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# The influence of non-genetic factors on early growth traits in the Tygerhoek Merino lambs

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## Abstract

*Records of 8310 lambs born from 2538 ewes and sired by 681 rams covering the period 1970 to 1998 were used in the analysis of birth weight (BW), weaning weight (WW) and pre-weaning average daily gain (ADG). All three traits were affected (p<0.001) by type of birth of lambs (single, multiple), sex, year of birth of lambs, group of animals (selection, control) and age of dam at lambing (2-to 6-year old). Male lambs and singles were heavier both at birth and weaning and grew faster (p<0.001) than females and multiples, respectively. Non-selected animals were lighter than selected animals at birth and weaning with an inferior growth rate. BW increased with increasing dam age at lambing until a maximum of 3.7 kg was reached at 6-year of age. However, both WW and ADG reached a maximum at about 4-year of age of the dam.*

*Keywords*: Non-genetic factors; early growth traits; Tygerhoek Merino lambs.

## Introduction

A large number of non-genetic factors influence lamb weights and preweaning weight gains. The effects of year of birth, sex, type of birth and dam age on early growth traits of lambs have been well documented (Heydenrych, 1975; Fourie and Heydenrych, 1982; Fahmy, 1989; Boujenane and Kerfal, 1990; Bunge *et al*., 1990; Schoeman, 1990; Sinha and Singh, 1997). Milk production also has a direct effect on weight gain of lambs (Hanrahan, 1976; Njwe and Manjeli, 1992). Post-natal factors account for 75 % of the maternal influence on weaning weight and are largely mediated through milk production (Bradford, 1972). Schoeman (2000) also reported that variation in pre-weaning weight might be due to poor milk production and composition or the environmental conditions under which the animal is maintained. The effect of dam age on early growth of lambs is also well documented (Heydenrych, 1975; Fourie and Heydenrych, 1982; Fahmy, 1989; Van Wyk *et al*., 1993). The effect of dam age on post-natal growth of lambs may be indirect

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through milk production in that mature ewes may produce more milk than younger ewes.

Selection of genetically superior individuals to be parents of the next generation is complicated by non-genetic factors that tend to mask the actual breeding values of the individuals being selected (Eltawil *et al*., 1970). Identifying those non-genetic factors could help to look for appropriate ways to eliminate biases caused by them and hence more accurate estimation of breeding values would be possible. Van Wyk *et al*. (1993) indicated that the specification of a model that influence the specific trait requires the study of non-genetic sources of variation, so that a model can be found which (according to the available data) best describes the biological processes concerned. Most estimates of genetic variances in any livestock species are probably biased because of missing pedigree information jointly affected by non-genetic factors in the model and non-random selection of parents (Schenkel and Schaeffer, 2000). Knowledge of the non-genetic factors on production traits allows a more accurate assessment of breeding values and increases the rate of response to selection (Napier and Jones, 1982).

The purpose of the present study was to investigate some non-genetic factors influencing early growth traits in a Merino flock maintained at the Tygerhoek Experimental Farm. This was done to fit the appropriate operational model for the estimation of genetic parameters in a follow-up investigation.

## Materials and Methods

### Location of the study area

The experimental animals originated from a selection experiment on the Tygerhoek Experimental Farm of the Department of Agricultural Development that was started in 1969. The farm is situated in the southern coastal area of the Western Cape province, about 150 km east of Stellenbosch at an altitude of approximately 168 m above sea level (34° 08′ S, 19° 54′ E). The area has an average annual rainfall of 429 mm, 60 % of which is recorded in winter (April – September). The average maximum (minimum) summer and winter temperatures are approximately 22°C (15°C) and 12°C (5°C), respectively.

### Animals and management

Originally, 800 ewes of 1.5 to 5.5 years of age were stratified according to wool production at 18 months of age, and randomly allotted to five equal groups of 160 breeding ewes. Twenty-six randomly chosen rams sired the progeny born in 1969. During the 1969 mating season, 20 available rams were allocated at random to each experimental group in sets of four rams per group.

Selection of breeding rams in groups 1 and 3 was based on the highest uncorrected clean fleece mass at 18 months, provided that they had a fibre diameter lower than the average of their contemporaries. Replacement ewes were selected on clean fleece mass at 18 months of age in group 1 and corrected 42-day body mass in group 3 (Heydenrych *et al*., 1984). Both groups consisted of 160 breeding ewes and 6 rams up to 1976, when they were pooled and reduced to 150 breeding ewes and 6 rams. This decision was based mainly on preliminary findings (Heydenrych, 1977; as cited by Cloete *et al*., 1992). Later selection of this group was predominantly based on uncorrected clean fleece mass at 18 months in both sexes but with a restriction on fibre diameter in rams. The size of the breeding flock ranged from 150 to 160 breeding ewes and 6 to 8 breeding rams. For the progeny groups born during the period 1986 to 1989, the prerequisite for breeding rams to grow wool with a lower fibre diameter than the mean of their contemporaries was relaxed to include individuals up to 2 μm stronger than their contemporaries. Group 5 (hereafter called control group for the purpose of this study) served as a genetically stable Control Group for the assessment of selection progress in the selected lines. It originally consisted of 160 breeding ewes and 16 rams, but was allowed to increase to 200 breeding ewes and 20 breeding rams from 1976. Rams for the Control Group were chosen at random in such a way that each ram was replaced by a son and was used for one season only. Ewes were normally replaced by a second daughter reaching joining age, thereby retaining the same age structure as in the selection groups (Heydenrych *et al*., 1984). Selection Group and Control Group individuals were maintained in one flock with males and females kept separately. These flocks grazed on mainly dryland lucerne pastures and occasionally on small grain pastures or crop residues, when available (Cloete *et al*., 1992).

## Statistical Analysis

Records of 8310, 7997 and 7997 lambs born from 1970 to 1998 were used in the analysis for birth weight (BW), weaning weight (WW) and preweaning average daily gain (ADG), respectively. The lambs were the progeny of 2538 ewes and 681 sires. Total number of records used and means for all traits are presented in Table 1. Records with missing or incomplete information, those found suspect due to duplicate animal identifications and other irreconcilable inconsistencies were eliminated from the data. Those lambs deviating more than three standard deviations from the mean weight for BW and WW were excluded. Lambs were weaned at approximately 120 days of age from 1970 to 1982, and at about 100 days of age thereafter, and before fitting the models WW was adjusted accordingly for all lambs. The few triplets (12 records) were pooled with twin lambs. After running a preliminary analysis, ewes above 6-year-old age were pooled with 6-year-old ewes due to their small numbers and no differences ($p>0.05$) between the two sub-classes for any of the traits.

Fixed effects fitted were lambing year (1970 to 1998), sex (male, female), birth type (single, multiple), dam age (2 to 6-year old age), group of animals (group of animals selected for increased clean fleece weight and unselected control group), lambing year by group interaction and lambing year by type of birth interaction. The analyses were first carried out fitting a full model including all main effects and interactions using the General Linear Model (GLM) procedures of the Statistical Analysis System (SAS, 1996) to determine whether any of the effects or their interactions have an influence on the traits ($p<0.05$). Those having no effect ($p>0.05$) were subsequently omitted using a step-down procedure. The reduced models were then refitted for each variable.

**Table 1.** Number of records, means and standard deviations for BW, WW and ADG.

| | BW (kg) | WW (kg) | ADG (g) |
|---|---|---|---|
| No. records | 8310 | 7997 | 7997 |
| No. dams | 2538 | 2538 | 2538 |
| No. sires | 681 | 681 | 681 |
| Weight | | | |
| Mean | 3.6 | 22.9 | 192 |
| s.d. | 0.8 | 4.8 | 46.4 |
| Dam age (yr) | | | |
| 2 | 1527 | 1460 | 1460 |
| 3 | 1851 | 1782 | 1782 |
| 4 | 1900 | 1835 | 1835 |
| 5 | 1662 | 1607 | 1607 |
| 6 | 1370 | 1313 | 1313 |
| Sex | | | |
| Males | 4031 | 3862 | 3862 |
| Females | 4279 | 4135 | 4135 |
| Type of birth | | | |
| Single births | 4946 | 4860 | 4860 |
| Multiple births | 3361 | 3137 | 3137 |
| Group of animals | | | |
| Selection | 4238 | 4096 | 4096 |
| Control | 4072 | 3901 | 3901 |

The following model was fitted:

$$Y_{ijklmn} = \mu + Y_i + S_j + T_k + G_l + A_m + (YG)_{il} + (YT)_{ik} + e_{ijklmn}$$

where: $Y_{ijklmn}$ = record of the $n^{th}$ animal

$\mu$ = the overall mean

$Y_i$ = the fixed effect of the $i^{th}$ birth year (i = 1970, 1971, ..., 1998)

$S_j$ = the fixed effect of the $j^{th}$ sex (j = 1 or 2; 1 = male, 2 = female)

$T_k$ = the fixed effect of the $k^{th}$ type of birth (k = 1 or 2; 1 = single, 2 = multiple)

$G_l$ = the fixed effect of the $l^{th}$ group of animals (l = 1 or 2; 1= selection group, 2 = unselected control)

$A_m$ = the fixed effect of $m^{th}$ ewe age (m = 2, 3, 4, 5 or 6-yr-old)

$(YG)_{il}$ = interaction effect between $i^{th}$ birth year and $l^{th}$ group

$(YT)_{ik}$ = interaction effect between $i^{th}$ birth year and $k^{th}$ type of birth

$\mathbf{e}_{ijklmn}$ = the residual effect

## Results

Analysis of variance for BW, WW and ADG is presented in Table 2, while least-squares means for the same traits are shown in Table 3. All the fixed main effects had significant (p<0.001) effect on all three traits. But the birth year by type of birth interaction was only significantly related to BW. The analyses of variance showed that the fixed effect models accounted for 39.8, 38.2 and 38.4 % of the variances for BW, WW and ADG, respectively. Of these, type of birth had the highest contribution to variation in BW, and year of birth to variation both in WW and ADG.

The effect of sex of lambs was significant (p<0.001) for BW, WW and ADG. Male lambs were by 6.3 % (0.2 kg) and 8.2 % (1.9 kg) heavier at birth and weaning than females, respectively. They also grew approximately 9 % (17 g/day) faster from birth to weaning than female lambs. The effect of sex accounted for about 1.9 and 3.8 % of the variation in BW and WW, respectively.

**Table 2.** Analysis of variance for BW, WW and ADG.

| Fixed effects | df | Mean Square and significance level | | |
|---|---|---|---|---|
| | | BW | WW | ADG |
| Year | 27 | 28.928*** | 1428.583*** | 161941.943*** |
| Sex | 1 | 102.828*** | 6991.854*** | 543823.467*** |
| Type of birth | 1 | 971.439*** | 15233.934*** | 856388.743*** |
| Group of animals | 1 | 85.369*** | 7782.480*** | 622206.758*** |
| Ewe age | 4 | 39.490*** | 190.818*** | 8069.298*** |
| BY*GR | 27 | 1.205*** | 86.056*** | 7149.017*** |
| BY*TB | 27 | 0.702** | | |
| Error degrees of freedom | | 8218 | 7935 | 7935 |
| Error mean square | | 0.403 | 14.42 | 1337.07 |
| $R^2$ | | 39.82 | 38.24 | 38.42 |
| C.V. | | 17.46 | 16.61 | 19.05 |

** p<0.01; *** p<0.001; BY*GR=birth year by selection group interaction; BY*TB=birth year by type of birth interaction

**Table 3.** Least squares means (±S.E.) for BW, WW and ADG

| Fixed effects | BW (kg) | WW (kg) | ADG (g) |
|---|---|---|---|
| Overall mean | 3.6 | 22.9 | 192 |
| Sex | | | |
| Male | 3.7±0.01[a] | 23.8±0.06[a] | 202±0.60[a] |
| Female | 3.5±0.01[b] | 21.9±0.06[b] | 184±0.60[b] |
| Type of birth | | | |
| Single | 3.9±0.01[a] | 24.4±0.06[a] | 204±0.55[a] |
| Multiple | 3.2±0.01[b] | 21.4±0.07[b] | 182±0.68[b] |
| Group of animals | | | |
| Selection | 3.7±0.01[a] | 23.9±0.06[a] | 202±0.62[a] |
| Control | 3.5±0.01[b] | 21.8±0.06[b] | 184±0.61[b] |

[a,b] Within effects, values with different superscripts in the same column are significantly different (p < 0.001).

Year of birth had a very significant (p<0.001) effect on live weights and growth rates up to weaning. Year of birth of lamb had greater effect on WW than on BW (Figure 1). BW was relatively stable throughout the study period except for the sudden increase in 1983. It increased by 1.0 kg in this particular year. The WW performance of this flock was, however, decreasing in the early years of the study from 1970 to 1986, whereafter it increased. About 14.2 and 20.8 % of the weight differences for BW and WW were due to year of birth, respectively.

Type of birth also had significant effect (p<0.001) on early growth traits of lambs. Single born lambs were heavier by 20.6 % (0.8 kg) and 13.0 % (3.0 kg) at birth and weaning than those born as multiples, respectively. They also grew faster at approximately 22 g/day than multiple born lambs. The effect of type of birth decreased with increase in age of the lamb. Type of birth accounted for 17.7 and 8.2 % of the liveweight variation at birth and at weaning, respectively.

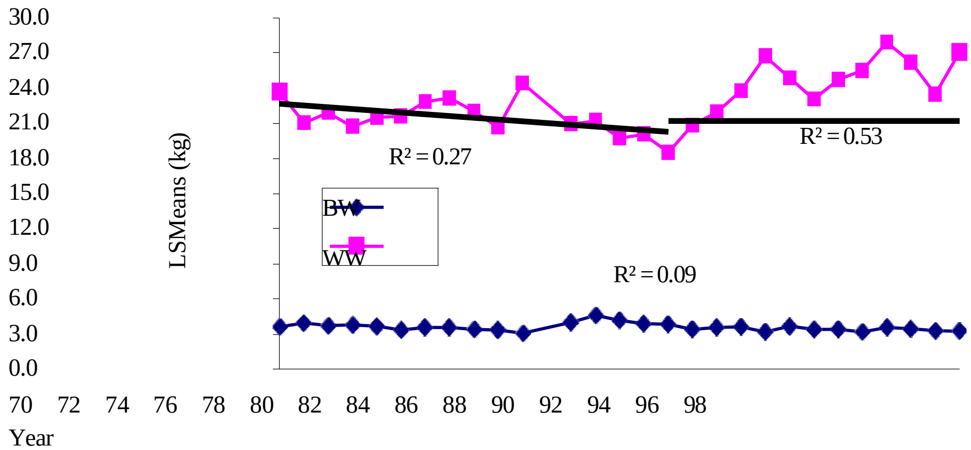


**Figure 1.** The relationship of year of birth with BW and WW.

Selection group also had significant effect (p<0.001) on BW, WW and ADG. Animals from the group selected for clean fleece weight were by 5.8 % (0.2 kg) and 9.0 % (2.1 kg) heavier at birth and weaning than the unselected control, respectively. They also grew faster than the unselected control group. A difference of about 18 g/day was observed between the selected and the unselected control groups.

The effect of age of dam was significant (p<0.001) for all three traits. Its effect followed the expected patterns for BW (Figure 2), where it increased with increasing dam age until the maximum of 3.7 kg was reached at 6-year of age of dam. However, the lack of adequate number of records on ewes older than 6-year of age in the present data set did not allow the estimation of age effects at older ages. Unlike BW, maximum WW and ADG were obtained for those lambs born to 4-year-old ewes (Figures 3 and 4), whereafter it declined. Quadratic regressions of both WW and ADG on age of dam reached maximum at about 4-year of age. Lambs born from maiden and older ewes grew slower and had lower liveweights at weaning as compared to lambs from middle-aged ewes (3 to 5-year-old ewes). The effect of dam age decreased with increasing age of lambs. Dam age accounted for about 2.9 and 0.4 % of liveweight variation at birth and at weaning, respectively.

For all three traits, the lambing year by group interaction was also significant (p<0.001). Nevertheless, it accounted only for about 0.6 to 1.3 % variation in the three traits. The lambing year by birth type interaction was only significantly (p<0.001) related to BW.

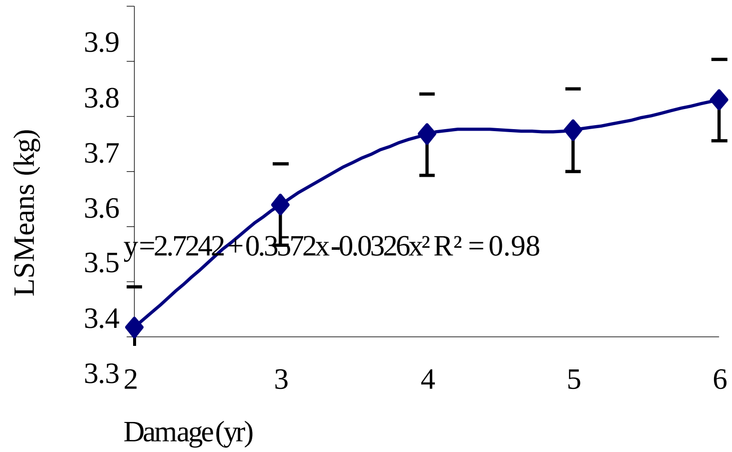


**Figure 2.** The regression of BW on dam age.

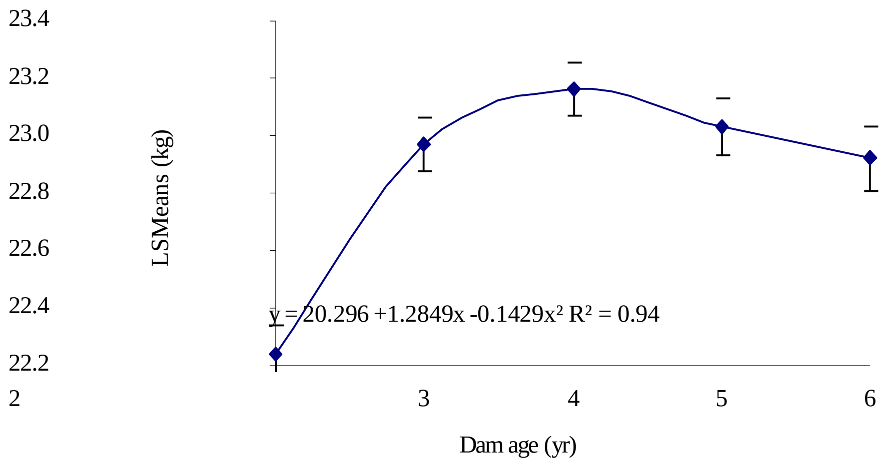


**Figure 3.** The regression of WW on dam age.

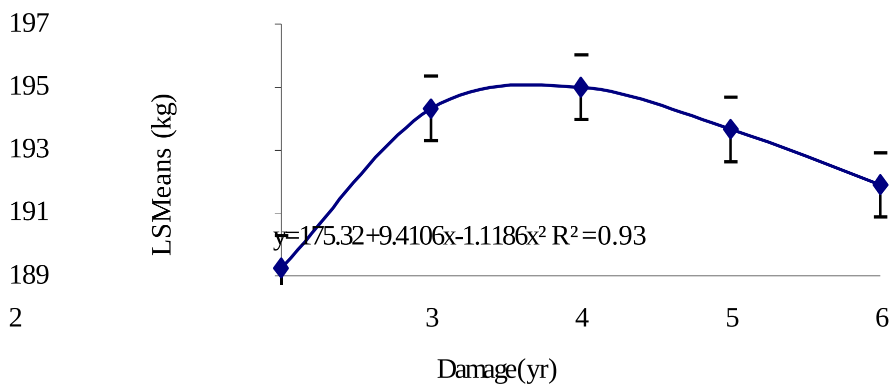


**Figure 4.** The regression of ADG on dam age.

## Discussion

The effect of environmental factors such as year, sex, type of birth and ewe age observed in the current study is in general agreement with those reported in the literature (Heydenrych, 1975; Fourie and Heydenrych, 1982; Boujenane and Kerfal, 1990; Schoeman, 1990; Van Wyk *et al*., 1993). Under arid conditions, the above-mentioned environmental fixed factors are known to predominate in determining sheep productivity (Eltawil *et al*., 1970).

Very few studies have been reported for BW in Merino sheep of South Africa. It was only analysed in a previous study conducted with this flock (Heydenrych, 1975) and one recently reported by Cloete *et al*. (2000) with a Merino flock in the Swartland region. It is, however, a trait of potential economic importance through its effect on lamb survival rate in the flock, in that very large and small lambs were at risk of preweaning death (Gemeda, 2001). Mean BW found in the present study was lower than those reported by Heydenrych (1975) based on part of the same data. This might be due to the smaller data set used in the previous study. It was, however, in accordance with that reported by Cloete *et al*. (2000). The mean WW obtained was also in agreement with these authors, but higher than those reported in the Carnarvon Merino flock (Snyman *et al*., 1996). It was, nevertheless, lower than results reported for several other breeds by Schoeman (2000). The mean ADG found in the current study was in good agreement with those reported for Baluchi sheep (Yazdi *et al*., 1998).

Male lambs were heavier at birth and at weaning than female lambs. They also grew faster than female lambs. This is in general agreement with reports in the literature (Heydenrych, 1975; Fourie and Heydenrych, 1982: Schoeman, 1990; Van Wyk *et al*., 1993; Mavrogenis, 1996; Yohannes *et al*., 1998; Solomon and Gemeda, 2000). The heavier WW of ram lambs than their female contemporaries may be due to heavier birth weights and faster growth rate of male lambs. According to Eltawil *et al*. (1970), lambs with a heavier BW, which might be due to being males, singles and/or from mature ewes, tend to achieve higher weights at weaning, partly because of the positive correlations between the traits. The influence of sex on liveweight increased with age, which agreed with results reported by Fourie and Heydenrych (1982) and Nagy *et al*. (1999). Such differences might be attributed to different physiological processes in the two sexes (Rajab *et al*., 1992).

In the current study, year had an important effect (p<0.001) on weights and growth rate up to weaning. Differences observed in weights between years may be a reflection of differences in feed availability between years, caused by variation in total annual precipitation and the distribution of rainfall. The southern Cape area is subjected to dry years with limited feed availability. Similar results of the effects of year on production traits are well documented (Eltawil *et al*., 1970; Blackburn and Cartwright, 1987; Rajab *et al*., 1992; Mavrogenis, 1996).

Differences in early growth traits were observed between the selected group and the unselected control. This could possibly be explained through the positive genetic correlation between liveweight and fleece weight. Heydenrych (1975), Heydenrych *et al.* (1984) and Cloete *et al.* (1992; 1998) reported that selection for clean fleece weight resulted in a correlated increase in liveweight due to this positive genetic correlation between fleece weight and body weight.

Type of birth also affected liveweight and growth rates of this flock. Single born lambs were heavier and grew faster than multiple born lambs. This is similar to results reported by Heydenrych (1975) for the same flock, Fourie and Heydenrych (1982) in Döhne Merino and several other breeds (Galal and Kassahun, 1981; Boujenane *et al*., 1991; Rajab *et al*., 1992; Solomon *et al*., 2000). Part of the type of birth differences on WW might be due to the carry-over of the heavier weight of singles at birth. Differences due to type of birth may be more important under arid conditions than under intensive sheep production systems (Eltawil *et al*., 1970). The difference of 0.8 kg found in the present study for BW corresponds to the 0.7 kg reported by Yazdi *et al*. (1998) for Baluchi sheep. However, a 1.8 kg heavier WW for singles than multiples reported by Yazdi *et al*. (1998) for the Baluchi breed was slightly less than the current result. Generally, in the current study, the effect of type of birth decreased as lambs became older. Fourie and Heydenrych (1982) reported similar results. According to Bradford (1985), environments with scarce forage, variable among seasons and years, and where supplemental feed is scarce and uneconomic, would only support sheep with single births. However, if such environments permit supplementation at critical times, twinning from mature ewes could be tolerated. The Tygerhoek Merino sheep grazed mainly on dryland lucerne pastures unless occasionally supplied with grain pastures or crop residues when available (Cloete *et al*., 1992).

The average weight of lambs at birth increased with increasing ewe age up to the maximum age (6-year) considered in this study. Three other South African studies observed an increase in BW up to 5- to 7-years of age in both Döhne Merino and Dormer sheep (Fourie and Heydenrych, 1982; Van Wyk *et al*., 1993; Schoeman, 1990). An increase in BW was observed up to an age of five years (fourth parity) in Horro sheep of western Oromia, Ethiopia (Solomon and Gemeda, 2000), seven years of age in Baluchi sheep of northeast Iran (Yazdi *et al*., 1998) and in Romanov sheep of Canada (Fahmy, 1989). The reasons for the differences may be attributed to differences in production environments and management levels (Schoeman, 2000). It might also be due to breed effects, in that earlier maturing breeds may reach their peak earlier than the late maturing breeds.

The influence of age of dam on growth traits of offspring was greatest at birth and decreased as the animal grew older to weaning. Lambs out of 2-year-old ewes were lighter ($p<0.001$) at birth and weaning than were lambs out of older ewes. This might be explained by the fact that young dams that had not reached adult size continued to grow during pregnancy and thus competed with the fetus for available nutrients. Moreover, maiden ewes as first-time lambers may produce less milk than average. Solomon and Gemeda (2000) indicated that maiden ewes may put their lambs at disadvantage in two possible ways. They produce lambs with lower body weight and their mothering ability is poor as a result of lack of experience and poorly developed udder. According to Snyman *et al*. (1996), problems related to young ewes may be carried over to the second and perhaps even to the third parities. Although 6-year-old ewes had lambs that were heavier at birth than all other age groups, their lambs were lighter at weaning than those reared by 3- to 5-year-old ewes. The general trend for the effect of age of ewe on WW and ADG was curvilinear. Maximum WW and growth rate of lambs were obtained from ewes of intermediate age groups, and lower WW and inferior growth rate performance from lambs of very young and old aged ewes. Therefore, the dam age effect observed on BW of lambs from 6-year-old ewes might be a manifestation of an age effect on pre-natal environment and that of WW and ADG of lambs from middle-aged ewes could be brought about by a higher milk production in the middle-aged ewes. An animal's WW is mostly a function of the milk production and mothering ability of its dam (Ercanbrack and Knight, 1998; Bourdon, 2000). It is also interesting to note that maximum WW and ADG were attained approximately at an age at which ewes of this flock attain their mature liveweight. In an earlier report, the Tygerhoek Merino flock breeding ewes reached their maximum liveweight at their fourth mating when they were 4.5-years old (Heydenrych, 1975). The superiority of lambs born to middle aged ewes in WW obtained in the current study agreed with the findings of Rajab *et al*. (1992), Van Wyk *et al*. (1993) and Solomon and Gemeda (2000). In contrast, Schoeman (1990) found non-significant ewe age effect on 100-day body weight in Döhne Merino (which is the same age as the current weaning age). The difference might be due to management practices.

## Conclusions

In this study, several non-genetic fixed factors were observed with significant influence on early growth traits. Male lambs and singles were heavier both at birth and weaning and grew faster up to weaning than females and multiples, respectively. Non-selected animals were lighter than selected animals at birth and weaning, and had inferior growth rates. BW increased with age of dam up to 6-year of age. However, the age of dam effects on WW and ADG were curvilinear. The heaviest lambs were from 3-to 5-year-old dams and the lightest from 2- and 6-year-old dams. Therefore, the heavier BW of lambs from 6-year-old ewes may be due to a better pre-natal environment, but these old ewes appeared to have produced lesser preweaning growth level. Thus, it becomes more profitable to keep a larger proportion of the middle-aged ewes (between 3-to 5-years-old ewes) to improve productivity of this flock.

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