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Non-genetic sources of variation influencing yield and composition of milk production parameters in South African Saanen goats

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Abstract

This study tested the importance of non-genetic effects on average lactation performance in yields of milk, fat, protein, and lactose; urea concentration; persistency; somatic cell count; net returns; as well as estimated phenotypic relationships between dam kidding age and these parameters in the South African Saanen goat population kidding between 1955 and 2018. Analysis of variance was carried out to test for effects; Pearson's correlation coefficients between phenotypic traits were estimated. Dam parity and birth year substantially influenced all parameters studied. Dam birth season was an important factor of variation for all parameters except milk yield, urea concentration, and net returns. There was a substantial variation due to dam kidding season in all parameters except protein yield and urea concentration, with dams kidding in spring attaining the highest average lactation milk and lactose yields. Dams giving birth to triplets attained the highest values for average lactation milk yield, lactose yield, and net returns. Pearson's correlation estimations indicated negative associations between dam kidding age and all parameters investigated except somatic cell count (r_p= 0.189). Non-genetic factors determine to what extent the genetic potential of animals is expressed. Dam parity, birth year, kidding age, litter size, birth, and kidding season should be adjusted for when comparing average lactation performance of various milk production parameters in this population. For optimal lactation performance, planned breeding should be applied for spring kidding. There is a need to estimate genetic correlation values for the various traits studied to evaluate their response to selection.

Keywords: phenotypic correlation, planned breeding, lactation performance, non-genetic effects
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Introduction

The primary role of animal breeding in dairy goat production is to improve traits that are associated with milk production. According to DAFF (2016), Africa, Asia, Europe, and America are the four main producers of goat milk with production estimates of 25.2%, 57.8%, 13.7%, and 3.2%, respectively, towards the global goat milk production. Globally, ~80% of the goats are kept in Asia and Africa (Hirst, 2017). In the year 2013, the top three goat milk producing countries globally were India, Bangladesh, and Sudan, with annual production estimates of 3.7, 1.7, and 1.3 million tons, respectively (DAFF, 2016). Approximately 2% of the overall annual global milk supply comes from goats (Rashmi *et al*., 2013). This statistic demonstrates that from a global perspective, goats are not a prominent source of milk compared to cattle and other livestock species (Rashmi *et al.,* 2013; FAO Statistical Database, 2016).

According to Muller (2005), both yield and composition of milk parameters in dairy animals depend on a variety of factors. Furthermore, these factors are dependent on differences in the environment animals are subjected to, as well as the genetic variation among animals. This implies that

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the phenotypic expression of an animal for traits of economic importance is influenced by the interaction between the animal's genotype and the environment in which the performance was measured. Serradilla (2001) stated that although Europe constitutes about 2.5% of the global goat population, it contributes substantially towards the global goat milk production with an estimate of 20.7%. Generally, dairy goat populations in developing countries have a low milk production potential (Muller, 2005). Although dairy goat breeds such as the Saanen are not native to South Africa, their adaptation should be fairly good, given that some parts of the country experience similar climatic conditions as their countries of origin. The high yields from relatively small animal populations in Europe compared to other global regions such as Africa could be due to the effective management of non-genetic factors in herds.

Various non-genetic factors such as dam parity, litter size, kidding age, and year–season of kidding affect milk production and component traits in goats. This is because these factors influence both the survival and productivity of animals (Idowu & Adewumi, 2017). The influence of these factors on various production traits and components in dairy goats should be regularly assessed to monitor how animals are coping with the forever-changing environmental conditions and thus, develop an understanding on how herd management efficiency can be improved. Moreover, during genetic evaluation of various production traits and components, the non-genetic sources of variation should be adjusted for in the models to improve accuracy of prediction and reduce bias.

The effects of non-genetic factors on yield and composition of various milk production parameters have been reported in the SA dairy goat population (Muller, 2005), U.S Alpine (Browning *et al*., 1995), Red Sokoto (Akpa *et al*., 2002), Mexican Saanen (Torres-Vasquez *et al*., 2009), Bangladesh Black Bengal (Mia *et al*., 2014), and Polish dairy goat populations (Bagnicka *et al*., 2015). From past findings, it is evident that these factors determine to what extent the genetic potential of animals is expressed. The effects of dam parity, litter size, kidding age, birth year and season, as well as kidding season, on parameters such as average lactation, somatic cell count index, and net returns have not been reported in South African dairy goat populations. Thus, there is currently limited literature in this area.

Due to fluctuations in environmental conditions over time, the importance of these factors on traits of economic importance should be regularly analysed in various animal populations to evaluate how animals are coping with the dynamic environmental conditions. This will permit the South African Saanen goat breeders to develop an understanding of which factors to adjust for during genetic predictions when comparing average lactation performance: urea concentration (urea), persistency (P), net returns (NR), somatic cell count index (SCCI), as well as yields of milk (MY), fat (FY), protein (PY), and lactose (LY). Furthermore, knowledge on the effects of these factors will serve as a management guideline for breeders on how to improve herd management efficiency. This study was aimed at investigating the significance of dam parity, litter size, season of kidding, kidding age, dam year, and season of birth on average lactation urea, P, NR, SCCI, MY, FY, PY, and LY in the South African Saanen goat population kidding between 1955 and 2018.

Materials and methods

Ethical clearance for this study was granted by the University of Limpopo Animal Research Ethics Committee (ethical clearance number: AREC/04/2020: PG). This study used secondary data on lactation records of all grade and registered Saanen goats participating in the official Milk Recording and Performance Testing Scheme of the Animal Improvement Institute of the Agricultural Research Council of South Africa kidding between 1955 and 2018. SA studbook and MILCH breeders' society availed a total of 31 294 lactation performance records from the LOGIX national database. Repeated lactation performance data on milk yield (MY), fat yield (FY), protein yield (PY), lactose yield (LY), urea concentration (urea), net returns (NR), persistency (P), and somatic cell count index (SCCI) were of interest for the purpose of this study. Data on fixed factors in the study included dam parity, litter size, kidding date, and birth date. Dam age was the only covariate included in the analysis. Average lactation performances of all parameters were determined using the international standard procedures as recommended by the International Committee for Animal Recording (ICAR).

Data edits included checks for lactation length and milk yield. Almost 15 518 (49.6%) animals in the original performance file had incomplete lactation length and no information on lactation milk yield. Subsequently, these animals were discarded from the data subject to analysis of variance (ANOVA) for significant effects. A total of 16 407 lactation performance records were analysed to determine significant effects of dam parity, litter size, season of kidding, as well as both the year and season of birth of the dam on lactation milking performance of MY, FY, PY, LY, urea, NR, P, and SCCI. Fixed and random factors together with their respective levels are shown in Table 1. Analysis of variance (ANOVA) was carried out using Minitab software (Version 18 of 2017); multiple comparisons between groups were done using Fisher's least significant difference (LSD) method at 95% confidence.

Pearson's correlation coefficients were calculated between various milk production parameters and dam kidding age, where dam kidding age was used as a covariate. The mixed model (in matrix notation) was:

$$Y_{ijk} = \mu + xb_i + za_j + e_{ijk} \qquad (1)$$

where:
Y_{ijk} = the response measured,
μ = overall mean,
xb_l = vector for random factors (dam kidding age),
za_j = Vector for fixed factors, and
e_{ijk} = random residual error associated with individual animal.

Table 1 Fixed and random factors and their respective levels

Factor	Levels
Parity	1, 2, 3, 4, 5, 6, and ≥7
Litter size	1 (single), 2 (twins), and 3 (triplets)
Kidding season	Summer (November–January), Autumn (February–April), Winter (May–July), and Spring (August–October)
Birth season	Summer (November–January), Autumn (February–April), Winter (May–July) and Spring (August–October)
Birth year	1955–2016
Kidding age	9–150 months

Results and Discussion

The significance of non-genetic factors on average lactation performance (305 d) of various milk production parameters is presented in Table 2. ANOVA results indicated that both dam parity level and birth season influenced the variation in average lactation performance of all parameters studied (P <0.05). While there was no variation (P >0.05) that was due to dam litter size in average lactation performance of FY and PY, there was variation (P <0.05) in average lactation performance of other parameters. The effect of birth season of the dam influenced (P <0.05) all parameters except average lactation, MY, urea, and NR. Dam kidding season influenced (P <0.05) average lactation performance of all parameters except average lactation and PY. Kidding age of the dam influenced (P <0.05) the variation in average lactation persistency and yields of milk, fat, protein, and lactose.

Least square means of lactation performance of MY, FY, PY, LY, urea, P, NR, and SCCI are presented in Table 3. The average lactation yields of MY, FY, PY and LY followed a similar production trend with dams maintaining high yields between the first and fourth parities, followed by a slight decline in yield between the fifth and sixth parities, and relatively low yields beyond the sixth parity. Third parity dams gave the highest lactation yields (1073.4 ± 40.0 kg, 40.6 ± 1.6 kg, 31.3 ± 1.4 kg, and 46.7 ± 1.9 kg for MY, FY, PY, and LY, respectively), whereas lowest lactation yields for these traits were estimated in the ≥7th parity group (775.4 ± 56.6, 29.5 ± 2.3, 20.6 ± 2.0, and 33.0 ± 2.9 kg for MY, FY, PY, and LY, respectively).

Table 2 Significance of non-genetic factors on average lactation yield of milk production traits in Saanen goats

Trait	Parity	Litter size	Birth year	Birth season	Kidding season	Kidding age
Milk yield	**	**	**	*	*	*
Fat yield	**	ns	**	ns	*	**
Protein yield	**	ns	**	ns	ns	**
Lactose yield	**	*	**	ns	*	*
Urea concentration	**	*	*	*	*	ns
Net returns	**	**	**	*	*	ns
Persistency	**	*	**	ns	*	*
Somatic cell count index	**	**	**	ns	*	ns

**, significant at *P* ≤0.01; *, significant at *P* ≤0.05; ns, not significant, *P* >0.05

According to Ishag *et al*. (2012), milk production tends to increase with the progress in lactation order because parity and age are closely related. The increase in milk production is probably attributed to the fact that older animals are larger in size and usually have a more prominent udder compared to young animals. Furthermore, the present findings could also be attributed to other factors such the difference in nutrient partitioning for growth in young and old animals, as well as few animals in the population reaching beyond 6th parity as a result of culling older animals from herds due to their low-quality milk. Average lactation urea increased with an increase in the level of parity with the highest value detected in ≥7th parity dams (29.5 ± 1.3 mg/dl). Various studies investigating the effect of crude protein (CP) content on milk urea concentration have been carried out (Giovanetti *et al*., 2019; Nousiainen *et al*., 2004). Findings from these studies indicate that dietary crude protein levels are the most ideal indicator of milk urea concentration, with the correlation between the two reported to be high and positive. Results obtained in the current study could be due to an increase in dietary crude protein intake in older animals. Average lactation P decreased with an increase in parity level with highest value estimated in first parity dams (103.9 ± 5.4%).

Somatic cell count index (SCCI) was found to increase with an increase in the parity, with the highest and lowest values estimated in the fifth and first parity groups, respectively (3.5 ± 0.3 and 2.2 ± 0.3 cells/ml). Jeretina *et al*. (2017) describe SCCI as the sum of the differences between calculated log(SCC) values that are interpolated and the standard SCC curve shape values for a given period, divided by the area above the standard SCC curve shape. SCCI has been shown to be a reliable tool for detecting intra-mammary infections, and its inclusion in selection indices for this population can aid in accurately predicting lactation and daily milk yield losses that are due to increases in concentrations of body cells found in milk. The increased susceptibility of older animals to pathogens accumulated from lying on surface may be attributed to their prominent teat canals, as they have been milked more frequently and have a higher number of parities. This is because the production and storage of milk in the mammary gland increases with advances in parity level, rather than being reduced. Consequently, the size of functional tissues responsible for the secretion also increase. This may explain the higher SCCI values observed in older animals, as the increased size of functional tissues may provide a more conducive environment for the proliferation of pathogens.

Selection effects may have also played a role in influencing current estimations. Animals diagnosed with abnormal levels of body cells in their milk may be more likely to get culled from herds, leading to a biased sample of animals with lower SCCI values. This suggests that selection for lower SCCI values may be an effective strategy in improving milk quality and reducing milk yield losses due to intra-mammary infections. However, it is important to consider the potential trade-offs between selection for lower SCCI values and other production traits, such as milk yield and fertility, in order to maintain a balanced breeding objective. Overall, the relationship between SCCI and parity level highlights the importance of considering both animal age and milk quality traits in selection decisions in order to optimize herd productivity and milk quality.

The values estimated for average lactation NR in this study suggest that 1st and ≥7th parity dams yield highest and lowest NR, respectively (R1084.6 ± 46.5 and R586.9 ± 78.7). Present results can be attributed to a variety of factors. One such factor is the low prevalence of mastitis cases in young animals, which results in a longer lactation length and less expenditure on medication for positive cases compared to older groups. Additionally, feeding costs are usually higher in older animals due to their increased intake of nutrients compared to younger groups. This study is the first of its kind to investigate the significance of parity level on average lactation NR in South African dairy goat populations. Therefore, limited comparable literature exists in this area.

The least square means of lactation performance of various milk production parameters and components across various litter size levels in SA Saanen goats are summarized in Table 4. The parameters under consideration include milk yield (MY), fat yield (FY), protein yield (PY), lactose yield (LY), urea, persistency (P), net returns (NR), and somatic cell count index (SCCI). Animals that gave birth to triplets exhibited the highest MY, with a mean value of 977.2 ± 41.5 kg. Similarly, the highest LY was also observed in the triplet-litter dams, with a mean value of 42.3 ± 2.0 kg. In contrast, the lowest MY and LY were recorded in single litter-bearing animals, with mean values of 939.6 ± 40.9 kg and 41.0 ± 2.0 kg, respectively. These findings align with the observations of Rabasco *et al*. (1993), who reported an 11% increase in milk production in animals with multiple births than those with single births. The variation in MY and LY can be attributed to differences in the quantity of hormones responsible for mammary gland stimulation during gestation, such as placental lactogen, progesterone, and prolactin. Single litter-bearing dams produced urea levels (26.7 ± 0.7 mg/dl) comparable to those in both twin- (27.1 ± 0.7 mg/dl) and triplet- (26.5 ± 0.7 mg/dl) bearing groups.

The lower urea levels in the milk of triplet-bearing animals could be due to these animals using more of their dietary crude protein intake for the maintenance of multiple foetuses during gestation, leaving less to be excreted. Triplet-bearing animals also yielded the highest average lactation NR. This finding is economically significant, as animals with higher lactation persistency have been reported to be more profitable (Dekkers *et al*., 1996). Furthermore, such animals have been found to have higher disease resistance (Harder *et al*., 2006), which could potentially result in fewer mastitis incidents within herds and improved profits. Regarding the average P, all three groups showed high values with estimates over 70%, indicating a slow rate of decline in daily milk production after reaching peak yield within lactation.

According to the research conducted by Hanson *et al*. (2011), the performance of adult animals can be substantially influenced by lasting changes in their metabolism. These metabolic changes are often the result of both the pre-natal and post-natal environments that the animals are exposed to. Furthermore, it is essential to consider various management practices, such as the level of feeding and the date of forage harvesting, as these can also impact an animal's performance, regardless of the season in which they were born. In Table 5, least square means of lactation performance of several variables, such as MY, FY, PY, LY, urea, P, NR, and SCCI, across various seasons in which the dams were born, are presented. Animals born during the spring season produced the highest amount of milk (955.7 ± 35.6kg) within a single lactation. Animals born during the summer season yielded a higher NR (R836.0 ± 56.2) and had higher milk crude protein content (P <0.05) than those born in other seasons.

The impact of an animal's season of birth on their lactation performance is supported by research conducted by Susanto *et al*. (2019), who demonstrated that average lactation MY increases as the season changes from dry to wet in cows. The differences observed in lactation performance across the various seasons of an animal's birth can be attributed to the quality and quantity of feed available during these respective seasons, as well as the photoperiod, or the length of daylight hours, during these seasons. Therefore, it is essential for animal managers, breeders, and researchers to consider these environmental factors when evaluating an animal's potential performance and implementing management practices. The current estimations could also reflect few occurrences of births of animals in other seasons as approximately 80% of the animals in this population are born during the spring season.

Table 3 Average lactation performance of MY, FY, PY, LY, urea, P, NR, and SCCI across various parity levels in Saanen goats

Parity	N	MY (kg)	FY (kg)	PY (kg)	LY (kg)	Urea (mg/dl)	P (%)	NR (rands)	SCCI (cells/ml)
1st	12344	947.3 ± 40.2[cd]	37.3 ± 1.6[b]	29.4 ± 1.3[b]	42.6 ± 1.8[bc]	25.9 ± 0.7[bc]	103.9 ± 5.4[a]	1084.6 ± 46.5[a]	2.2 ± 0.3[c]
2nd	7750	1043.2 ± 39.7[b]	39.8 ± 1.6[a]	31.1 ± 1.3[a]	45.9 ± 1.8[a]	25.3 ± 0.6d	75.7 ± 5.7[b]	912.6 ± 45.5[b]	2.9 ± 0.3[b]
3rd	5167	1073.4 ± 40.0[a]	40.6 ± 1.6[a]	31.3 ± 1.4[a]	46.7 ± 1.9[a]	25.5 ± 0.7[cd]	65.9 ± 5.9[c]	852.0 ± 46.8[c]	3.3 ± 0.3[a]
4th	2985	1020.3 ± 41.4[b]	38.3 ± 1.7[b]	28.8 ± 1.4[b]	44.1 ± 2.1[b]	26.0 ± 0.7[bcd]	65.6 ± 6.3[c]	763.5 ± 50.6[d]	3.4 ± 0.3[a]
5th	1718	972.8 ± 44.2[c]	37.1 ± 1.8[b]	27.5 ± 1.6[c]	42.1 ± 2.2[c]	26.8 ± 0.9[b]	67.8 ± 7.2[bc]	730.5 ± 57.5[de]	3.5 ± 0.3[a]
6th	894	901.6 ± 48.6[d]	34.1 ± 2.0[c]	24.6 ± 1.7[d]	38.4 ± 2.5[d]	28.4 ± 1.0[a]	63.0 ± 8.3[c]	663.4 ± 66.0[ef]	3.5 ± 0.4[ab]
≥7th	646	775.4 ± 56.6[e]	29.5 ± 2.3[d]	20.6 ± 2.0[e]	33.0 ± 2.9[e]	29.5 ± 1.3[a]	66.6 ± 9.9[bc]	586.9 ± 78.7[f]	3.2 ± 0.4[ab]

Within a column, means that share a superscript are not significantly different (*P* >0.05)
MY: milk yield; FY: fat yield; PY: protein yield; LY: lactose yield; urea: urea concentration; P: persistency; NR: net returns; SCCI: somatic cell count index; N: number of dams

Table 4 Average lactation performance of MY, FY, PY, LY, urea, P, NR and SCCI in single- and multiple-birth Saanen dams

Litter size	N	MY (kg)	FY (kg)	PY (kg)	LY (kg)	Urea (mg/dl)	P (%)	NR (rands)	SCCI (cells/ml)
1	10960	939.6 ± 40.9[b]	36.4 ± 1.7[a]	27.2 ± 1.4[b]	41.0 ± 2.0[b]	26.7 ± 0.7[ab]	74.6 ± 6.2[a]	775.1 ± 49.8[b]	3.0 ± 0.3[b]
2	5775	969.2 ± 41.1[a]	36.7 ± 1.7[a]	27.9 ± 1.4[a]	42.2 ± 2.0[a]	27.1 ± 0.7[a]	70.3 ± 6.2[b]	778.5 ± 49.2[b]	3.3 ± 0.3[a]
3	5378	977.2 ± 41.5[a]	36.9 ± 1.7[a]	27.7 ± 1.4[ab]	42.3 ± 2.0[a]	26.5 ± 0.7[b]	73.1 ± 6.4[ab]	843.7 ± 50.7[a]	3.2 ± 0.3[ab]

Within a column, means that share a superscript are not significantly different (*P* >0.05)
MY: milk yield; FY: fat yield; PY: protein yield; LY: lactose yield; urea: urea concentration; P: persistency; NR: net returns; SCCI: somatic cell count index; N: number of dams

Table 5 Average lactation performance of MY, FY, PY, LY, urea, P, NR, and SCCI across various dam birth seasons in Saanen goats

Dam Birth season	N	MY (kg)	FY (kg)	PY (kg)	LY (kg)	Urea (mg/dl)	P (%)	NR (rands)	SCCI (cells/ml)
Winter	4830	918.9±37.4^{b}	36.1±1.5^{a}	26.4±1.3^{a}	39.8±1.8^{b}	26.1±0.6^{b}	75.4±5.5^{a}	734.4±44.2^{b}	3.0±0.3^{b}
Spring	24937	955.7±35.6^{a}	35.2±1.4^{a}	27.2±1.2^{a}	41.1±1.7^{a}	26.3±0.6^{b}	71.1±5.4^{b}	747.7±42.9^{b}	3.2±0.2^{a}
Summer	1411	938.6±40.9^{ab}	35.7±1.7^{a}	26.8±1.4^{a}	40.9±2.0^{ab}	28.1±0.8^{a}	77.0±7.0^{ab}	836.0±56.2^{a}	3.4±0.3^{ab}
Autumn	116	1034.8±82.2^{ab}	39.8±3.3^{a}	30.0±2.7^{a}	45.6±3.8^{ab}	26.6±1.4^{ab}	67.1±12.0^{ab}	878.1±96.1^{ab}	3.0±0.5^{ab}

Within a column, means that share a superscript are not significantly different (P >0.05)
MY: milk yield; FY: fat yield; PY: protein yield; LY: lactose yield; urea: urea concentration; P: persistency; NR: net returns; SCCI: somatic cell count index; N: number of dams

Table 6 Average lactation performance of MY, FY, PY, LY, urea, P, NR and SCCI across various dam kidding seasons in Saanen goats

Kidding season	N	MY (kg)	FY (kg)	PY (kg)	LY (kg)	Urea (mg/dl)	P (%)	NR (rands)	SCCI (cells/ml)
Winter	4243	1046.9±25.6^{a}	38.1±1.3^{a}	29.4±1.0^{ab}	46.0±1.4^{a}	27.3±0.5^{a}	61.3±4.6^{bc}	779.2±36.7^{b}	3.2±0.2^{c}
Spring	25685	1054.4±24.1^{a}	36.9±1.0^{b}	29.2±0.9^{ab}	46.2±1.3^{a}	26.9±0.5^{b}	60.4±4.5^{c}	781.8±36.1^{b}	3.3±0.2^{b}
Summer	1263	1004.5±39.5^{a}	38.8±1.6^{ab}	30.2±1.4^{a}	44.0±1.9^{a}	27.9±0.8^{ab}	68.6±5.9^{ab}	889.7±47.2^{a}	3.9±0.3^{a}
Autumn	103	742.0±129.0^{b}	32.9±5.2^{ab}	21.6±4.1^{b}	31.1±5.9^{b}	29.9±1.9^{ab}	100.0±16.7^{a}	746.0±133.0^{a}	2.2±0.7^{bc}

Within a column, means that share a superscript are not significantly different (P >0.05)
MY: milk yield; FY: fat yield; PY: protein yield; LY: lactose yield; urea: urea concentration; P: persistency; NR: net returns; SCCI: somatic cell count index; N: number of dams

Average lactation performance of various milk production parameters and components, including MY, FY, PY, LY, urea, P, NR, and SCCI, across different dam kidding seasons, are detailed in Table 6. In order to achieve the highest average lactation MY and LY in this population, animals should ideally be bred for spring kidding. Muller (2005) stated that the majority (82%) of animals in the South African dairy goat population kid during the spring season (between August and September). This seasonal kidding pattern aligns naturally with the spring flushing of pastures, thus providing a conducive environment for milk production. Whereas winter kidding animals produced the highest average FY, they also exhibited the highest milk crude protein content (27.3 ± 0.5 mg/dl). This suggests a possible correlation between the season and the quality of milk produced. Summer season kidding animals demonstrated the highest NR and least rate of decline in daily milk production, which is a positive indicator of reproductive efficiency. Variations in animal performance across different kidding seasons can be attributed to the extended photoperiod, which has been suggested to promote milk production (Dahl *et al*., 2000). The wet conditions associated with both spring and summer seasons may also contribute to slower rates of milk yield decline (Marete *et al*., 2014; Pesántez *et al*., 2014). However, the summer kidding season also presents a challenge in the form of elevated somatic cell counts (SCCI), indicating an increased risk of mastitis. This could be due to the increased humidity and temperature during the summer months, which can create favourable conditions for the growth of mastitis-causing pathogens (Godden *et al*., 2003). The season of kidding substantially impacts the average lactation performance of various traits of economic importance in dairy goats. This underscores the importance of considering environmental factors and their influence on milk yield and quality when planning breeding and management strategies for dairy goat herds.

Figure 1 shows trends of average lactation performance for various milk production parameters across 61 birth years (between 1955 and 2016) in the South African Saanen goat population. Trends for average lactation performance of milk and fat yields follow a similar fluctuating trend, suggesting that positive correlated responses to selection may exist between these traits. Dams born during the first 12 years (from 1955 to 1967) except for the period between 1956 and 1957, yielded averages above 1000 kg and 35 kg for milk and fat, respectively. During this period, only 1020 lactation records were available. Between the years 1968 and 2000, 14 905 records were available with almost all animals yielding lactation averages below 1000 kg for milk yield, except groups born in the years 1978 (1090 kg), 1980 (1014.4 kg), and 1985 (1031 kg), while the lowest average lactation performance of milk yield between this period was estimated in dams born 1977 (688.7 kg). Almost all animals born between the years 1971 and 1997 yielded average lactation fat below 35 kg. The period between 2001 and 2016 saw a total of 16 098 available lactation performance records. Dams born particularly during the years 2003, 2004, 2005, 2006, and 2008 gave average lactation milk yields below 1000 kg, whereas the rest yielded above 1000 kg per lactation. Furthermore, all animals born during the same period produced average lactation fat yield over 35 kg. Groups born specifically in the years 2004 (896.9 kg and 39.18 kg) and 2016 (1285.8 kg and 57.92 kg) yielded lowest and highest averages for milk and fat, respectively.

The official recording of lactation averages for protein yield and net returns commenced from 1974 and 1991, respectively. Average lactation performance of both these parameters follows a similar fluctuating trend to that of average lactation milk yield, also suggesting possibilities of positive correlated responses to selection between these parameters. Between the period 1974 and 2000, animals born particularly during the years 1976 and 1974 yielded lowest and highest average lactation protein yields of 18.98 kg and 31.8 kg, respectively. Animals born during the years 1991 and 1996 gave lowest and most net returns per lactation (R618 and R1035.5, respectively). All dams born between 2001 and 2016, except in the year 2005 (28.65kg), yielded average lactation protein above 30 kg, with the highest yield attained by the group born during the year 2016 (41.31 kg). During the same period, dams born in the year 2016 also gave the highest average lactation net returns (R951.9).

Recording of average lactation performance of lactose and SCCI commenced in the years 1981 and 1991, respectively. The trend in average lactation SCCI fluctuated between years 1991 and 1995. This was followed by an almost consistent trend between 1996 and 2016, with the lowest and highest SCCI recorded in animals born during the years 2006 (3.887 cells/ml) and 2016 (2.313 cells/ml). Recent reductions in SCCI can be attributed to intense selection methods applied against this trait, as well as improved management practices in most herds within the population. Average lactation performance of lactose yield has also not been consistent and shows a fluctuating trend that is almost similar to that of average lactation milk yield, with improved yields estimated in dams born during 2016. Recent improvements in averages of lactation net returns and parameters such as milk, fat, and protein yield are probably due to the use of genetically superior animals for breeding in most herds; increased population size could also have increased the intensity of selection in the population. However, advances in environmental and management factors such as biosecurity, welfare, climate, and feeding cannot be ignored because these factors determine whether an animal's full genetic potential is attained or not.

Average lactation urea concentration and persistency were first recorded during the years 1997 and 1991, respectively. Lactation trends for the rate of decline in milk production post peak yield have not been consistent over the years, with average increases and decreases of over 20% between the period 1993 and 2001. The average lactation persistency estimated between the period 2002 and 2006 was below 10%. Between 1991 and 2016, highest and lowest values for average lactation persistency were estimated in groups born during the years 1996 and 1993, respectively (97.9% and 58.5%). Animals born particularly during the years 1997 and 2010 yielded least and most averages for lactation urea concentration (22.54 and 32.388 mg/dl, respectively). Given that urea indicates levels of dietary crude protein, variations in urea levels over the years could have been related to differences in feeding practices applied, as well as availability of forages over the years.

Generally, variation in lactation performance of various milk production parameters in the population across various birth years could have been influenced by a host of factors. Differences in genetic composition of animals, climate, and management practices applied in each year are among the factors that could have influenced current estimations.

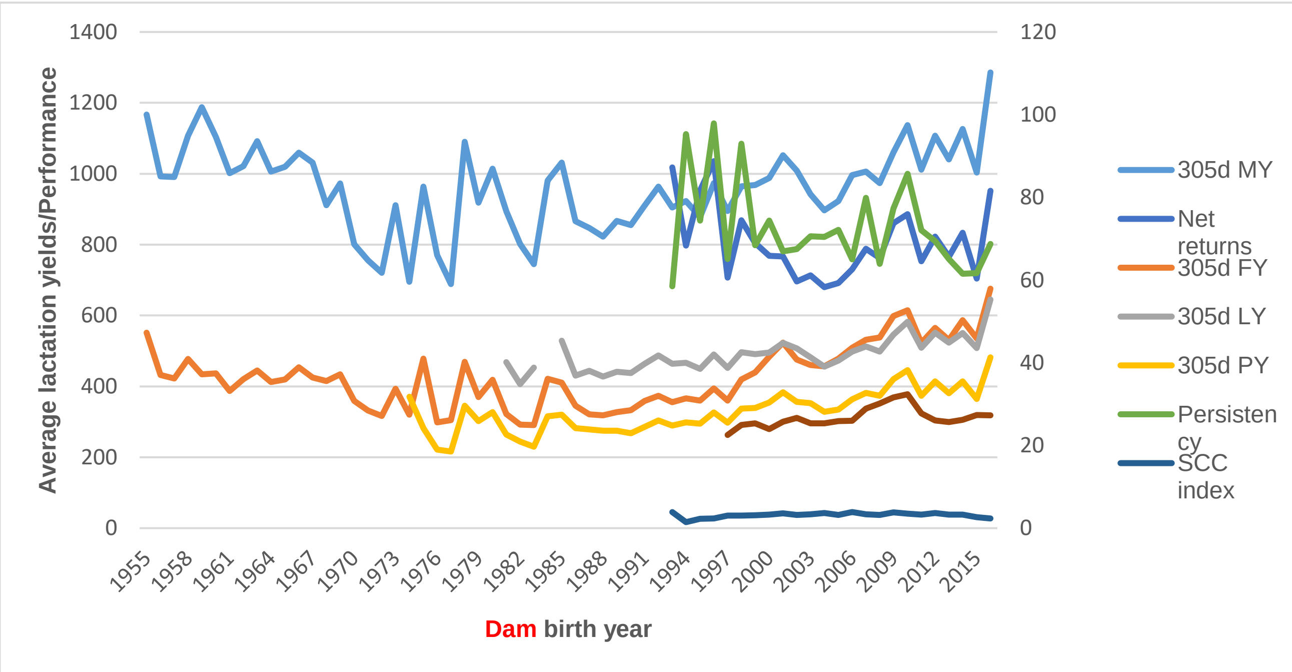

Figure 1 Lactation yield trends for various milk production traits and components of does born in various years
305d MY: Milk yield; 305d FY: Fat yield; 305d PY: Protein yield; 305d LY: Lactose yield; Urea: 305d urea concentration; Persistency: 305d Persistency; Net returns: 305d Net returns; SCCI index: 305d somatic cell count index

Phenotypic relationships between dam kidding age and various milk production parameters are shown
in Table 7. Average lactation performance of all milk production parameters investigated (except somatic cell count index; r_p= 0.189) were negatively correlated to dam kidding age (r_p= -0.30, -0.004, -0.057, -0.051, -0.015, -0.265, and -0.271 for urea, milk yield, fat yield, protein yield, lactose yield, net returns, and persistency, respectively). Average lactation somatic cell count index in milk increased with dam kidding age, whereas average lactation performance of other parameters declined with an increase in age. Therefore, older animals in this population (usually beyond the 6th parity) produced high somatic

cell count indices per lactation and had the lowest average lactation net returns as a result of milk yield losses associated with somatic cell counts. Moreover, the rate of decline in daily milk yield post-peak within lactation increased, whereas average lactation urea concentration and yields of milk, fat, protein, and lactose declined. Due to more experience in lactation, the secretory parenchyma, teat, and udder size in older animals are usually more developed. Increases in these factors could have contributed substantially towards their susceptibility to pathogens accumulated from lying on surfaces.

The correlations between average lactation urea and somatic cell count index, and between urea and average lactation persistency were low and negative. Estimations from this study further illustrate that the phenotypic relationships between average lactation milk yield and parameters such as fat yield, protein yield, lactose yield, and net returns are very high and positive, suggesting the possibility of high and positive genetic correlations among these traits. Average lactation protein yield was highly and positively correlated to both lactose yield and net returns, whereas low and positive phenotypic relationships existed between protein yield and persistency (r_p = 0.061), protein yield and somatic cell count index (r_p = 0.071), and protein yield and urea concentration (r_p = 0.136).

High and positive associations existed between average lactation fat yield and protein yield (r_p = 0.947), fat yield and lactose yield (r_p =0.884), and fat yield and net returns (r_p = 0.926), whereas low and positive relationships existed between average lactation fat yield and parameters such as persistency, somatic cell count index, and urea concentration (r_p = 0.027, 0.145, and 0.119 for somatic cell count index, persistency, and urea concentration, respectively). It is necessary to monitor and control somatic cell count indices in herds because abnormal levels will result in average lactation milk yield losses associated with clinical mastitis. Generally, phenotypic correlation values estimated between the various traits studied should be considered in selection programs as their corresponding genetic correlation values may be close. Thus, there is a need to estimate genetic correlation values for this population to evaluate the response in selection of the various traits studied.

Table 7 Phenotypic correlations between dam kidding age and various milk production parameters

	Kidding age	Urea	Milk yield	Fat yield	Protein yield	Lactose yield	Net returns	Persistency	Somatic cell count index
Kidding age	-								
Urea	-0.030**	-							
Milk yield	-0.004^{ns}	0.101*	-						
Fat yield	-0.057**	0.119**	0.891**	-					
Protein yield	-0.051**	0.136**	0.955**	0.947**	-				
Lactose yield	-0.015^{ns}	0.094**	0.982**	0.884**	0.946**	-			
Net returns	-0.265**	0.146**	0.886**	0.926**	0.933**	0.894**	-		
Persistency	-0.271**	-0.038**	-0.005^{ns}	0.145**	0.071**	0.047**	0.209**	-	
Somatic cell count index	0.189**	-0.029**	0.071**	0.027**	0.061**	0.007^{ns}	-0.019*	-0.157**	-

**, significant at *P* <0.01; *, significant at *P* ≤0.05; ns, not significant at *P* >0.05

Conclusion

Non-genetic factors determine to what extent the genetic potential of animals for various economic traits of importance is expressed. Dam parity, birth year, kidding age, litter size, birth and kidding seasons should then be adjusted for when comparing average lactation performance of various milk production parameters in this population, by incorporating their effects in statistical models of genetic evaluations. The average lactation performance of these parameters increased between the first and sixth parities, with better performance estimated in third parity dams. For optimal lactation performance, multiple-birth animals should be selected over their single-birth counterparts. Animals born and kidding during the spring season yield better per lactation compared to the rest. There is a need to estimate genetic correlation values for the traits studied to evaluate their response to selection.

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Authors' contributions

Project idea, design, and study execution were contributed by MJM, KRN, and OT. MJM and OT were responsible for the analysis of the data. KRN and OT oversaw supervision of the manuscript. MJ was responsible for writing of the manuscript. All authors have read and approved the finalized manuscript.

Conflict of interest

Authors declare that no conflict of interest was encountered concerning publication of this manuscript.

References

Dahl, G.E., Buchanan, B.A. & Tucker, H.A., 2000. Photoperiodic effects on dairy cattle: A review. Int J Dairy Sci, 83(4), 885–93.

Dekkers, J.C.M., Jamrozik, J., ten Hag, J.H., Schaeffer, L.R. & Weersink, A., 1996. Genetic and economic evaluation of persistency in dairy cattle. Proc. Int. Workshop on Genetic improvement of functional traits in cattle. Gembloux, Belgium. INTERBULL Bulletin. 12, 97–102.

Godden, S., Rapnicki, P., Stewart, S., Fetrow, J., Johnson, A., Bey, R. & Farnsworth, R., 2003. Effectiveness of an internal teat seal in the prevention of new intra-mammary infections during the dry and early-lactation periods in dairy cows when used with a dry cow intra-mammary antibiotic. J Dairy Sci. 86, 3899–3911.

Giovanetti, G., Boe, F., Decandia, M., Bomboi, G.C., Atzori, A.S., Cannas, A. & Molle, G., 2019. Milk urea concentration in dairy sheep: Accounting for dietary energy concentration. Animals, 9(12).

Hanson, K.M., Godfrey, K.A., Lillycrop, K.A., Burge, G.C. & Gluckman, P.D., 2011. Developmental plasticity and developmental origins of non-communicable disease: Theoretical considerations and epigenetic mechanisms. Prog Biophys Mol Biol. 106(1), 272–280.

Harder, B., Bennewitz, J., Hinrichs, D. & Kalm, E., 2006. Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. J Dairy Sci. 89, 3202–3212.

Idowu, S.T. & Adewumi, O.O., 2017. Genetic and non-genetic factors affecting yield and milk composition in goats. J Dairy Res. 5, 175.

Ishag, I.A., Abdalla, S.A. & Ahmed, M-K.A., 2012. Factors affecting milk production traits of Saanen goat raised under Sudan-semi arid conditions. J Anim Feed Res. 2(5), 435–438.

Jeretina, J., Skorjanc, D. & Babnik, D., 2017. A new somatic cell count index to more accurately predict milk yield losses. Arch Anim Breed. 60, 373–383.

Marete, A.G., Mosi, R.O., Amimo, J.O. & Junga, J.O., 2014. Characteristics of lactation curves of the Kenya Alpine dairy goats in smallholder farms. S Afr J Anim Sci. 4, 92.

Minitab 18 Statistical Software., 2017. [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com).

Muller, C.J.C., 2005. Genetic parameter estimation and breeding plans for the South African dairy goat herd. PhD Thesis. Department of Animal Science, Faculty of Agricultural and Forestry Sciences, University of Stellenbosch. South Africa.

Nousiainen, J., Shingfield, K.J. & Huhtanen, P., 2004. Evaluation of milk urea nitrogen as a diagnostic of protein feeding. Int J Dairy Sci. 87(2), 386–398.

Pesántez, M., Hernández, A. & Fraga, L., 2014. Persistency of milk yield in Anglo Nubia × Criolla goats. Cuban J Agric Sci. 48(4), 337–342.

Rabasco, A., Serradilla, J.M., Padilla, J.A. & Serrano, A., 1993. Genetic and non-genetic sources of variation in yield and composition of milk in Verata goats. Small Rumin Res. 11.

Susanto, A., Hakim, L. & Nurgiartiningish, V.M.A., 2019. Environmental (year-season of birth) effects on first-lactation milk yield of dairy cows. IOP Conference Series: Earth and Environmental Science, 372.