning average daily gain of the kid. The birth weight of kid model included fixed effects for breed of sire of the dam, production year, sex of kid, type of birth, month of birth nested within production year, body weight at breeding, as a covariate, and random effects for sire of kid, sire of doe nested within breed, and doe nested within sire of doe and breed. The sire of kid, sire of doe, doe and error term were assumed to be normally distributed.

The model for birth weight of kid was:

$Y_{ijklmnopq} = \mu + B_i + Y_j + A_k + T_l + M_{m(j)} + W_n + k_o + s_{p(i)} + d_{q(p\ i)} + e_{ijklmnopq}$

Table 7. Means and standard deviations for total litter weight at birth and total litter weight at weaning from F_1 Boer-Spanish and Spanish does by breed, and age of doe

	Breed											
	F_1 Boer-Spanish						Spanish					
Item	TLWB, kg			TLWW, kg			TLWB, kg			TLWW, kg		
	n	Mean	Std	n	Mean	Std	n	Mean	Std	n	Mean	Std
Age of doe, yr												
2	124	4.70	1.52	92	22.97	8.92	92	4.47	1.64	80	23.10	8.88
3	126	4.33	1.42	111	24.37	8.20	98	4.11	1.40	90	24.58	8.00
4	110	4.39	1.34	88	28.82	8.78	74	4.41	1.43	60	28.59	8.83
5	99	5.31	1.58	76	31.09	12.66	74	4.89	1.42	64	26.46	12.81
6	79	6.46	1.91	54	26.99	7.75	55	5.99	1.60	44	25.36	8.94
7	67	6.45	2.02	47	33.09	11.63	46	5.75	1.88	36	26.81	9.62
8	54	6.67	2.03	37	29.16	8.25	30	5.86	2.15	24	28.54	9.83
9	40	6.57	1.95	29	28.25	9.93	24	6.26	1.86	19	26.48	9.84
Overall												
	699	5.30	1.90	534	27.39	10.04	493	4.91	1.75	417	25.75	9.68

Where:

$Y_{ijklmnopq}$ = observed value for the ijklmnopqth trait measured,

μ = overall mean for kid birth weight,

B_i = the fixed effect of the ith breed of sire of the dam,

Y_j = the fixed effect of the jth production year,

A_k = the fixed effect of the kth sex of kid,

T_l = the fixed effect of the lth kid type of birth,

$M_{m(j)}$ = the fixed effect of the mth kid month of birth nested within the jth production year,

W_n = the linear regression coefficient for body weight at breeding,

k_o = the random effect of the oth sire of kid,

$s_{p(i)}$ = the random effect of the pth sire of the doe nested within the ith breed,

$d_{q(p\ i)}$ = the random effect of the qth doe of kid nested within the pth sire of the doe and the ith breed,

$e_{ijklmnopq}$ = the random error associated with the ijklmnopqth observation.

Interactions in the birth weight of the kid model were found not to be significant.

The models for weaning weight of the kid and pre-weaning average daily gain of the kid included fixed effects for breed of sire of dam, production year, sex of kid, type of birth and weaning, age at weaning fixed as a covariate, body weight at breeding, as a covariate, and random effects for sire of kid, sire of doe nested within breed, doe nested within sire of doe and breed. The sire of kid, sire of doe, doe and error term were assumed to be normally distributed. In the weaning weight model, weaning weights of the kids were adjusted to 90 days.

The model for kid weaning weight and pre-weaning average daily gain was:

$$Y_{ijklmnopq} = \mu + B_i + Y_j + A_k + T_l + W_m + G_n + k_o + s_{p(i)} + d_{q(p\ i)} + e_{ijklmnopq}$$

Where:

$Y_{ijklmnopq}$ = observed value for the ijklmnopqth trait measured,

μ = overall mean for kid weaning weight or pre-weaning average daily gain,

B_i = the fixed effect of the ith breed of sire of the dam,

Y_j = the fixed effect of the jth production year,

A_k = the fixed effect of the kth sex of kid,

T_l = the fixed effect of the lth kid type of birth and type of weaning,

W_m = the average linear regression coefficient for age at weaning,

G_n = the linear regression coefficient for body weight at breeding,

k_o = the random effect of the oth sire of kid,

$s_{p(i)}$ = the random effect of the pth sire of the doe nested within the ith breed,

$d_{q(p\ i)}$ = the random effect of the qth doe of kid nested within the pth sire of the doe and the ith breed,

$e_{ijklmnopq}$ = the random error associated with the ijklmnopqth observation.

Interactions in the birth weight of the kid model were found not to be significant Simple means and standard deviations for kid birth weight and weaning weight, and pre-weaning average daily gain are found in Tables 8 and 9, respectively.

Table 8. Means and standard deviations for birth weight and weaning weight of kids from F1 Boer-Spanish and Spanish does by breed, type of birth, and sex

Item	Breed											
	F_1 Boer-Spanish						Spanish					
	BWT, kg			WWT, kg			BWT, kg			WWT, kg		
	n	Mean	Std	n	Mean	Std	n	Mean	Std	n	Mean	Std
Type of birth												
Single	268	3.34	0.58	241	19.32	5.30	238	3.37	0.63	215	19.17	5.02
Twin	778	3.13	0.58	630	16.81	4.19	470	3.09	0.50	420	16.38	4.73
Triplet	127[a]	2.93	0.60	91[a]	15.12	4.33	60	2.80	0.49	42	15.08	3.03
Sex												
Female	569	3.02	0.52	473	16.26	4.13	399	3.06	0.52	344	16.05	4.19
Male	604	3.28	0.63	489	18.26	4.97	369	3.26	0.60	333	18.35	5.36
Overall	1173	3.16	0.59	962	17.28	468	768	3.15	0.57	677	17.18	4.93

[a] - 4 quadruplets have been grouped with the triplets

Table 9. Means and standard deviations for pre-weaning average daily gain of kids from F_1 Boer-Spanish and Spanish does by breed, type of birth and weaning, and sex

Item	Breed					
	F_1 Boer-Spanish			Spanish		
	ADG, g			ADG, g		
	n	Mean	Std	n	Mean	Std
Type of birth and weaning						
single/single	232	158.12	46.84	215	162.80	45.25
twin/single	71	156.50	46.60	33	175.49	52.23
twin/twin	547	146.41	42.11	385	141.10	43.49
triplet/single	5	196.64	43.43	3	129.88	18.60
triplet/twin	40	140.35	54.38	12	129.93	30.57
triplet/triplet	46[a]	150.24	40.39	27	142.36	45.76
Sex of kid						
Female	461	139.34	39.01	342	141.93	41.64
Male	480	160.74	46.95	333	157.27	48.50
Overall	941	150.26	44.52	675	149.49	45.77

[a] - 4 quadruplets have been grouped with the triplets

Doe longevity analysis. Doe longevity was measured using the variable age at which doe was culled from the herd (longevity), as the dependant variable. The model for longevity of the doe included the fixed effects for breed, year of birth and random effects for sire of the doe nested within breed. Sire of the doe and the error term were assumed to be normally distributed.

The model for doe longevity was:

$Y_{ijk} = \mu + B_i + Y_j + s_{k(i)} + e_{ijk}$

Where:

Y_{ijk} = observed value for the Yijkth trait measured,

μ = the overall mean for doe longevity,

B_i = the fixed effect for the ith breed,

Y_j = the fixed effect for the jth year of birth,

$s_{k(i)}$ = the random effect of the kth sire of doe nested within the ith breed,

e_{ijk} = the random error term associated with the ijkth observation.

Interactions in the doe longevity model were found not to be significant

Doe survival analysis. Doe survival was measured using chi-square analysis to test for equal proportions between four groups for cause of doe leaving the herd (cause of culling). The four groups were identified as old age, udder related, Caseous lymphadenitis, and other. The four groups were tested for differences of equal cause of culling proportions between the two breed types. The written hypothesis for the goodness of fit test was:

$H_o = \pi_a = \pi_d = \pi_c = \pi_o$

H_a = At least one of the cell probabilities is different from the hypothesized value.

Where:

π_a = the population of does that left the herd due to old age

π_d = the population of does that left the herd due to dam related causes,

π_c = the population of does that left the herd due to Caseous Lymphadenitis,

π_o = the population of does that left the herd due to other causes,

Simple means, and standard deviations for doe longevity and cause of doe leaving the herd are in Table 10 and Table 11, respectively.

Table 10. Means and standard deviations for longevity of F1 Boer-Spanish and Spanish does by breed and type of birth

	Breed					
	F_1 Boer-Spanish			Spanish		
	Years			Years		
Item	n	Mean	Std	n	Mean	Std
Type of birth						
Single	41	6.10	2.92	46	5.57	2.84
Twin	103	6.07	2.41	77	5.40	2.53
Triplet	16[a]	6.00	2.53	8	6.63	2.13
Overall	160	6.07	2.55	131	5.53	2.62

[a] Three F1 Boer-Spanish quadruplet does included the triplet group

Table 11. Means and standard deviations for cause of culling of F_1 Boer-Spanish and Spanish does by breed

Item	Breed					
	F_1 Boer-Spanish			Spanish		
	Years			Years		
	n	Mean	Std	n	Mean	Std
Cause						
Old age	44	9.0	0	30	9.0	0
Caseous[a]	39	5.18	1.50	28	5.14	1.60
Udder[b]	38	5.68	1.90	32	5.13	1.58
Other	39	4.03	2.48	41	3.59	2.34
Overall	160	6.07	2.55	131	5.53	2.62

[a] Caseous lymphadenitis
[b] Udder related problems

RESULTS AND DISCUSSION

Doe growth traits

Birth weight and weaning weight. The analyses of variance for birth weight and weaning weight of the doe were based on 291 observations and are presented in Table 12. For birth weight, all effects in the model were significant ($P < .05$) sources of variation. Type of birth of the doe had the highest level of significance for birth weight ($P < 0.0001$). For weaning weight, type of birth was a significant source of variation while fixed effects of breed, the regression weaning age and month of birth nested within year of birth were not ($P \geq 0.52$). The age at weaning regression on doe weaning weight was -0.0177 ± 0.02767 kg/d. The lack of significance from the age at weaning regression on weaning weight, indicates that there were not weaning age effects beyond what was accounted for by the pre-weaning adjustment for weaning age.

Least squares means for birth weight and weaning weight by breed and type of birth are found in Table 13. The F_1 Boer-Spanish does weighed 2.79 ± 0.05 kg and were significantly heavier at birth than Spanish does that had an average birth weight of 2.67 ± 0.05 kg. Does born as singles had an average birth weight of 3.05 ± 0.04 kg and were significantly heavier than twins that averaged 2.74 kg. Twins were significantly heavier (2.74 kg) than triplets who averaged 2.40 kg at birth. There was no significant difference in weaning weight between the F_1 Boer-Spanish does and Spanish does, whose values

Table 12. Analysis of variance for birth weight and weaning weight of F_1 Boer-Spanish and Spanish does

	Birth weight, kg			Weaning weight, kg		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	4.27	0.05	1	0.40	0.53
Type of birth	2	33.61	<.0001	2	24.74	<.0001
MOB[a] (year of birth)	3	2.70	0.05	3	0.22	0.88
Weaning age	—	—	—	1	0.41	0.52
Variance estimates						
Sire of doe (breed)	0.0060	—	—	0	—	—
Dam	0.0402	—	—	0.9172	—	—
Error	0.0924	—	—	8.5539	—	—
Regression coefficient						
Weaning age				-0.0177 ± 0.02767		

[a] Month of birth

Table 13. Least squares means and standard errors for birth weight and weaning weight of F_1 Boer-Spanish and Spanish does

		Birth weight, kg			Weaning weight, kg		
Effect	n	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed							
F_1 Boer-Spanish (BS)	160	2.79	0.05	—	15.14	0.36	—
Spanish	131	2.67	0.05	—	14.89	0.39	—
Type of birth							
Single	87	3.05	0.04	—	17.24	0.38	—
Twin	180	2.74	0.04	—	14.73	0.33	—
Triplet	24[d]	2.40	0.09	—	13.07	0.68	—
Differences of LSM							
F_1 BS and Spanish	—	0.12	0.59	0.05	0.25	0.39	0.53
Single and twin	—	0.31	0.05	<.0001	2.51	0.42	<.0001
Twin and triplet	—	0.34	0.09	.0002	1.66	0.69	0.01

[d] Three F_1 Boer-Spanish quadruplets included in triplet group analysis.

were 15.14 ± 0.36 kg and 14.89 ± 0.39 kg, respectively. Does born as singles, averaged 17.24 ± 0.38 kg at weaning and were significantly heavier than twins that averaged 14.73 ± 0.33 kg. In addition, does born as twins were significantly heavier than triplets.

Breed effects in this study are a combination of heterosis and the additive breed effect. At the time this trial was initiated, few purebred Boer females were in the US, and therefore the design of this trial did not permit separate estimates for heterosis and a breed effect. The greater birth weights of the Boer-sired kids, is consistent with reports of the larger weights of Boer goats as reported in Van Niekerk and Casey (1998). However, in the results for weaning weight of the doe there was no significant difference between breeds. The lack of breed effect on weaning weight suggests that other factors are more important sources of variation than breed, in this management situation (i.e. extensive pasture management). Reports from Luo et al. (2000) and Casey and Van Niekerk (1988) indicate Boer and Boer crossbred kids had a higher pre-weaning daily gain than Spanish kids. However, Browning et al. (2004) reported Boer kids had lower pre-weaning average daily gain compared to Kiko goats. Carter et al. (1971) reported in sheep and Blackburn (1995), reported in a simulation study involving goats, that differences in performance from different breeds may be the effect of adaptation to certain environments. Because goats are primarily reared in extensive management situations, adaptation to the environment is important. If genotype by environment interactions are important for birth and weaning weights, the results of the present study may not be applicable to a more intensive management system. Estimates of the effect of type of birth of the doe at birth and weaning are similar to what previous research has shown in that singles are typically heavier at birth and weaning than twins and that twins are heavier than triplets (Bogui, 1986; Browning et al., 2004).

Body weight at breeding. Analysis of variance results for doe body weight at breeding are found in Table 14. All effects in the analysis, including breed and age of doe, were significant sources of variation for body weight. Least squares means for body weight are in Table 15. The F_1 Boer-Spanish does had an average body weight of 46.53 ± 0.51 kg and were significantly heavier at breeding than Spanish does who averaged 43.49 ± 0.61 kg. Two year old does had an average body weight of 24.18 kg, which steadily increased by approximately 6 to 7 kg per year from ages 3 to 7. Does from ages 7 to 9 showed a smaller rate of increase of approximately 2 kg per year. Body weights of does at all ages were significantly different from preceding and subsequent ages. The largest difference for adjacent ages of the doe, was between the ages of 4 and 5 (7.63 ± 0.85 kg).

Typical body weights of mature Boer goats usually range from 60 to 75 kg for females (Gall, 1981; Erasmus, 2000; Greyling, 2000), while Gall (1981) reported the North Mexican Criollo averaging from 35-50 kg for females, which are consistent with the results of the present study, where the comparison was made with goats in the same environment. Although not analyzed in the study, Bogui (1986) stated that Spanish does seemed to be slower in reaching mature body weight as compared to Boer does as stated by Erasmus et al. (1985).

Table 14. Analyses of variance for body weight at breeding of F_1 Boer-Spanish and Spanish does

	Body weight, kg		
Source	df	F value	*P* value
Breed	1	14.95	0.0008
Age of doe	7	17.49	<0.0001
Production year	8	23.31	<0.0001
Breeding date (year)	3	26.79	<0.0001
Variance estimates			
Sire of doe (breed)	1.51	—	—
Doe (breed sire)	17.32	—	—
Error	13.10	—	—

Table 15. Least squares means and standard errors for body weight at breeding of F_1 Boer-Spanish and Spanish does

	Body weight, kg		
Effect	LSM	Std. error	*P* value
Breed			
F_1 Boer-Spanish (BS)	46.53	0.51	—
Spanish	43.49	0.61	—
Age of doe			
2	24.18	2.61	—
3	30.63	1.94	—
4	37.02	1.31	—
5	44.65	0.78	—
6	50.06	0.72	—
7	55.46	1.22	—
8	58.00	1.91	—
9	60.10	2.65	—
Differences of LSM			
F_1 BS and Spanish	2.04	0.79	<0.0001
2 vs. 3	-6.45	0.83	<0.0001
3 vs. 4	-6.39	0.83	<0.0001
4 vs. 5	-7.63	0.85	<0.0001
5 vs. 6	-5.41	0.90	<0.0001
6 vs. 7	-5.40	0.95	<0.0001
7 vs. 8	-2.53	1.00	0.01
8 vs. 9	-2.10	1.07	0.05

Fertility, prolificacy, and kid production traits

Fertility traits. Results of analyses of variance, of whether or not the doe kidded in a given year (FERT1), and whether or not the doe kidded within the first thirty days of the kidding season (FERT2) are in Table 16. Production year and age of doe were significant sources of variation of FERT1, while breed and breeding date had no substantial impact ($P \geq 0.21$). Effects of age of doe, production year and breeding date all were significant sources of variation for FERT2, while breed was not ($P = 0.09$).

Least squares means (LSM) for FERT1 and FERT2 are found in Table 17. Two year old does had the lowest value for FERT1 of 0.75 ± 0.08, while five year old does had the highest value for FERT1 of 0.95 ± 0.05. Does age 2 versus 3, 3 versus 4, and 4 versus 5, were significantly different. The F_1 Boer-Spanish value for FERT2 was 0.53 ± 0.04, but was not significantly different from Spanish does whose value was 0.48 ± 0.04. Does starting from age 2, showed an increase in FERT2 for every increase in year of age through the age of eight, with the highest FERT2 value of 0.81 ± 0.10 found in eight year old does. Does age 2, 3, 4 were lower than does age 5 through 9 for FERT2. The largest difference between adjacent ages of doe for FERT1 was between 4 and 5 year old does, and for FERT2 was between 2 and 3 year old does ($P \leq 0.0007$). Eight year old does had the highest value for FERT2, while two year old does had the lowest value.

Analysis of variance results for FERT1, including the covariate body weight, showed age of doe and production year, were significant sources of variation while breed and breeding date nested within production year were not ($P \geq 0.35$). In the FERT2

Table 16. Analysis of variance for percentage of F_1 Boer-Spanish and Spanish does that kidded (FERT1) and that kidded within the first 30 days of the kidding season (FERT2)

	FERT 1			FERT 2		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	1.61	0.21	1	3.04	0.09
Age of doe	7	4.41	<0.0001	7	5.12	<0.0001
Production Year	8	6.95	<0.0001	8	10.86	<0.0001
Breeding date (year)	3	0.61	0.61	3	18.45	<0.0001
Variance estimates						
Service sire	0.0004	—	—	0.0450	—	—
Sire of doe (breed)	0	—	—	0	—	—
Doe (breed dsire[a])	0.0097	—	—	0.0084	—	—
Error	0.1094	—	—	0.1700	—	—

[a] Sire of doe

Table 17. Least squares means and standard errors for percentage of F_1 Boer-Spanish and Spanish does that kidded (FERT1) and that kidded within the first 30 days of kidding season (FERT2)

	FERT 1			FERT 2		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	0.87	0.02	—	0.53	0.04	—
Spanish	0.84	0.02	—	0.48	0.04	—
Age of doe						
2	0.74	0.08	—	0.01	0.10	—
3	0.87	0.07	—	0.23	0.09	—
4	0.78	0.06	—	0.37	0.08	—
5	0.95	0.05	—	0.56	0.07	—
6	0.89	0.05	—	0.61	0.07	—
7	0.90	0.06	—	0.65	0.08	—
8	0.83	0.08	—	0.81	0.10	—
9	0.87	0.10	—	0.80	0.13	—
Differences of LSM						
F_1 BS and Spanish	0.03	0.02	0.22	0.05	0.03	0.09
2 vs. 3	-0.13	0.04	0.002	-0.23	0.05	<0.0001
3 vs. 4	0.09	0.04	0.05	-0.14	0.05	0.01
4 vs. 5	-0.17	0.05	0.0003	-0.20	0.06	0.0007
5 vs. 6	0.07	0.05	0.21	-0.04	0.06	0.50
6 vs. 7	-0.01	0.06	0.85	-0.04	0.07	0.60
7 vs. 8	0.07	0.07	0.28	-0.16	0.08	0.05
8 vs. 9	-0.04	0.07	0.56	0.01	0.09	0.95

analysis of variance, all fixed effects were found to significantly impact FERT2, except breed and the covariate body weight ($P \geq 0.16$). The body weight regression was 0.00077 ± 0.00081 % does kidded/kg, and 0.00134 ± 0.00096 % does kidded/kg for FERT2. The F_1 Boer-Spanish does had a higher average for FERT1 of 0.86 ± 0.02, but were not significantly different from Spanish does that averaged 0.84 ± 0.02. Does age 5 had the highest FERT1 value of 0.95 ± 0.05. The F_1 Boer-Spanish does had an average for FERT2 of 0.51 ± 0.04, but were not significantly different from the Spanish does that averaged 0.48 ± 0.04. Does age 2, 3, and 4 had a lower value, than does age 5 through 9, for FERT2. The largest difference between adjacent ages of doe for FERT1 was between 4 and 5 year old does, and FERT2 was between 2 and 3 year old does ($P \leq 0.0007$). Results of analyses of variance and least squares means for FERT1 and FERT2 of the doe including body weight as a covariate are found in Table 18 and Table 19, respectively.

Average for FERT1, including the covariate body weight (0.86) and excluding the covariate variable body weight (0.87), for F_1 Boer-Spanish does were considerably higher than the findings of Erasmus et al. (1985) and Lawson et al. (1984) in Spanish does which showed conception rates of 74.4%, but lower than the 98% in Boer does, as reported by Campbell (1984), when Boer goats were managed on a high plane of nutrition. When the covariate body weight was not included in the model, Spanish does average of 0.84 for FERT1 did not change, and the F_1 Spanish-Boer doe average only changed by 0.01, indicating that accounting for body weight of the does had little effect on FERT1. Results of does age 5 having the maximum level of FERT1 is later than

Table 18. Analysis of variance for percentage of F_1 Boer-Spanish and Spanish does that kidded (FERT1) and that kidded the first thirty days of kidding season (FERT2) including body weight as a covariate

	FERT 1			FERT 2		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	0.90	0.35	1	1.87	0.18
Age of doe	7	4.08	0.0002	7	3.75	0.0005
Production year	8	7.09	<0.0001	8	10.55	<0.0001
Breeding date (year)	3	0.47	0.70	3	18.89	<0.0001
Body weight	1	0.93	0.33	3	1.92	0.16
Variance estimates						
Service sire	0.0002	—	—	0.0457	—	—
Sire of doe (breed)	<0.0000	—	—	0	—	—
Doe (breed dsire[a])	0.010	—	—	0.0079	—	—
Error	0.1082	—	—	0.1702	—	—
Regression coefficient						
Body weight	0.00077 ± 0.00081			0.00134 ± 0.00096		

[a] Sire of doe

Table 19. Least squares means and standard errors for percentage of F_1 Boer-Spanish and Spanish does that kidded (FERT1) and that kidded within the first thirty days of kidding season (FERT2) including the covariate body weight

	FERT 1			FERT 2		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	0.86	0.02	—	0.51	0.04	—
Spanish	0.84	0.02	—	0.48	0.04	—
Age of doe						
2	0.77	0.09	—	0.05	0.11	—
3	0.89	0.07	—	0.26	0.09	—
4	0.79	0.06	—	0.38	0.08	—
5	0.95	0.05	—	0.56	0.07	—
6	0.87	0.05	—	0.59	0.07	—
7	0.87	0.06	—	0.61	0.08	—
8	0.80	0.08	—	0.77	0.10	—
9	0.84	0.11	—	0.75	0.13	—
Differences of LSM						
F_1 BS and Spanish	0.022	0.02	0.35	0.04	0.03	0.19
2 vs. 3	-0.12	0.05	0.01	-0.21	0.06	0.0002
3 vs. 4	0.10	0.05	0.03	-0.12	0.06	0.03
4 vs. 5	-0.16	0.05	0.001	-0.18	0.06	0.003
5 vs. 6	0.07	0.07	0.16	-0.03	0.07	0.66
6 vs. 7	-0.002	0.06	0.06	-0.02	0.07	0.74
7 vs. 8	0.07	0.07	0.25	-0.15	0.08	0.05
8 vs. 9	-0.04	0.07	0.61	0.01	0.09	0.90

Erasmus et al. (1985) reported in Boer goats of 3.5 years, but very similar to the Angora doe value at 6 to 7 years (Landman, 1984 as cited by Erasmus et al., 1985), and the Dohne Merino at six years (FERT1 = 0.88) of age (Fourie and Heydenrych, 1983) for maximum FERT1. F_1 Boer-Spanish does having a higher FERT2 with the covariate body weight in the model (0.51) and without the covariate body weight in the model (0.53), may indicate that the Boer females have a slight advantage to coming in heat faster as reported by Casey and Van Niekerk (1988). However according to Lawson et al. (1984), where kids were weaned off does early, Spanish does have been reported to have up to 74% of does conceiving within the first sixty days postpartum.

Taking body weight out of the analysis resulted in a larger difference between breeds (P = 0.09), with the F_1 Boer- Spanish having a higher FERT2 value. The effect age of doe had on FERT2 steadily increased per year of age with does age eight having the highest value, when the covariate body weight was excluded from the model (FERT2 = 0.81), and when the covariate body weight was included in the model (FERT2 = 0.77). Breeding date of the doe significantly affected FERT2 but had no effect on FERT1. These findings are consistent with reports from Shelton (1978) that showed seasonality effects on heat cycles in Spanish does. In order to fully understand the significant differences in breeding dates for FERT2 in this study, further research would need to be performed.

The regression on body weight was larger for FERT2 (0.00134 ± 0.00096) than for FERT1 (0.00077 ± 0.00081), indicating a stronger relationship with body weight and does conceiving within the first thirty days of the kidding season than for does kidding in a given year. Although body condition of the does was not measured, there may be a correlation between body weight of the doe and body condition of the doe for FERT2, thus indicating does with a higher body condition scores, have the ability to conceive early in the breeding season.

Prolificacy traits. Results for number of kids born (NKB) and number of kids weaned (NKW) for the does for analysis of variance and least squares means are found in Table 20 and Table 21, respectively. In the analysis of variance results, production year, season of breeding, and body weight of the doe were all significant sources of variation of NKB, while breed was not ($P = 0.06$). In the NKW analysis of variance results, all effects accounted for significant variation except for breed ($P = 0.88$). The F_1 Boer-Spanish does averaged 1.73 ± 0.5, and Spanish does averaged 1.64 ± 0.05 for NKB. Two year old does averaged 0.92, while nine year olds averaged 2.22 for NKB. Doe ages 2 through 5, had lower values for NKB than does age 6 through 9. Doe ages 5 and 6 had the largest difference, 0.38 ± 0.09, among adjacent ages of doe analyzed. There was no significant difference for NKW between the two breeds, with Spanish does averaging 1.32 ±.06 and F_1 Boer-Spanish does averaging 1.31 ± 0.05 for NKW. Two year old does averaged 0.52 ± 0.18, while nine year old does, had the highest average of all ages, averaged 2.27 ± 0.19 for NKW. Does ages 2 through 5 had lower values for NKW than does ages 6 through 9. The largest difference of adjacent ages of the does for NKW was between the ages of 5 and 6, which was 0.36 ± 0.11.

Table 20. Analysis of variance for number of kids born (NKB) and number of kids weaned (NKW) from F_1 Boer-Spanish and Spanish does

	NKB			NKW		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	3.75	0.06	1	0.02	0.88
Age of doe	7	4.07	0.0002	7	3.89	0.0004
Year of production	8	2.94	0.003	8	3.06	0.0021
Season (year)	17	3.60	<0.0001	17	5.25	0.0001
Breeding date (year)	3	3.88	0.009	3	4.51	0.003
Variance estimates						
Sire of doe (breed)	0.0037	—	—	0	—	—
Doe (breed dsire[a])	0.0205	—	—	0.0404	—	—
Error	0.2697	—	—	0.3723	—	—

[a] Sire of doe

Table 21. Least squares means and standard errors for number of kids born (NKB) and number of kids weaned (NKW) from F_1 Boer-Spanish and Spanish does

	NKB			NKW		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	1.73	0.05	—	1.31	0.05	—
Spanish	1.64	0.05	—	1.32	0.06	—
Age of doe						
2	0.92	0.17	—	0.52	0.18	—
3	1.17	0.13	—	0.75	0.15	—
4	1.37	0.11	—	0.89	0.12	—
5	1.60	0.09	—	1.10	0.11	—
6	1.98	0.09	—	1.46	0.12	—
7	2.10	0.11	—	1.60	0.16	—
8	2.17	0.15	—	1.93	0.22	—
9	2.22	0.20	—	2.27	0.19	—
Differences of LSM						
F_1 BS and Spanish	0.09	0.05	0.06	-0.01	0.05	0.88
2 vs. 3	-0.24	0.08	0.003	-0.23	0.10	0.01
3 vs. 4	-0.20	0.08	0.01	-0.14	0.09	0.12
4 vs. 5	-0.23	0.09	0.009	-0.21	0.10	0.03
5 vs. 6	-0.38	0.09	<0.0001	-0.36	0.11	0.0008
6 vs. 7	-0.09	0.10	0.34	-0.14	0.11	0.22
7 vs. 8	-0.10	0.11	0.38	-0.33	0.13	0.01
8 vs. 9	-0.05	0.13	0.70	-0.33	0.15	0.02

Results for NKB and NKW of the doe for analysis of variance and least squares means including the covariate body weight are in Table 22 and Table 23, respectively. In the NKB analysis of variance, season of breeding and the covariate body weight were significant sources of variation for NKB, while breed, age of doe, production year, and breeding date were not. Conversely, in the NKW analysis of variance, all effects except for breed were significant sources of variation. The regression on body weight was 0.00913 ± 0.00135 kids born/kg for NKB, and 0.00635 ± 0.00167 kids weaned/kg for NKW. The F_1 Boer-Spanish does averaged 1.65 ± 0.04 which was not significantly different than the Spanish does that averaged 1.62 ± 0.05 for NKB. Two year old does averaged 1.25 while nine year old does, which showed the highest average for NKB, had an average of 1.96 for NKB. Does in the age group of 2 through 5, had lower numerical values for NKB than does in the age group of 6 through 8. The largest LSM difference among the adjacent ages for NKB was between 5 and 6 year old does, and had a value of 0.28 ± 0.09. Least squares means of Spanish does for NKW averaged 1.30 ± 0.05, but were not significantly different from the F_1 Boer-Spanish does, who averaged 1.25 ± 0.05. Doe ages 2 through 5 had lower numerical values than does ages 6 through 9 for NKW. Two year old does had the lowest average NKW of 0.73 ± 0.19, while 9 year old does had the highest NKW at 2.10 ± 0.23. The largest LSM difference for adjacent ages of doe was between the ages of 5 and 6 (0.29 ± 0.11) for NKW. Although not significantly different (*P* = 0.06) from the Spanish does, the F_1 Boer-Spanish does had a numerically higher prolificacy (NKB) value. These results from the two different breed types are

Table 22. Analysis of variance for number of kids born (NKB) and number of kids weaned (NKW) from F_1 Boer-Spanish and Spanish does including body weight as a covariate

	NKB			NKW		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	0.47	0.50	1	1.11	0.30
Age of doe	7	1.61	0.12	7	2.38	0.02
Production year	8	1.92	0.05	8	2.59	0.008
Season (year)	17	4.07	<0.0001	17	5.66	<0.0001
Breeding date (year)	3	2.35	0.07	3	3.94	0.008
Body weight	1	45.33	<0.0001	1	14.41	0.0002
Variance estimates						
Sire of doe (breed)	0.0016	—	—	0	—	—
Doe (breed dsire[a])	0.0169	—	—	0.0414	—	—
Error	0.2657	—	—	0.3716	—	—
Regression coefficient						
Body weight	0.00913 ± 0.00135			0.00635 ± 0.00167		

[a] Sire of doe

Table 23. Least squares means and standard errors for number of kids born (NKB) and number of kids weaned (NKW) from F_1 Boer-Spanish and Spanish does including body weight as a covariate

	NKB			NKW		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish	1.65	0.04	—	1.25	0.05	—
Spanish	1.62	0.05	—	1.30	0.05	—
Age of doe						
2	1.25	0.16	—	0.73	0.19	—
3	1.36	0.13	—	0.87	0.15	—
4	1.45	0.10	—	0.93	0.12	—
5	1.54	0.09	—	1.05	0.11	—
6	1.82	0.09	—	1.34	0.11	—
7	1.84	0.11	—	1.45	0.13	—
8	1.89	0.14	—	1.75	0.17	—
9	1.96	0.19	—	2.10	0.23	—
Differences of LSM						
F_1 BS and Spanish	0.03	0.04	0.50	-0.05	0.05	0.30
2 vs. 3	-0.11	0.08	0.18	-0.14	0.10	0.15
3 vs. 4	-0.09	0.08	0.24	-0.06	0.09	0.49
4 vs. 5	-0.09	0.09	0.32	-0.11	0.11	0.31
5 vs. 6	-0.28	0.09	0.002	-0.29	0.11	0.007
6 vs. 7	-0.02	0.10	0.83	-0.11	0.12	0.35
7 vs. 8	-0.05	0.11	0.62	-0.30	0.13	0.02
8 vs. 9	-0.06	0.13	0.62	-0.35	0.15	0.02

consistent with the literature reports of Spanish females reported by Lawson and Shelton (1982) and Bogui (1986), but were lower than results from purebred Boer females reported by Malan (2000) and Browning et al. (2004). Nonetheless, the higher average for NKB of the F_1 Boer-Spanish seems to support literature reports that the purebred Boer is a more prolific breed than the Spanish goat (Lawson and Shelton, 1982; Casey and Van Niekerk, 2000; Malan, 2000), but may also result from the maternal heterosis advantage of the F_1 Boer-Spanish does over that of the Spanish does. Although in this study heterosis levels are not able to be estimated, sheep estimates for maternal hybrid vigor are 8% for NKB as stated by Bourdon (1997). Furthermore, previous reports from Bradley et al. (1972) in sheep and Anous and Mourad in goats (1993) confirm the added increase in performance levels due to heterosis, in particular maternal heterosis.

When accounting for differences in breeding weight of the does, the difference between breeds for NKB was substantially less ($P = 0.50$). This is a result of the greater mature size (Table15) of the F_1 Boer-Spanish does. Age of doe was a significant source of variation for NKB in both models (including vs. excluding the covariate body weight). The steady increase in NKB per year associated with increase in age, resulted in does of age 6 through 9 having the highest levels for NKB, which is fairly consistent with previous reports in the literature (Fourie and Heydenrych, 1983). Does age 9 having the highest NKB value, including the covariate body weight in the model (1.96) and excluding body weight in the model (2.22), is different from findings of Erasmus et al. (1985), who showed Boer does between ages 3.5 and 4.5 as having the maximum NKB. Additionally, these values are also different from findings from Bogui (1986) in Spanish does where the highest occurrence of multiple birth (twins and triplets), was at age 4. However, Angora does had the highest level for NKB at ages 8 and 9 (Landman, 1984 as cited by Erasmus et al., 1985) which is consistent with the results of this study.

Even though F_1 Boer-Spanish does had higher estimates for NKB, Spanish females numerically had higher averages of NKW in analysis with the covariate body weight ($P = 0.30$) and without the covariate body weight ($P = 0.88$). Differences between breeds for NKB and NKW were small. In general F_1 Boer-Spanish does had a non-significant advantage for NKB. The result for NKW showed that any advantage disappeared by time of weaning. The NKW value of 1.31 for F_1 Boer-Spanish does is substantially lower than values of 1.82 reported by Erasmus et al. (1985), and 1.48 reported by Campbell (1984) as cited by Casey and Van Niekerk (1988), for purebred Boer does. Previous literature from Bogui (1986) showed a NKW number of 1.38 for Spanish does, which is similar to results seen in this study (1.32). These results indicate that the survivability rate of F_1 Boer-Spanish doe’s kids was lower than that of the Spanish doe’s kids. Based on past literature, low survivability rates are usually due to kids with extremely low birth weights and kids who are born as triplets or quadruplets (Gall, 1981; Erasmus et al., 1985; Holst, 1990). The cause of having lower NKW numbers could be due to F_1 Boer-Spanish does not performing as well on a lower plane of nutrition and as a result the inability of the doe to adequately provide for the kid, as seen in Casey and Van Niekerk (1988) where Boer does reportedly had 30% kid mortality rates. However, due to the fact that the kids of the F_1 Boer-Spanish females had a maternal heterosis advantage over that of the kids from the Spanish does, one might expect to see higher survivability rates in the kids from the F_1 Boer-Spanish does, as reported by Sebhatu et al. (1993) where favorable maternal heterosis was seen in kid mortality rates of kids 90 days of age. Nonetheless, because of the possible lack of adaptation to the given environment these maternal heterosis effects were not seen in the kids of the F_1 Boer-Spanish does when analyzing NKW.

The doe age effect in respect to NKW was consistent with that of a earlier report where Angora does reached a maximum level of NKB and NKW at ages 8 and 9, respectively (Landman, 1984 as cited by Erasmus et al., 1985). However, results from Bogui (1986) in Spanish does, and Erasmus et al. in Boer does show NKW reaching peak levels at earlier ages of 4 and 5, which is not consistent with results of this study. Nonetheless, one consistency from the literature and results from this study seems to be that a dramatic increase in performance is seen in does at age 5 and older as compared to does ages 2 through 4 (Erasmus et al., 1985; Landman, 1984 as cited by Erasmus et al. 1985, Bogui, 1986). Although there was not a large difference between the regression of body weight for NKB and NKW, the value for NKB was larger than NKW. As noted previously, the linear relationship between body weight and NKB/NKW, is most likely a combination of the increase in mature size as the does increase in age, and also the relationship of body condition and fertility of the does

Kid production traits. Results of analysis of variance and least squares means for total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) of the doe are found in Table 24 and Table 25, respectively. All effects were found to be significant

Table 24. Analysis of variance for total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) from F_1 Boer-Spanish and Spanish does

	TLWB, kg			TLWW, kg		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	2.71	0.11	1	1.24	0.27
Age of doe	7	5.44	<0.0001	7	5.93	<0.0001
Production year	8	3.49	0.0006	8	10.05	<0.0001
Season (year)	15	2.41	0.002	14	4.27	<0.0001
Breeding date (year)	3	4.85	0.002	3	3.98	0.008
Variance estimates						
Sire of kid	0.0065	—	—	1.21	—	—
Sire of doe (breed)	0.0464	—	—	1.53	—	—
Doe (breed dsire[a])	0.2556	—	—	4.52	—	—
Error	2.22	—	—	64.70	—	—

[a] Sire of doe

Table 25. Least squares means and standard errors for total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) from F_1 Boer-Spanish and Spanish does

	TLWB, kg			TLWW, kg		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	5.72	0.14	—	27.48	0.80	—
Spanish	5.47	0.16	—	26.59	0.88	—
Age of doe						
2	2.93	0.52	—	11.09	2.82	—
3	3.54	0.42	—	15.84	2.33	—
4	4.15	0.33	—	20.76	1.92	—
5	4.99	0.27	—	27.71	1.67	—
6	6.47	0.27	—	32.38	1.63	—
7	7.05	0.33	—	34.24	1.94	—
8	7.70	0.45	—	37.09	2.59	—
9	7.93	0.61	—	37.18	3.51	—
Differences of LSM						
F_1 BS and Spanish	0.25	0.15	0.11	0.89	0.80	0.27
2 vs. 3	-0.61	0.24	0.01	-4.76	1.34	0.0004
3 vs. 4	-0.61	0.24	0.01	-4.92	1.36	0.0003
4 vs. 5	-0.84	0.27	0.001	-6.95	1.51	<0.0001
5 vs. 6	-1.48	0.28	<0.0001	-4.66	1.73	0.007
6 vs. 7	-0.58	0.29	0.04	-1.86	1.78	0.29
7 vs. 8	-0.65	0.33	0.05	-2.85	2.05	0.16
8 vs. 9	-0.23	0.39	0.55	-0.09	2.45	0.96

sources of variation for TLWB and TLWW except for breed ($P \geq 0.11$). The F_1 Boer-Spanish does had the high average TLWB of 5.72 ± 0.14 kg, but were not significantly different than the Spanish does which averaged 5.47 ± 0.16 kg. For every additional year of doe age TLWB increased from ages 2 though 9, with 9 year old does having the highest TLWB value of 7.93 ± 0.61 kg. Does in the age groups of 2 through 5 had lower values for TLWB than does age 6 through 9. The largest difference between adjacent ages of the does for TLWB was between does age 5 and 6, which was 1.48 ± 0.28 kg. For TLWW there was no difference ($P = 0.27$) between F_1 Boer-Spanish and Spanish does. Does age 2 through 4 had lower values for TLWW than does age 5 through 9. There was no significant difference between does ages 6 versus 7, 7 versus 8, and 8 versus 9, within each adjacent age group. Nine year old does had the highest value for TLWW of 37.18 ± 3.51 kg, while the largest difference between adjacent ages of does was between 4 and 5 year old does, which was 6.95 ± 1.51 kg.

Results of analysis of variance and least squares means for TLWB and TLWW of the doe including body weight as a covariate are found in Table 26 and Table 27, respectively. All effects in the analysis of variance results were significant sources of variation for TLWB and TLWW except breed which had a *P*-value of 0.61 and 0.90 for TLWB and TLWW, respectively. The regression for body weight yielded coefficients of 0.02972 ± 0.00401 kg/kg and 0.1416 ± 0.02361 kg/kg, for TLWB and TLWW, respectively. The F_1 Boer-Spanish does averaged 5.42 ± 0.13 kg, but were not significantly different than the Spanish does, who averaged 5.47 ± 0.13 kg for TLWB. Does in the age group of 2 through 5, had lower values for TLWB than does between the

Table 26. Analysis of variance for total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) from F_1 Boer-Spanish and Spanish does including body weight as a covariate

	TLWB			TLWW		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	0.17	0.68	1	0.01	0.90
Age of doe	7	2.89	0.0005	7	3.12	0.003
Production year	8	3.93	0.0001	8	9.56	<0.0001
Season (year)	15	2.61	0.0007	14	4.42	<0.0001
Breeding date (year)	3	3.46	0.01	3	3.16	0.02
Body weight	1	54.91	0.0001	1	35.96	<0.0001
Variance estimates						
Sire of kid	0.0079	—	—	0.3721	—	—
Sire of doe (breed)	0.0250	—	—	1.552	—	—
Doe (breed dsire[a])	0.1885	—	—	2.731	—	—
Error	2.1582	—	—	63.536	—	—
Regression coefficient						
Body weight	0.02972 ± 0.00401			0.1416 ± 0.02361		

[a] Sire of doe

Table 27. Least square means and standard errors for total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) from F_1 Boer-Spanish and Spanish does including body weight as a covariate

	TLWB, kg			TLWW, kg		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	5.47	0.13	—	26.11	0.78	—
Spanish	5.42	0.14	—	26.03	0.79	—
Age of doe						
2	4.06	0.49	—	15.48	2.56	—
3	4.24	0.39	—	18.36	2.12	—
4	4.48	0.31	—	21.74	1.79	—
5	4.83	0.26	—	26.62	1.61	—
6	6.00	0.27	—	30.13	1.63	—
7	6.24	0.33	—	30.39	1.93	—
8	6.73	0.43	—	32.73	2.47	—
9	6.98	0.57	—	33.11	3.25	—
Differences of LSM						
F_1 BS and Spanish	0.05	0.13	0.68	0.07	0.67	0.90
2 vs. 3	-0.18	0.24	0.45	-2.88	1.31	0.02
3 vs. 4	-0.24	0.23	0.31	-3.38	1.32	0.01
4 vs. 5	-0.36	0.26	0.17	-4.49	1.50	0.001
5 vs. 6	-1.17	0.27	<0.0001	-3.51	1.68	0.03
6 vs. 7	-0.23	0.29	0.41	-0.26	1.73	0.88
7 vs. 8	-0.49	0.32	0.12	-2.33	1.99	0.23
8 vs. 9	-0.25	0.37	0.50	-0.38	2.38	0.87

ages of 6 through 9. The largest difference for adjacent ages for TLBW of the does was between does of age 5 and 6 (1.17 ± 0.26 kg). There was no significant difference between the breeds for TLWW, with F_1 Boer-Spanish does averaging 26.11 ± 0.78 kg, and Spanish does averaging 26.03 ± 0.79 kg. Nine year old does had the largest TLWW value of 33.11 ± 3.25 kg, with the largest difference between adjacent ages for TLWW of does coming from the doe ages of 4 and 5, which was 4.49 ± 1.50 kg.

The least squares means for both breeds for TLWB and TLWW were considerably higher than those reported by Bogui (1986) of 4.10 kg for TLBW and 24.74 kg for TLWW of Spanish does, and also values of 7.20 kg for TLBW and 16.60 kg for TLWW of several breeds of sheep as reported by Rosati et al. (2002). Although not significant ($P = 0.11$) between breeds, F_1 Boer-Spanish does did have a higher value for TLWB than the Spanish does. These results are consistent with past literature where purebred Boer does have typically been found to be more prolific and produce kids with higher birth weights than Spanish does (Bogui, 1986; Erasmus, 2000; Campbell, 2003). The effect of TLWB and TLWW by age of the doe is consistent with the previous research results of Landman (1984) in Angora goats, Fourie and Heydenrych (1983) in sheep, and Cundiff et al. (1992) in cattle, where the highest levels of production in females, was found between the ages of age 5 to 9 (in all species). These results show the importance of does remaining in the herd through age 5, so that breeders can take advantage of the most productive years in females' lives.

When analyzing TLWW there was not as large of a difference between breeds ($P = 0.27$) as compared to the TLWB analysis (analyses that did not include body weight as a covariate). With the sires of the kids of the does being purebred Boer or a high percentage Boer, the kids from Spanish does have $\leq$ 100% direct hybrid vigor and the kids from the F_1 Boer-Spanish does have $\leq$ 50% direct hybrid vigor and 100% maternal hybrid vigor. Thus, the expected increase in performance due to heterosis, in kid survivability and pre-weaning growth would be found in the TLWW trait. For example, in research involving sheep, Boujenane et al. (1991) reported that crossbred ewes had a higher total lamb production over that of purebreds, which in part was due to maternal heterosis effects in the crossbred ewes. However, as seen in the NKB and NKW results, kids from the F_1 Boer-Spanish does had a higher rate of pre-weaning kid mortalities than kids from the Spanish does, thus leading to a similar TLWW value between the two different dam breed types.

One reason for certain breeds or crossbred animals not maximizing their performance potential may be due to a genotype by environment interaction. Although in this study no test can be made for genotype by environment interactions, because all goats were raised in the same environment, results from Nabeel et al. (1984) showed a significant interaction between different environments and crossbred groups of ewes, which explains why genetically diverse breeds perform better or worse in different environments. Another reason for a similar performance in TLWW between the two breeds in this study may be due to the fact that kids from crossbred goats show more of a weight difference at a later age such as 150 or 210 days (Anous and Mourad, 1993). Nonetheless, in this study, the lower TLWW values in the F_1 Boer-Spanish does are primarily due to F_1 Boer-Spanish females having a higher rate of NKB over the Spanish does, but in the end weaning less kids (NKW) than the Spanish does, and thus having a lower TLWW value

With the covariate body weight in the model, less of a difference was found between breeds for TLWB (*P* =0.68) and TLWW (*P* =0.90) as compared with the original TLWB and TLWW model. Since the F_1 Boer-Spanish does significantly heavier at breeding than the Spanish does, as seen is the previous body weight analysis, fitting the variable as a covariate would result in a similar performance between breeds as seen in these models, if the breed difference was due to size difference.

Kid growth traits

Birth weight. Results of analysis of variance and least squares means for birth weight of the kid are reported in Table 28 and Table 29, respectively. Analysis of variance results showed all fixed effects being significant sources of variation for birth weight except for breed (P = 0.44). The regression on doe body weight for birth weight of the kids was 0.004162 ± 0.00093 kg /kg. Least squares means for kids from Spanish does (3.27 ± 0.04 kg) were higher, but not significantly different than the kids of F_1 Boer-Spanish does who averaged 3.24 ± 0.04 kg. Male kids at birth weighed 3.37 ± 0.04 kg, and were significantly heavier than female kids who averaged 3.14 ± 0.04 kg. Kids born as singles were 0.36 kg heavier than twins, and 0.72 kg heavier than triplets. Single born kids were significantly heavier than twin born, while twins were significantly heavier than triplets.

Table 28. Analysis of variance for birth weight of kids from F_1 Boer-Spanish and Spanish does

Source	Birth weight, kg		
	df	F value	*P* value
Breed	1	0.60	0.44
Type of birth	2	157.17	<0.0001
Sex	1	141.04	<0.0001
Production year	8	21.36	<0.0001
Month (year of birth)	28	5.74	<0.0001
Body weight	1	20.20	<0.0001
Variance estimates			
Sire of kid	0.0158	—	—
Sire of doe (breed)	0.0032	—	—
Doe (breed sire)	0.0203	—	—
Error	0.1749	—	—
Regression coefficient			
Body weight	0.0042 ± 0.00093		

Table 29. Least squares means and standard errors for birth weight of kids from F_1 Boer-Spanish and Spanish does

	Birth weight, kg		
Effect	LSM	Std. error	*P* value
Breed			
F_1 Boer-Spanish (BS)	3.24	0.04	—
Spanish	3.27	0.04	—
Sex			
Male	3.37	0.04	—
Female	3.14	0.04	—
Type of birth			
Single	3.62	0.04	—
Twin	3.26	0.04	—
Triplet[d]	2.90	0.05	—
Differences of LSM			
F_1 BS and Spanish	-0.03	0.04	0.44
Male and Female	-0.24	0.02	<0.0001
Single and twin	0.36	0.03	<0.0001
Twin and triplet	0.36	0.04	<0.0001

[d] Three F_1 Boer-Spanish quadruplets included in triplet group analysis

Weaning weight and pre-weaning average daily gain. Analysis of variance and least squares means for weaning weight (WWT) and pre-weaning average daily gain (ADG) of the kid are in Table 30 and Table 31, respectively. All effects were significant sources of variation for kid weaning weight except for breed (P =0.46). Also, all effects except breed (P = 0.45), were significant sources of variation on kid pre-weaning average daily gain. The regression of body weight on weaning weight and pre-weaning average daily gain were 0.0415 ± 0.00677 kg/kg and 0.4359 ± 0.07426 g/kg, respectively. Additionally, the regression of weaning age on weaning weight and pre-weaning average daily gain were -0.05133 ± 0.00579 kg/d and -0.557 ± 0.06347 kg/d, respectively.

Kids of Spanish does had the highest weaning weight average of 16.18 ± 0.40 kg, but were not significantly different than the kids of the F_1 Boer-Spanish does which averaged 15.95 ± 0.38 kg. Male kids averaged 17.09 ± 0.37 kg and were significantly heavier than female kids that averaged 15.03 ± 0.37 kg. Weaning weights for single kids raised as single, averaged 18.33 ± 0.32 kg, but were not significantly heavier than twins raised as singles whose average was 17.47 ± 0.41 kg. There was no significant difference in weaning weight of triplet kids raised as twins and triplets raised as triplets. Pre-weaning average daily gain (ADG) of the kid resulted in kids of the Spanish does having the highest pre-weaning daily gain of 146.45 ± 4.46 g, but not being significantly different from kids of the F_1 Boer-Spanish does which averaged 143.96 ± 4.26 g. Male kids had a value of 155.34 ± 4.13 g ADG and significantly out gained female kids that had a value of 135.08 ± 4.13 g. Concerning type of birth and weaning, single kids weaned

Table 30. Analysis of variance for weaning weight and pre-weaning average daily gain of kids from F_1 Boer-Spanish and Spanish does

	Weaning weight, kg			Average daily gain, g		
Source	df	F value	*P* value	df	F value	*P* value
Breed	1	0.54	0.46	1	0.57	0.45
Sex	1	191.53	<0.0001	1	155.1	<0.0001
Production year	8	49.43	<0.0001	8	58.46	<0.0001
Body weight	1	37.48	<0.0001	1	34.45	<0.0001
Type of birth / weaning	5	65.60	<0.0001	5	51.97	<0.0001
Weaning age	1	78.38	<0.0001	1	82.69	<0.0001
Variance estimates						
Sire of the kid	1.8451	—	—	252.07	—	—
Sire of doe (breed)	0.2773	—	—	29.27	—	—
Doe (breed dsire[a])	0.8216	—	—	96.50	—	—
Error	8.1624	—	—	964.68	—	—
Regression coefficient						
Body weight	0.0415 ± 0.00677			0.4359 ± 0.07426		
Weaning age	-0.05133 ± 0.00579			-0.5772 ± 0.06347		

[a] Sire of doe

Table 31. Least squares means and standard errors for weaning weight and pre-weaning average daily gain of kids from F_1 Boer-Spanish and Spanish does

	Weaning weight, kg			Average daily gain, g		
Effect	LSM	Std. error	*P* value	LSM	Std. error	*P* value
Breed						
F_1 Boer-Spanish (BS)	15.95	0.38	—	143.96	4.26	—
Spanish	16.18	0.40	—	146.45	4.45	—
Sex						
Male	15.05	0.37	—	135.08	4.13	—
Female	17.09	0.37	—	155.34	4.11	—
Type of birth / weaning						
(1) single / single	18.33	0.32	—	163.53	3.64	—
(2) twin / single	17.47	0.41	—	160.15	4.59	—
(3) twin / twin	15.45	0.31	—	136.00	3.49	—
(4) triplet / single	17.54	1.10	—	167.10	11.97	—
(5) triplet / twin	14.20	0.53	—	126.53	5.81	—
(6) triplet / triplet	13.40	0.49	—	117.93	5.41	—
Differences of LSM						
F_1 BS and Spanish	-0.23	0.31	0.46	-2.49	3.29	0.45
Male and Female	-2.06	0.15	<0.0001	-20.25	1.62	<0.0001
1 vs. 2	0.86	0.33	0.0099	3.37	3.63	0.35
2 vs. 3	2.02	0.31	<0.0001	24.15	3.42	<0.0001
3 vs. 4	-2.09	1.06	0.04	-31.09	11.57	0.007
4 vs. 5	3.33	1.13	0.003	40.16	12.22	<0.0001
5 vs. 6	0.80	0.57	0.16	8.60	6.19	0.16

as singles were not significantly different than twins weaned as singles for ADG. Triplet kids weaned as triplets had the lowest average ADG of 117.93 ± 5.41 g.

No significant difference was found between the two breed types of does for kid birth weight (*P* = 0.44), weaning weight (*P* =0.46) and pre-weaning average daily gain (*P* =0.45), with the kids from Spanish does numerically having the highest averages for all three traits. The values for birth and weaning weight from kids of both dam breed types are higher than previous reports of Spanish kids which averaged birth and weaning weights of 2.41 kg and 17.86 kg (Bogui, 1986), respectively, when weaned from 3 to 5 months of age. At the same time, results from this study for birth and weaning weights from kids of both dam breed types are somewhat lower than reports of past literature where Boer goats averaged up to 3.9 kg at birth and 29 kg at weaning (weaned at 120 days) (Erasmus, 2000; Malan, 2000). The ADG results for kids of both dam breed types are lower than the 150 g/day and 200 g/day under extensive/intensive conditions, respectively, as reported by Casey and Van Niekerk (1988) for Boer goat kids. However, results for ADG from this study for both dam breed types were higher than reports by Bogui (1986), which showed pre-weaning average daily gain of Spanish kids as averaging 132 g/day. Results from kid type of birth and weaning are consistent with past literature reports where single kids or multiple birthed kids (twin or triplet) raised as singles were heavier at weaning and averaged higher daily gain than kids born as twins and triplets and raised as twins and triplets (Bogui, 1986; Sebhatu, 1993).

Maternal heterosis in the F_1 Boer-Spanish females would make it logical to expect the kids from the F_1 Boer-Spanish females would be higher for growth traits than the kids of the Spanish does. However, with the Spanish does kids being ≤ 50% Boer, they have a direct heterosis advantage over that of the F_1 Boer-Spanish does' kids. Therefore, the magnitude of maternal versus direct hybrid vigor would affect the relative performance of the two kid types. If the mature hybrid vigor in the F_1 Boer-Spanish does was similar in magnitude to the difference in direct hybrid vigor, the result could be similar growth performance in the kids, as reported in past literature (Sebhatu et al., 1993; Zhiquan et al., 2001). With past research showing Boer kids to have higher birth weights and weaning weights than Spanish does' kids (Bogui, 1986; Luo et al., 2000; Malan, 2000), conclusions could be made that kids with a higher combination of maternal and direct heterosis, coupled with being a higher percentage of Boer would outperform other kids having less overall heterosis and being more percentage of the Spanish breed.

In addition to the impact of heterosis in the kids, there is literature that states Boer goat crosses may show equal performance levels for growth traits as compared with purebred Boer goats. Gebrelul and Iheanacho (1997), as cited by Luo et al. (2000), and Newman and Paterson (1997), reported no difference between crossbred Boer goats and purebred Boer goats for growth traits. Nonetheless, as indicated from past literature (Blackburn, 1995, Erasmus, 2000), on a low plane of nutrition, breeds that may have a higher nutritional requirement such as the Boer, may show low performance levels as compared to when managed on a higher plane of nutrition. Therefore, one conclusion from these results that may be made is that, because of the environmental constraints, kids from the F_1 Boer-Spanish females could not perform at their optimum level and, therefore, were not significantly different than kids from the Spanish does. However, since there was no other environment in which these goats were raised, testing for genotype by environment interactions was not possible and, thus, conclusions must be made by comparing previous research results and analyzing additive and non-additive genetic components.

Doe longevity

Analysis of variance and least squares means for doe longevity are in Table 32 and Table 33, respectively. Fixed effects of year of birth was a significant source of variation for longevity of the does, while breed was not (P = 0.06). Least squares means for F_1 Boer-Spanish doe longevity (6.15 ± 0.21 years) was higher, but was not significantly different from Spanish does that had a value of 5.56 ± 0.22 years. Even though not significant, the sire breed difference between the does approached significance (P =0.06), indicating there is a non-significant difference for F_1 Boer-Spanish does remaining in the herd longer than the Spanish does. Although the literature is limited in longevity studies in goats, results from this study are somewhat lower than what Malan (2000) reported of Boer does staying in the herd up to ten years. However, Erasmus et al. (1985) reported that in order to achieve maximum genetic potential and economic return, does should not be retained in the flock after 5.5 years of age. In order to validate these claims, further total doe production and economic analysis would be needed than was collected in this study.

Table 32. Analysis of variance for longevity of F_1 Boer-Spanish and Spanish does

	Longevity, years		
Source	df	F value	*P* value
Breed	1	3.76	0.06
Year of birth	1	3.61	0.05
Variance estimates			
Sire of doe (breed)	0	—	—
Error	6.59	—	—

Table 33. Least squares means and standard deviations for longevity of F_1 Boer-Spanish and Spanish does

	Doe longevity (years)		
Effect	LSM	Std. error	*P* value
Breed			
F_1 Boer-Spanish (BS)	6.15	0.21	—
Spanish	5.56	0.22	—
Differences of LSM			
F_1 BS and Spanish	0.59	0.30	0.06

Doe survivability

Chi-square analysis of doe survivability is in Table 34. No significant difference was found between the four different proportions (causes of doe leaving the herd) for F_1 Boer-Spanish and Spanish does (P = 0.54). F_1 Boer-Spanish does had a higher (but not significantly) percentage of does leaving the herd caused by Caseous Lymphadenitis of 13.40 %, while Spanish does had a value of 9.62 %. Moreover, F_1 Boer-Spanish does had the highest percentage of does leaving the herd due to old age (age 9) of 15.12 %, while Spanish does had a value of 10.31 %. Although there is little research pertaining to doe survivability, information from Gall (1981) and Larsgard and Vaabenoe (1993) showed that udder related causes and Caseous Lymphadenitis are among the most common diseases/problems in goats. Even though the udder category is not totally comprised of does with mastitis, Gall (1981) reports that typical numbers of does with mastitis can range from 3 to 25.9% within a herd. Although analyzing how age of doe affects goats with Caseous Lymphadenitis was not performed, Gall (1981) reported that occurrences seem to be higher in older aged goats. With limited knowledge concerning the measurement and analysis of doe survivability, perhaps this study could be a platform on which to build for further research in this area.

Table 34. Chi-square analysis for cause of culling of does by breed

	F_1 Boer-Spanish		Spanish	
Effect	n	%	n	%
Cause of doe leaving herd				
Old age	44	15.12	30	10.31
Udder related	38	13.06	32	11.00
Caseous lymphadenitis	39	13.40	28	9.62
Other	39	13.40	41	14.09
Overall	160	54.98	131	45.02
Chi-square test				
Chi-square	2.15	—	—	—
df	3	—	—	—
P value	0.54	—	—	—

CONCLUSION

In this study, F_1 Boer-Spanish does were significantly heavier at birth and maturity (measured at breeding time) than the Spanish does. Nonetheless, for fertility traits, no significant difference was seen between the two doe breed types. Although there was also no significant difference for number of kids born between the F_1 Boer-Spanish and Spanish does, F_1 Boer-Spanish does did have a higher value ($P = 0.06$) than Spanish does for prolificacy, which is consistent with past literature where the Boer has been reported to be a highly prolific breed (Malan, 2000). However, when analyzing number of kids weaned, there were no significant differences ($P = 0.88$) between the two breeds with Spanish does weaning more kids on average than the F_1 Boer-Spanish does. The kid production traits of the does resulted in no significant difference for total litter weight at birth ($P = 0.15$) and total litter weight at weaning ($P = 0.80$) between the two doe breed types.

In addition to the traits of the doe, the growth traits of the does' kid, were not significantly different between F_1 Boer-Spanish and Spanish does for kid birth weight ($P = 0.44$), kid weaning weight ($P = 0.46$), and kid pre-weaning average daily gain ($P = 0.46$). The results of the kids' growth traits were considerably high and comparable to previous performance of purebred Boer kids from past literature. However the added maternal heterosis of the F_1 Boer-Spanish doe did not indicate an increase in performance over that of the kids' from the Spanish does. Finally, for doe survivability and longevity, no differences were found between the two breed for cause of doe leaving the herd, and the length of time in years, doe remained in the herd.

Birth weight of the doe, number of kids born, and total litter weight at birth, were all either significantly higher or approached significance for the F_1 Boer-Spanish does over that of the Spanish doe. However, when the doe traits were analyzed at weaning, there was little or no difference between the two doe breed types for performance of doe weaning weight, number of kids weaned, and total litter weight at weaning. From these observations, the added prolificacy benefits of the F_1 Boer-Spanish does are seen at birth, but, because of a possible lack of adaptation to environmental conditions, a lower performance was seen in number of kids weaned and therefore resulting in no differences between the doe breed types for total litter weight at weaning.

Overall conclusions from the study are that there is no significant difference between the F_1 Boer-Spanish and Spanish does for reproduction, production and progeny growth differences when analyzed at weaning. Therefore, based on these environmental conditions and management system, no added benefit is seen in using F_1 Boer-Spanish does over Spanish does. Further research is needed in order to fully understand what environmental conditions are needed in order to fully capitalize on the genetic potential of the Boer goat.

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