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Evaluation of Non-Genetic Factors Affecting Birth Weight of Kalahari Red Goats in South Africa

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ABSTRACT

This study investigates the effect of non-genetic factors on the birth weight of Kalahari Red goats, a critical economic parameter in livestock production. Analysing data from 1902 goat kids born between 2008 and 2017 in different regions of South Africa, including the Northern (Gauteng, Mpumalanga, Northwest, and Limpopo), Southern (Eastern Cape and the eastern part of Western Cape), and Eastern (KwaZulu-Natal and the eastern part of Eastern Cape), the research employs a least-squares analysis of variance (ANOVA) using the General Linear Model (GLM) procedure. The results highlight the significance of various factors in determining birth weight. Season of birth, sire age, doe age, sex of the kid, breeder, year of birth, and birth type emerge as influential sources of variation ($p < 0.05$). Notably, region and kidding interval show no significant effect on birth weight ($p > 0.05$). Male kids generally have a higher average birth weight compared to females. Single births result in higher weights than multiple births (twins, triplets, and quadruplets). The study underscores the importance of considering these factors in genetic evaluation models. It emphasises their relevance in enhancing the understanding of prenatal growth and postnatal development in Kalahari Red goats within the context of livestock production.

Keywords: Adaptability, Growth, Reproductive Potential

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1. INTRODUCTION

Goats are considered valuable genetic resources for producing meat, milk, skin, and fibre (Atoui et al., 2017). Furthermore, they play a crucial role in the socio-economic aspects of human lives. Due to their remarkable adaptability to diverse environments, goats are extensively distributed in tropical and subtropical regions (Mbayahaga et al., 1998). Kalahari Red goats were developed from two lines of the brown lop-eared 'unimproved' Indigenous goats in South Africa and the Boer goats of Namibia (Campbell, 2003). In 1991, Albie Horn also conducted the selection of indigenous brown and brown and white goats from the former homelands of the Eastern Cape, the Karoo, and Namibia. In livestock production, birth weight is considered an economically significant trait (Atoui et al., 2017). It has been established by Bailgy et al. (1990) that birth weight influences the future performance of individuals within their respective environments. A positive genetic correlation exists between body weights at different stages of development (Safari et al., 2005).

Consequently, selecting for increased birth weight is anticipated to result in elevated mature body weight, positively impacting enterprise profitability. Birth weight is subject to influence by both genetic and non-genetic factors, with performance traits being susceptible to various factors (Afzal et al., 2004). Non-genetic factors such as the age of the animal, sex, birth type, and the age of the does significantly influence growth traits in many livestock species, including birth weight, as extensively documented in the literature.

However, there is a shortage of information regarding the growth traits and non-genetic factors affecting the South African Kalahari Red goat breed. To accurately estimate breeding values and ensure unbiased results in multiple trait analyses of growth traits, it is imperative to have precise knowledge of the covariances among random and fixed effects in the model (Neser et al., 2012). Incorrectly specified covariance components may lead to biased breeding values and an inaccurate assessment of the effectiveness of genetic selection. While various studies in South Africa have focused on traits such as milk yield in different goat breeds, there is limited research on growth traits. Similarly, studies on growth traits have been conducted for various breeds globally, but South Africa has yet to contribute significantly to this body of knowledge. Despite the indigenous status of the Kalahari Red goat breed, there is a notable scarcity of information about it in the existing literature. Understanding the impact of environmental factors on economically important traits is crucial for goat production. This knowledge can contribute to reducing kid mortality rates and enhancing overall production potential (Husain, 2004). Production traits are known to be influenced by non-genetic factors such as sex, season, year, and type of birth (Kumar et al., 2007). Therefore, the primary objective of the current study was to assess the non-genetic factors affecting the birth weight trait of Kalahari Red goats in South Africa.

2. MATERIALS AND METHODS

2.1. Data Sampling

The SA Studbook availed a total of 26204 performance records for the purebred Kalahari Red breed. The records ranged from the year 1977 to 2018, and kids were born all year round in different provinces/regions of South Africa: Northern (Gauteng, Mpumalanga, Northwest, and Limpopo), Southern (Eastern Cape and the eastern part of Western Cape), and Eastern (KwaZulu-Natal and the eastern part of Eastern Cape). The information included pedigree information, birth date, season of birth, birth weight (BW), birth type, breeder, sex, age of sire & dam at kidding. Most of the provinces had no records on the birth weight of Kalahari Red goats. Birth weight, an important trait correlated with mature body weight and could have a desirable impact on overall profitability, was analysed. Purposive sampling was done, targeting goats with birth weight measurements.

2.2. Data Editing

Edits consisted of checks for sex, litter size, the season of birth, year of birth, sire ID, breeder, region, kidding interval, sire age, and dam age. All animals without birth weight were excluded from the analyses. Data for 10 years (2008 to 2017) was used because years before 2007 had a deficient number of records missing information on litter size, sire and the dam. Only sires with more than 15 progeny were retained. Breeders with less than 15 records were discarded. Only Eastern, Northern and Southern regions were used. Kidding intervals ranged from 170 to 390 days, and anything outside this range was discarded as they indicated errors in data capturing. Only 1902 kids were used after data editing. The structure of the edited data that was subsequently used in the analyses of non-genetic factors affecting BW of Kalahari Red goats is shown in Table 1.

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TABLE 1: **Structure of Edited Data That Was Used in the Analyses of Non-Genetic Factors Affecting BW of Kalahari Red Goats**

Factor	Records of kids used.
Number of animals	1902
Number of Males	978
Number of Females	929
Kidding interval range (days)	170 to 390
Birth type	single (142), twins (330), triples (66) and quadruplets (4)
Breeders (code)	134091563, 480156152, 484770884, 503407721, 509512900, 541020517, 542190721, 610190480, 614783869, 698383515, 782691341
Period (year)	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017

2.3. Data Analysis

The growth performance trait analysed was birth weight, measured using a weighing scale. Some of the data used were calculated as follows: birth weight was recorded at birth; age of dam and age of sire recorded at kidding and was calculated as kid birth date minus birth date of sire/does; kidding interval, calculated as number of days between successive dam kidding. The significance of fixed effects such as sex, birth type, season of birth, year of birth, breeder and region and random effects such as dam age, sire age and kidding interval was tested by conducting least-squares analyses of variance (ANOVA) using the General Linear Model (GLM) procedure of the Minitab 18.1 (2017) Statistical software. The model, in matrix notations, is presented as follows:

$$y = Xb + Zu + e$$

Where: y = vector of observation (BW); b = vector of fixed effects (sex, region, year of birth, season of birth, breeder, birth type); u = vector of covariates (animal effects: does age, sire age, kidding interval); e = vector of random residual effects; X and Z are incidence matrices relating records to the fixed effects and animal effects, respectively.

3. RESULTS AND DISCUSSION

The study evaluated non-genetic factors that influence the birth weight of purebred Kalahari Red goat kids from different flocks in three regions of South Africa, which include Northern

(Gauteng, Mpumalanga, Northwest, and Limpopo), Southern (Eastern Cape and the eastern part of Western Cape), and Eastern (KwaZulu-Natal and the eastern part of Eastern Cape). A summary of the Analysis of Variance (ANOVA) of BW is shown in Table 2. Fischer's Least Significant Difference was employed as the mean separation technique at a significance level of 5% (α = 0.05).

TABLE 2: Analysis of Variance for Non-Genetic Factors Affecting BW of Kalahari Red Goat

Source	DF	SS	MS	P-Value
Kidding interval	1	0.04	0.03	0.73
Does age at kidding (days)	1	0.02	0.02	0.82
Sire age at kidding (days)	1	1.62	1.64	0.02
Sex	1	2.16	2.16	0.01
Birth type	3	3.23	1,08	0.01
Season of birth	3	2.59	0.86	0.04
Year of birth	9	90.51	10.06	0.00
Region	2	1.03	0.52	0.18
Sex*Season of birth	3	2.35	0.78	0.05
Error	517	154	0.30	

DF= Degree of freedom; SS= Sum of square; MS= Mean of square

TABLE 3: Least Squares Means of Birth Weight For Different Groups of Kalahari Red Goats' Kids

Factors	Mean ± SEM
Season	**S**
Autumn	3.12±0.21[a]
Winter	3.02±0.21[ab]
Spring	2.97±0.21[ab]
Summer	2.77±0.22[b]
Region	**NS**
Northern (Gauteng, Mpumalanga, North West, and Limpopo)	3.32±0.15[a]

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Southern (Eastern Cape and the eastern part of Western Cape)	3.14±0.08[a]
Eastern (KwaZulu-Natal and the eastern part of Eastern Cape)	2.45±0.57[a]
Sex	**S**
Male	3.05±0.21[a]
Female	2.89±0.20[b]
Birth type	**S**
Single	3.11±0.19[a]
Twins	2.92±0.20[b]
Triplets	2.99±0.20[ab]
Quadruplets	2.87±0.35[ab]

Values with different superscripts in each column (or raw) significantly differ at $p<0.05$, S-Significant, NS-Not Significant.

3.1. The Effect of Season of Birth

Table 3 summarises the effect of season on birth weight. Kids born in the autumn and winter seasons had a higher average birth weight (3.12 ± 0.216 kg and 3.06 ± 0.215 kg) than those born in summer and spring (2.78 ± 0.218 kg and 2.97 ± 0.218 kg), respectively. However, only the autumn and summer seasons significantly affected the birth weight of Kalahari Red goats. These seasons are known to be lush with fresh grazing and browsing fodder. Moreover, no significant differences were recorded for the birth weight of kids born in winter and spring, which are cold and dry in most parts of South Africa. The season was found to have a significant effect (p<0.05) on the birth weight of Kalahari Red goats, which is consistent with the findings of Singh *et al.* (1992) and Mioč *et al.* (2011). Yadav *et al.* (2008) also reported that season significantly affected growth traits in Kutchi goats. This could be attributed to goat pregnancy occurring in different seasons and pastoral conditions (Khan *et al.*, 1983).

3.2. The Effect of Year

The birth year significantly affected the weight ($p<0.05$) of Kalahari red goats, as illustrated in the ANOVA in Table 2. The effect of birth year on birth weight is shown in Figure 1. The maximum birth weight (3.39 kg) was recorded for the kids born in 2015, whereas the minimum

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(1.91 kg) was observed in 2016. From 2008 to 2015, an average birth weight of 3 kg was observed. However, in 2016, birth weight declined; this was attributed to the drought conditions in South Africa, leading to reduced pasture availability for adequate feeding. This fluctuation in birth weights may be linked to variations in rainfall patterns and the subsequent recovery of veld capacities. Notably, the diminished nutritional resources during the drought in 2016 resulted in insufficient feed for pregnant goats to sustain both the developing fetus and them. Subsequently, a recovery in birth weights commenced in 2017.

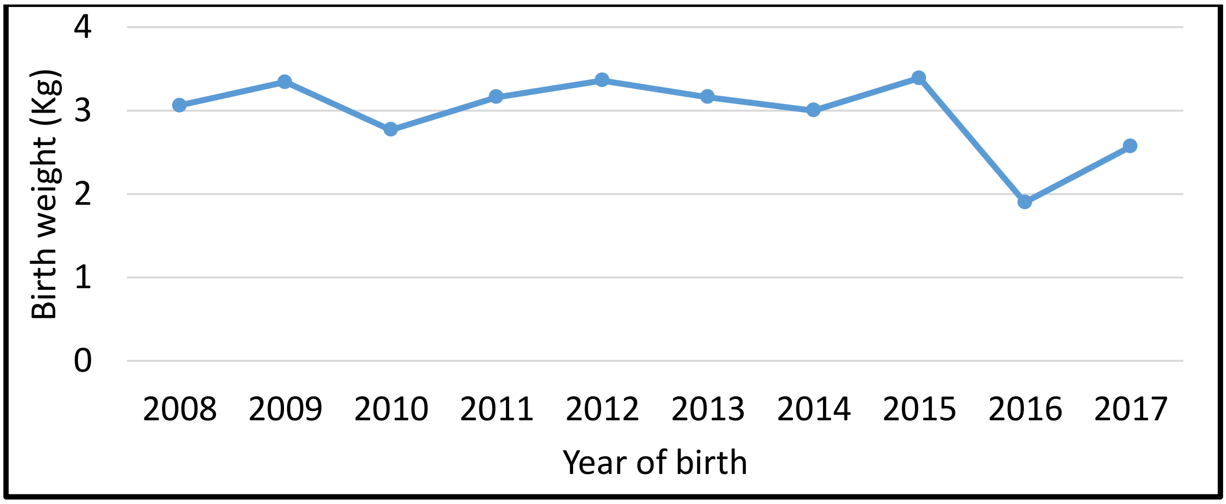

FIGURE 1: Means for Birth Weight Per Year for Kalahari Red Goats From 2008 to 2017

The contribution of the birth year can be highly variable due to differences in climatic conditions, feeding, and management, as well as the genetic composition of the herd (Smith, 2010). The results of the current study conform to the findings of Talekar (2015), who reported a highly significant ($p<0.01$) effect of the birth year on the birth weights of the kids in all months. However, Sharma *et al.* (1995) observed a highly significant effect of year of birth at all ages except for the third month of age in Jamunapari goats. Similarly, Kumar *et al.* (1993) reported that birth year directly and significantly influenced the relative growth rate in body weight at wither in Black Bengal and its half-bred goats with Jamunapari and Beetal. This result explains a variation in the birth weight of Kalahari Red goat's kids every year from 2008 to 2017. The trends can be explained by differences in rainfall, which leads to marked differences between each year's quality and quantity of forage available (Khombe, 1985).

3.3. The Effect of Region

The kids were born in different regions of the country; thus, the Northern, Southern, and Eastern, but no significant effect of region on birth weight was observed (p>0.05), as shown in Table 2 and Table 3. This indicates that the numerical differences across the region where the kids were born were not statistically different among the purebred Kalahari Red goats. However, it is important to note that a reduced weight at birth can be an adaptation to harsh environmental conditions in arid regions of other countries (Oltenacu, 1999). Furthermore, genetic variance in constant or unpredictable environments can reduce the population's mean fitness and increase the risk of extinction (Lande *et al.*, 1996). This justifies the difference in Kalahari Red goats' birth weight in other countries.

3.4. The Effect of Breeder

Table 4 illustrates the analysis of variance for the effect of the breeder on BW; it was tested at 95% level of significance. It can be seen that the breeder contributes significantly to the effects of birth weight ($p<0.05$). Sushma *et al.* (2006) found that young animals bred by different breeders differed significantly from each other due to environmental conditions and human choice variation. The decisions made by the breeder mainly relate to management practices, selection objectives, and the choice of breeding animal accounts for the majority of the variation associated with growth traits (Krupa *et al.*, 2005).

TABLE 4: Analysis of Variance (ANOVA) for Effects of Breeder on Birth Weight

Source	DF	SS	MS	P-Value
Breeder	10	411	41.1	0.000
Error	1896	841	0.444	
Total	1906	1253		

DF- degree of freedom, SS- sum of squares, MS- mean of squares

3.5. The Effect of Sex

The result in Table 3 indicates that male kids had a higher average birth weight (3.05 ± 0.21 kg) compared to female kids (2.89 ± 0.20 kg), and this difference was statistically significant (p<0.05), as shown in Table 2. This difference in weight between sexes may be due to the longer pregnancy period of carrying male kids for one to two days longer than those carrying females (Ugur *et al.*, 2004). The literature supports these findings, with studies reporting similar results on the effect of sex on birth weight in various breeds (Husain *et al.*, 1996; Mioč *et al.*, 2011; Hristova *et al.*, 2013).

3.6. The Effect of Birth Type

The influence of birth type on birth weight is presented in Table 2 and Table 3, with a significant effect ($p < 0.05$) observed. The average birth weights of single, twin, triplet, and quadruplet kids were found to be 3.10 ± 0.198 kg, 2.92 ± 0.200 kg, 2.99 ± 0.205 kg, and 2.87 ± 0.36 kg, respectively (Table 3). The results showed that kids born as twins had significantly lower birth weights than those born as singles and multiples. This finding is consistent with previous studies, such as De Groot et al. (1992), who reported significantly lower birth weights of twin kids than single kids during the first six months. Moreover, Kuralkar *et al.* (2002) found that kids born as singles were significantly heavier than those born as twins and triplets.

3.7. The Effect of Dam Kidding Interval

The results in Table 2 show no significant ($p>0.05$) effect of kidding interval on birth weight. As shown in Figure 2, the Coefficient of Determination (R^2) value of 14% indicates that the kidding interval cannot explain the variation observed in the birth weights of the kids. This may be because the kidding interval is often associated with controlled mating (Wilson *et al.*, 1989). Kidding interval is more influenced by management restrictions than any other environmental factor.

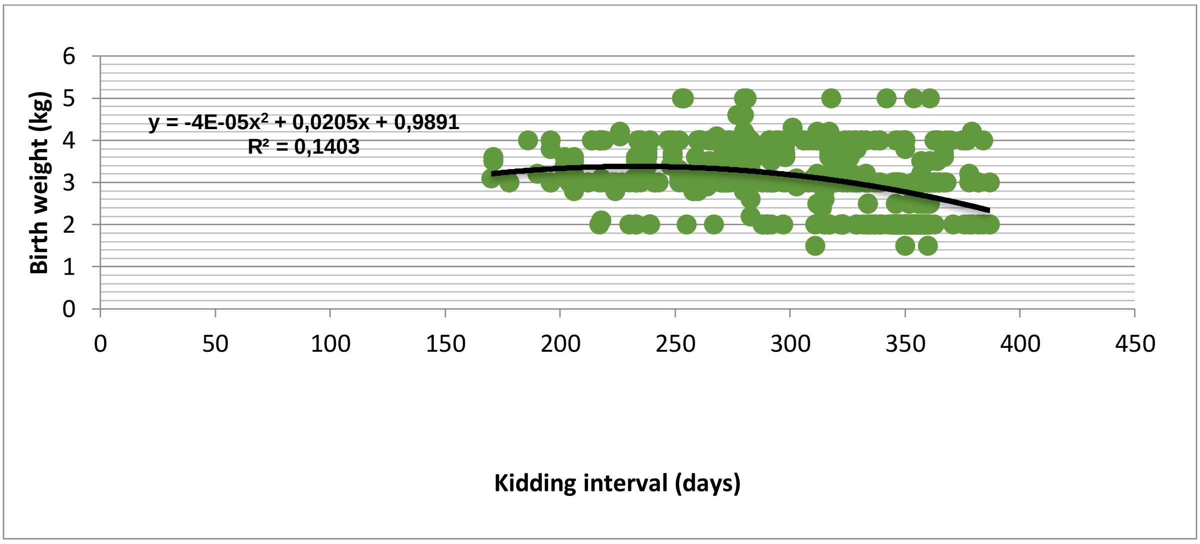

FIGURE 2: The Regression of Birth Weight on Kidding Interval for the Kalahari Red Goat

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3.8. The Effect of Age of Dam

The results in Table 2 and Figure 3 demonstrate a significant ($p<0.05$) effect of dam age on birth weight. Birth weight steadily increased with dam's age up to 5 years, after which it declined with the advancing dam age. The maximum birth weight of 5.2 kg was observed in the 5-6 year group, while the minimum birth weight of 1.8 kg was found in the 7-8 year group. The R^2 value of 82% indicates a good account of the variation in birth weight over the different dam ages. The quadratic equation determined the optimum dam age of 4.5 years. It is generally accepted that older does give birth to heavier offspring than younger does (Portolano *et al.*, 2002; Liu *et al.*, 2005). Djemali *et al.* (1994) observed that kids born from the young dam had lower body weights than those from an adult dam and that growth traits increased with the age of the ewe up to five. The dam's capacity to nourish the developing foetus increases once they have reached reproductive maturity (Zishiri, 2009). As the dam becomes older, its ability to provide an adequate uterine environment for the unborn kids may diminish (Zishiri, 2009). This trend reflects the mature's greater ability to provide the foetus with the necessary nutrients and environmental conditions for its development (Elzo *et al.*, 1987). Likewise, as dams become older, their ability to provide an adequate uterine environment for the unborn kid may diminish. A similar trend has been observed in livestock species such as cattle and sheep (Elzo *et al.*, 1987).

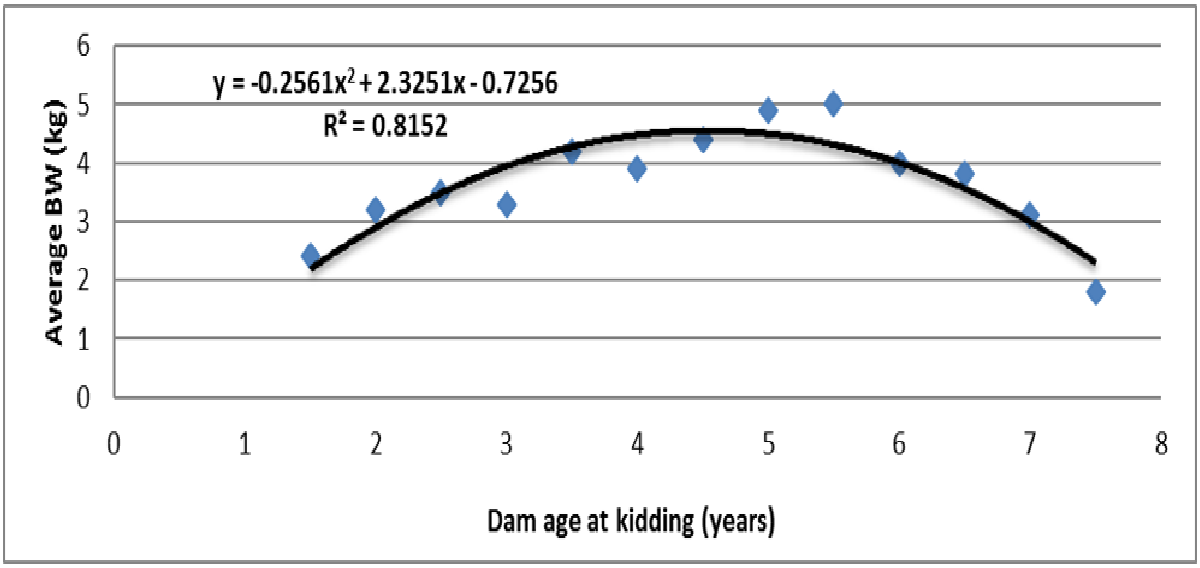

FIGURE 3: The Regression of Birth Weight on Does Age for the Kalahari Red Goat

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3.9. The Effect of Age of Sire

The sire age significantly affected birth weight ($p<0.05$), as displayed in Table 2 and Figure 4. The young (1.5 years) and old (8.5 years) sires significantly affect birth weight. The R^2 73% gives a good account of the variation in birth weight on different sire ages, with the optimum age of 6 years. As illustrated in Figure 4, the highest birth weight of 3.1 kg was observed in kids aged 2-3 years, while the lowest birth weight of 2.4 kg was observed in kids aged 4-5 years. The results are consistent with previous studies by Karna *et al.* (2001) in Cheghu kids, which found that sire age significantly affected birth weight. The higher body weight and larger scrotal circumference of mature bucks result in increased semen and sperm concentration, which may explain the observed effect of age of sire on birth weight (Karna *et al.* 2001). The study's findings are also consistent with those of Salhab *et al.* (2003), who found a highly significant effect of sire age on morphometric traits at birth. Additionally, Dudhe *et al.* (2015) reported a highly significant effect of sire age on morphometric traits at birth. However, Tomar *et al.* (2001) reported no significant effect of sire age on the three morphometric traits. It is important to note that lack of experience and low libido in young bucks and senility in old bucks may contribute to the observed lower effects of the age of the sire on birth weight.

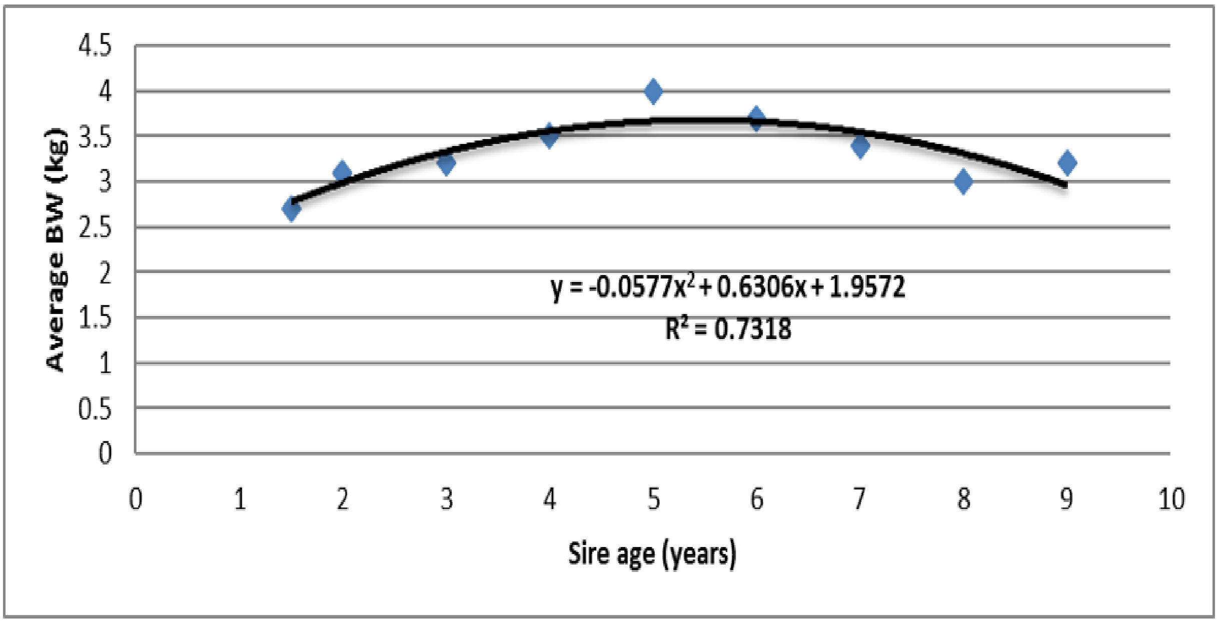

FIGURE 4: The Effect of Sire Age on Birth Weight for the Kalahari Red Goat

4. CONCLUSION

The study found that several non-genetic factors, birth type, year of birth, sex of kid, breeder, age of sire at kidding, age of does at kidding, and season of birth, significantly affected birth weight in Kalahari Red goats. These factors need to be accounted for in genetic evaluation models. Accurate adjustments for non-genetic factors are essential for predicting covariance components for growth performance and for genetic improvement of the breed. The positive response of Kalahari Red goats to the harsh and diverse conditions of South Africa provides a foundation for estimating genetic parameters and implementing a selection program for growth performance. Understanding the effects of different environmental conditions, reproductive parameters, and parental age factors on birth weight is a tool which can be used in breeding programs for goats. Since birth weight significantly impacts an animal's productive performance, it needs to be monitored and improved through sound recording and genetic evaluations.

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