HAIR PRODUCTION, REPRODUCTION AND INCOME OF ANGORA GOAT EWES THAT HAD FIVE OR SIX KIDDING OPPORTUNITIES IN THE FLOCK

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INTRODUCTION

The ewe flock plays an important role in the generation of income from any small stock enterprise. In the case of Angora goats it generates income from the current flock through hair production and reproduction (which to a large extent comes from hair production from kids) and contributes to future flock income through genetic improvement of the progeny. The longer the ewes are kept in the flock, the longer is the generation interval. A longer generation interval in turn will lead to a slower genetic response per generation. However, a longer generation interval means fewer young ewes need to be selected for replacement purposes, with a subsequent higher selection intensity. Therefore it is important that ewes should be kept in the flock for an optimum number of years. This optimum number of years will differ between stud breeders and commercial producers. It will be longer in the latter case, as most of the genetic progress will come from sires bought from stud breeders.

In order to maximise current flock income, producers must ensure that high-producing ewes are selected and retained when keeping ewes in the flock for a longer period. The identification of high producing ewes at an early age that will maintain their production levels throughout their lifetime in the flock is thus imperative. It is expected that Angora goat ewes maintain high levels of fleece production, as well as reproduction, throughout their lifetime in the flock. The aim of this study was to determine the range in hair production, reproduction and income of Angora ewes that had five or six kidding opportunities in the flock. Furthermore, the relative contributions of hair production and reproduction to income of these ewes were also investigated.

MATERIALS AND METHODS

Animals and data collected

Data collected on the flocks of three South African Angora goat producers from 2000 until 2015 were included in this study. Details on the various traits that were recorded, as well as on which animals and in which flocks the data were recorded (if not on all animals and flocks) are summarised in Table 1. During kidding, full pedigrees, birth date, sex and birth status of each kid were recorded.

Table 1. Description of the traits recorded

Trait	Details of recording of the trait	Collected since [a]
Body weights		
Birth weight (kg)	Within 24 hours after birth	2000
Weaning weight (kg)	Recorded weight, date and management groups at 100 to 120 days of age	2000
8-Month body weight (kg)	Recorded weight, date and management groups at 8 months of age	2000
12-Month body weight (kg)	Recorded weight, date and management groups at 12 months of age	2000
16-Month body weight (kg)	Recorded weight date and management groups at 16 months of age	2000
Adult body weight (kg)	Before mating on all ewes	2005
Second and third shearing fleece traits		
Fleece weight (kg)	Recorded fleece weight, management groups and current and previous shearing dates	2000
Fibre diameter (µm)	Midrib fleece sample for determination of fibre traits with the OFDA2000 - fibre diameter, coefficient of variation of fibre diameter, standard deviation of fibre diameter, comfort factor, standard deviation of fibre diameter along the length of the fibre	
Fibre diameter traits		
Staple length (mm)		
Clean yield (%)	Only Flock B Determined on the midrib sample	2005
Style	Only Flock A and B Subjective assessment of style on a scale from 10 to 50 on the fleece before shearing	
Character	Only Flock A and B Subjective assessment of character on a scale from 10 to 50 on the fleece before shearing	
Adult fleece traits (Ewes winter shearing)		
Fleece weight (kg)	Winter shearing of ewe flock Recorded fleece weight, management groups and current and previous shearing dates	2005
Fibre diameter (µm)	Midrib fleece sample for determination of fibre traits with the OFDA2000 - fibre diameter, coefficient of variation of fibre diameter, standard deviation of fibre diameter, comfort factor, standard deviation of fibre diameter along the length of the fibre	
Fibre diameter traits		
Staple length (mm)		
Clean yield (%)	Only Flock B Determined on the midrib sample	
Style	Only Flock A Subjective assessment of style on a scale from 10 to 50 on the fleece before shearing	
Character	Only Flock A Subjective assessment of character on a scale from 10 to 50 on the fleece before shearing	
Reproduction		
Number of ewes mated	Recorded annually during mating and kidding seasons	2000
Number of kids born		
Number of kids weaned		
Total weight of kids weaned		

[a] Data on Flock A and B collected until 2015; Data on Flock C collected until 2010.

The main management practices followed in the three flocks at various stages of the reproductive cycle of the ewes and growth cycle of the kids are presented in Table 2 (from Snyman, 2007; Snyman, 2010).

Table 2. Management systems followed in the various flocks

Management practices:	Flock A [a]	Flock B	Flock C
Before mating	Ewes on veld, no supplementation	Ewes on veld, no supplementation	Ewes on pastures
During pregnancy	Ewes supplemented with energy blocks last part of pregnancy	Ewes on veld, no supplementation	Ewes on pastures
During kidding	Ewes kid on pastures and in veld	Ewes kid on veld, no supplementation	Ewes kid on pastures
Ewes during lactation	Ewes on veld, some years supplemented with pellets / blocks	Ewes on veld, some years supplemented with chocolate grain	Ewes on pastures
Kids during lactation	Kids in different rearing groups on veld	Kids with ewes on veld	Kids on pastures until weaning
Weaning to 8 months of age	Ewe kids on veld without supplementation Ram kids supplemented	Kids on veld, no supplementation	Kids on pastures
Kids from 8 to 16 months of age	Kids on veld, no supplementation	Kids on veld, no supplementation	Kids on pastures

[a] Flock A corresponded to Flock 5 in Snyman (2007) and Snyman (2010), while Flock B and Flock C respectively corresponded to Flock 7 and Flock 12.

Data analyses

Description of the datasets

The mean, minimum, maximum and coefficients of variation of the various traits were obtained with PROC MEANS of SAS (2016) for the datasets of the individual flocks, as well as for the pooled dataset. Various data sets were compiled.

Data sets A: Top 100 and Bottom 100 trait lists of ewes that had 5 or 6 kidding opportunities

For these analyses, only ewes in the dataset that had 5 (1021 ewes) or 6 (682 ewes) kidding opportunities were included. That implies ewes that remained in the flock until 6 or 7 years of age respectively. For the ewes that had 5 or 6 kidding opportunities respectively, lists were created with the 100 best performing (Top 100 list) and the 100 worst performing (Bottom 100 list) ewes for each of the following traits: Lifetime total weight of kids weaned, lifetime number of kids born, lifetime number of kids weaned, adult body weight, adult fleece weight, adult fibre diameter. These different lists were compared to determine the percentage ewes common in the Top 100 and Bottom 100 trait lists for the various traits.

Spearman rank correlations among lifetime total weight of kids weaned, adult body weight, fleece weight and fibre diameter of ewes that had 5 or 6 kidding opportunities were estimated with the CORR procedure of SAS (SAS, 2016).

Data sets B: Top and Bottom producing ewes that had 5 or 6 kidding opportunities

For these data sets, Top and bottom producing ewes were identified among the ewes that had 5 or 6 kidding opportunities according to the following criteria:

Top producing ewes:

- Produced 7 or more kids for the 5 kidding opportunity ewes (8 or more for the 6 kidding opportunity ewes), and
- Weaned 6 or more kids for the 5 kidding opportunity ewes (7 or more for the 6 kidding opportunity ewes), and
- Had a lifetime total weight of kid weaned among the highest 25% ewes, and
- Had an adult body weight among the heaviest 25% ewes, and
- Had an adult fleece weight among the heaviest 25% fleeces, and
- Had an adult fibre diameter among the finest 25% fleeces.

A total of 179 top and 118 bottom performing ewes conformed to these criteria.

Bottom producing ewes:

- Produced 3 or fewer kids for the 5 kidding opportunity ewes (4 or fewer for the 6 kidding opportunity ewes), and
- Weaned 2 or fewer kids for the 5 kidding opportunity ewes (3 or fewer for the 6 kidding opportunity ewes), and
- Had a lifetime total weight of kid weaned among the lowest 25% ewes, and
- Had an adult body weight among the lightest 25% ewes, and
- Had an adult fleece weight among the lightest 25% fleeces, and
- Had an adult fibre diameter among the strongest 25% fleeces.

A total of 207 top and 137 bottom performing ewes conformed to these criteria.

Data sets C: Early and adult production and reproduction traits of the Top 100 and Bottom 100 ewes according to lifetime number of kids born of ewes that had 5 or 6 kidding opportunities

The dataset where the 100 best and 100 worst ewes were assigned according to their lifetime number of kids born was used to evaluate the early and adult production and reproduction traits of the ewes in the Top 100 NLB and Bottom 100 NLB categories respectively. Ewes that had 5 kidding opportunities were assigned to the Top 100 NLB list when they had more than 7 kids, while those that had 6 kidding opportunities were assigned to the Top 100 NLB list when they had more than 8 kids. The corresponding numbers of kids for the Bottom 100 NLB lists were fewer than 3 and 4 respectively.

The GLM procedure of SAS (SAS, 2016) was used for these analyses. Top / bottom category, together with the respective fixed effects as described previously, were included for the various traits.

Data sets D: Early and adult production and reproduction traits of the Top 100 and Bottom 100 ewes according to yearly income of ewes that had 5 or 6 kidding opportunities

Income per ewe was calculated as hair production income and reproduction income. Hair production income was based on the average of the summer and winter market indicators for the previous seasons. A value of R238/kg was taken for fleeces with an average fibre diameter of 34 micron and less, while a value of R222/kg was taken for fleeces with an average fibre diameter above 34 micron. Only adult hair production was taken into account. An average yearly hair production income for each ewe was obtained by dividing her total hair production income by her number of shearings.

Reproduction income was determined by multiplying the lifetime number of kids weaned by R1060 (obtained from income per ewe generated at different weaning percentages). An average yearly reproductive income for each ewe was obtained by dividing her total reproductive income by her number of kidding opportunities. Total yearly income per ewe was obtained by adding the yearly hair production income and the yearly reproduction income of each ewe.

Ewes that had 5 or 6 kidding opportunities were assigned to Top 100 Income and Bottom 100 Income lists according to their total yearly income. The Top 100 Income and Bottom 100 Income lists were used to evaluate the early and adult production and reproduction traits of the ewes in the top and bottom income categories respectively. The GLM procedure of SAS (SAS, 2016) was used for these analyses. Top / bottom category, together with the respective fixed effects as described previously, were included for the various traits.

The relationship among the hair production and reproduction income and total yearly income was determined for ewes that had 6 kidding opportunities. The ewes that had 6 kidding opportunities were also divided into 4 categories on the basis of their total yearly income. The relative sources of income for these ewes were compared.

RESULTS AND DISCUSSION

Description of the dataset

The abbreviation, number of records, mean, minimum, maximum and coefficients of variation of the various traits for the pooled dataset are presented in Table 3. Only the description of the pooled dataset is provided here. The body weights of the kids varied considerably within and amongst the flocks. Among flock variation contributed to the higher coefficient of variation for the pooled value for most

of the recorded body weights. The high maximum 12-month body weight was due to fed ram kids in Flock A being included in this specific dataset. The difference in adult body weight among flocks could, apart from possible genetic differences, be ascribed to different management practices followed (Table 2).

Coefficients of variation (CV) for the various fleece traits at the second and third shearings ranged between 6% and 30%, with the exception of the CV of standard deviation of fibre diameter along the length of the staple which was in the range of 40%. For some of the adult fleece traits, CV varied markedly among the flocks, which contributed to the high CV of the pooled data. Reproductive traits had higher CV than the fleece traits or body weights. Reproductive performance of the three flocks also differed largely. This could also, apart from possible genetic differences, be ascribed to different management practices followed (Table 2).

Table 3. Description of the dataset

Trait	Abbreviation of trait	Number of records	Mean	Minimum	Maximum	Coefficient of variation (%)
Body weights						
Birth weight (kg)	BW	9460	3.20	1.0	6.0	17.58
Weaning weight (kg)	WW	10580	17.25	5.0	38.0	26.41
8-Month body weight (kg)	W8	6877	22.59	9.0	49.8	31.15
12-Month body weight (kg)	W12	4713	22.02	8.0	72.0	28.95
16-Month body weight (kg)	W16	3572	24.95	11.0	52.5	23.51
Adult body weight (kg)	ABW	3065	35.19	11.0	63.6	19.49
Second shearing fleece traits						
Fleece weight (kg)	FW2	6432	1.36	0.5	3.6	31.00
Fibre diameter (µm)	FD2	6492	26.30	17.8	40.9	12.89
Coefficient of variation of fibre diameter (%)	CV2	5882	26.78	6.6	47.4	15.98
Standard deviation of fibre diameter (µm)	SD2	5882	7.07	0.4	26.0	19.86
Comfort factor (%)	CF2	5595	74.50	8.3	99.7	21.58
Standard deviation of fibre diameter along the length of the staple (µm)	SDA2	5595	1.29	0.3	4.5	42.45
Spinning/effective fineness (µm)	SF2	5595	27.27	18.3	41.9	13.27
Staple length (mm)	SL2	5349	87.98	25.0	160.0	23.26
Clean yield (%)	CY2	950	79.97	58.3	91.6	6.00
Style	ST2	2775	32.24	10.0	50.0	24.24
Character	CH2	2775	31.04	10.0	50.0	21.84

Third shearing fleece traits						
Fleece weight (kg)	FW3	4831	1.27	0.5	4.1	25.72
Fibre diameter (µm)	FD3	4946	27.53	18.9	43.0	12.75
Coefficient of variation of fibre diameter (%)	CV3	3087	24.42	13.8	40.0	15.84
Standard deviation of fibre diameter (µm)	SD3	3047	6.66	3.7	12.1	17.24
Comfort factor (%)	CF3	2704	70.96	10.9	99.0	23.50
Standard deviation of fibre diameter along the length of the staple (µm)	SD3	2690	1.34	0.3	3.7	39.65
Spinning/effective fineness (µm)	SF3	2704	27.53	19.1	41.6	11.65
Staple length (mm)	SL3	2927	99.87	35.0	149.0	16.57
Clean yield (%)	CY3	855	74.37	45.8	98.6	7.25
Style	ST3	2255	33.01	10.0	50.0	23.70
Character	CH3	2255	29.26	10.0	50.0	22.57
Adult fleece traits (Ewes winter shearing)						
Fleece weight (kg)	AFW	12208	1.46	0.1	4.5	31.94
Fibre diameter (µm)	AFD	12382	33.25	19.4	54.3	12.97
Coefficient of variation of fibre diameter (%)	CV	9549	27.68	14.9	55.9	17.63
Standard deviation of fibre diameter (µm)	SD	10549	8.75	0.5	19.0	29.26
Comfort factor (%)	CF	9363	41.03	3.1	94.4	45.13
Standard deviation of fibre diameter along the length of the staple (µm)	SDA	9363	1.40	0.3	5.6	43.51
Spinning/effective fineness (µm)	SF	9363	34.81	19.6	57.2	12.14
Staple length (mm)	SL	9361	82.20	20.0	150.0	21.75
Clean yield (%)	CY	4210	79.21	51.0	99.0	6.01
Style	ST	5487	29.45	10.0	50.0	28.56
Character	CH	5487	30.40	10.0	50.0	24.19
Reproduction						
Total weight of kid weaned / year (kg)	TWW	13396	13.64	0	72.5	81.72
Number of kids born / year	NKB	13396	0.99	0	3	61.87
Number of kids weaned / year	NKW	13396	0.81	0	3	76.75
Number of kidding opportunities		3755	3.62	1	10	
Total weight of kid weaned / lifetime (kg)	LTTWW	3755	48.68	0	269.6	90.95
Number of kids born / lifetime	LTNKB	3755	3.52	0	14	79.42
Number of kids weaned / lifetime	LTNKW	3755	2.88	0	13	86.13
Total weight of kid weaned at first parity (kg)	TWW1	2231	9.46	0	55.40	110.27
Number of kids born at first parity	NKB1	2231	0.69	0	2	80.57
Number of kids weaned at first parity	NKW1	2231	0.55	0	2	100.24

Data sets A: Top 100 and Bottom 100 trait lists of ewes that had 5 or 6 kidding opportunities

The Top 100 and Bottom 100 trait lists of ewes that had 5 or 6 kidding opportunities were compared to determine the percentage ewes common in the two lists for the various traits. The results of these comparisons are summarised in Table 4. From the results it is obvious that there is a positive correlation among the reproductive traits, as well as between the reproductive traits and body weight. However, the fleece traits are negatively correlated with reproduction and body weight. Fleece weight and fibre

diameter *per se* is also negatively correlated.

Spearman rank correlations among lifetime total weight of kids weaned, adult body weight, fleece weight and fibre diameter of ewes that had 5 or 6 kidding opportunities are given in Table 5. These results are in agreement with those obtained with the Top 100 and Bottom 100 trait lists results in Table 4.

Table 4. Percentage ewes common in the Top 100 and Bottom 100 trait lists for reproduction, adult body weight, fleece weight and fibre diameter for ewes that had 5 or 6 kidding opportunities

Trait combinations		**5 Kidding opportunities**				**6 Kidding opportunities**			
		Top / Top	**Bottom / Bottom**	**Top / Bottom**	**Bottom / Top**	**Top / Top**	**Bottom / Bottom**	**Top / Bottom**	**Bottom / Top**
AFW with	TWW	4	5	14	37	7	11	17	44
	LG	16	4	14	43	23	14	17	41
	LS	16	4	13	51	23	14	20	46
	ABW	5	0	16	48	9	6	23	48
	AFD	2	3	28	27	3	4	28	29
AFD with	TWW	15	7	14	6	13	10	22	14
	LG	23	5	16	19	19	10	29	28
	LS	23	6	16	20	20	11	28	23
	ABW	18	5	15	11	16	11	29	10
ABW with	TWW	59	28	2	0	65	38	3	0
	LG	61	40	1	1	64	43	4	7
	LS	66	37	1	0	65	41	8	2
TWW with	LG	74	71	0	1	79	69	0	3
	LS	92	78	0	0	89	97	0	0
LG with	LS	100	93	0	0	100	87	1	0

For trait abbreviations, please see Table 3

Table 5. Spearman rank correlations (± s.e.) among Total weight of kids weaned (TWW), adult body weight (ABW), fleece weight (AFW) and fibre diameter (AFD) of ewes that had 5 or 6 kidding opportunities

Trait	**ABW5**	**AFW5**	**AFD5**
TWW5	0.55 ± 0.00	-0.28 ± 0.00	-0.07 ± 0.03
ABW5		-0.27 ± 0.00	0.09 ± 0.00
AFW5			-0.41 ± 0.00
	ABW6	**AFW6**	**AFD6**
TWW6	0.54 ± 0.00	-0.26 ± 0.00	-0.08 ± 0.03
ABW6		-0.24 ± 0.00	-0.08 ± 0.03
AFW6			-0.42 ± 0.00

Data sets B: Top and Bottom producing ewes that had 5 or 6 kidding opportunities

The adult productive performance of the 179 top and 118 bottom performing ewes that produced more than 8 and fewer than 4 kids respectively over 6 kidding opportunities are presented in Table 6. Although there were 179 ewes that produced 8 or more kids, not all of these ewes were in the top categories for the other traits. The number of ewes in the top category for the other traits is also indicated in Table 6. The same applies for the ewes in the bottom category.

Table 6. Adult productive performance of the top and bottom performing ewes over 6 kidding opportunities

Trait	Top performers (n=179)		Bottom performers (n=118)	
	Average production	Number of ewes	Average production	Number of ewes
TWW	153.5 kg	103	37.3 kg	97
NKB	8.59 lambs	179	3.25 lambs	118
NKW	7.78 lambs	132	2.11 lambs	87
ABW	46.5 kg	97	30.8 kg	50
AFW	1.82 kg	38	0.97 kg	25
AFD	29.5 µm	36	36.8 µm	17

For trait abbreviations, please see Table 3

The adult productive performance of the 207 top and 137 bottom performing ewes that produced more than 7 and fewer than 3 kids respectively over 5 kidding opportunities are presented in Table 7. Although there were 207 ewes that produced 7 or more kids, not all of these ewes were in the top categories for the other traits. The number of ewes in the top category for the other traits is also indicated in Table 7. The same applied for the ewes in the bottom category.

Table 7. Adult productive performance of the top and bottom performing ewes over 5 kidding opportunities

Trait	Top performers (n=207)		Bottom performers (n=137)	
	Average production	Number of ewes	Average production	Number of ewes
TWW	132.5 kg	121	26.3 kg	137
NKB	7.51 lambs	207	2.51 lambs	137
NKW	6.82 lambs	157	1.46 lambs	95
ABW	47.5 kg	115	30.4 kg	68
AFW	1.84 kg	42	1.04 kg	32
AFD	28.96 µm	55	36.6 µm	21

For trait abbreviations, please see Table 3

The number of ewes that were in the top categories for reproduction, body weight and fleece traits is given in Table 8. From Table 8 it is obvious that ewes that are top performers with regard to reproduction are not top performers with regard to fleece production. These results are again in agreement with those obtained with the Top 100 and Bottom 100 lists results in Table 4 and the Spearman rank correlation results in Table 5.

Table 8. Number of ewes in the top categories for reproduction, body weight and fleece traits

Traits	5 Kidding opportunities	6 Kidding opportunities
All ewes	207	179
TWW + NKB + NKW	111	92
TWW + NKB + NKW + ABW	85	75
TWW + NKB + NKW + ABW + AFW	9	8
TWW + NKB + NKW + ABW + AFW + AFD	1	1

For trait abbreviations, please see Table 3

Reproduction and hair production income of ewes that had 6 kidding opportunities

The yearly reproduction and hair production income of ewes that had 6 kidding opportunities are illustrated in Figure 1. There was more variation in yearly reproduction income than in hair production income among the ewes.

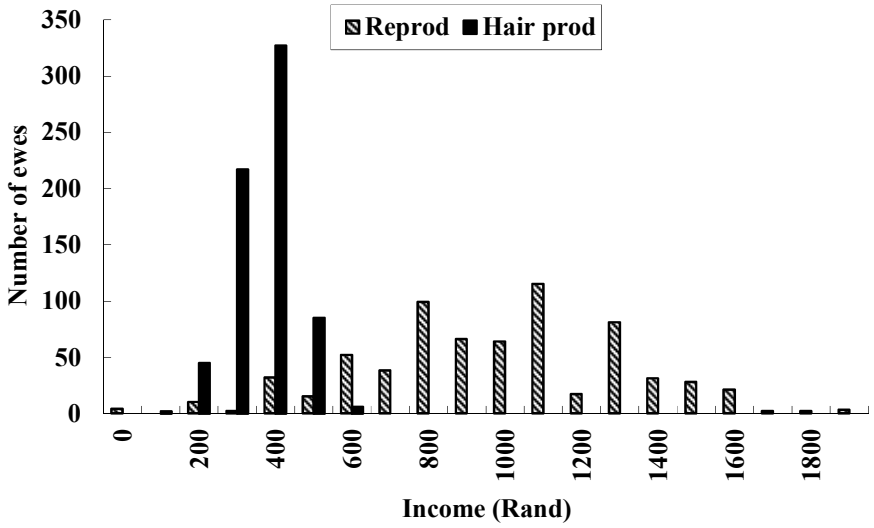

Figure 1. Yearly reproduction and hair production income of ewes that had 6 kidding opportunities

The relationship among the two sources of income and total yearly income are depicted in Figures 2 to 4. There was a slight negative relationship between yearly hair production income and yearly reproduction income (Figure 2). This is in line with the results reported earlier regarding the negative relationship between adult reproduction and hair production. Consequently, there was no discernible relationship between yearly hair production income and total yearly income (Figure 4). The relationship between yearly reproduction income and total yearly income on the other hand, was significantly positive (Figure 3).

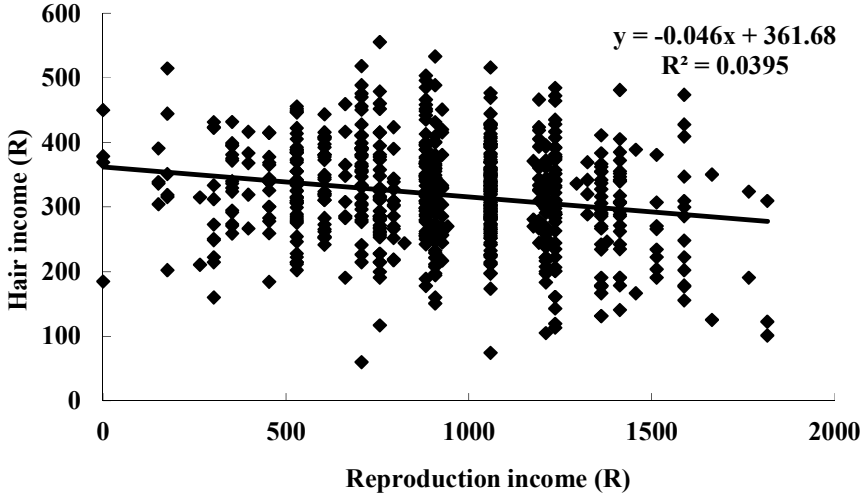

Figure 2. Relationship between yearly hair production income and yearly reproduction income

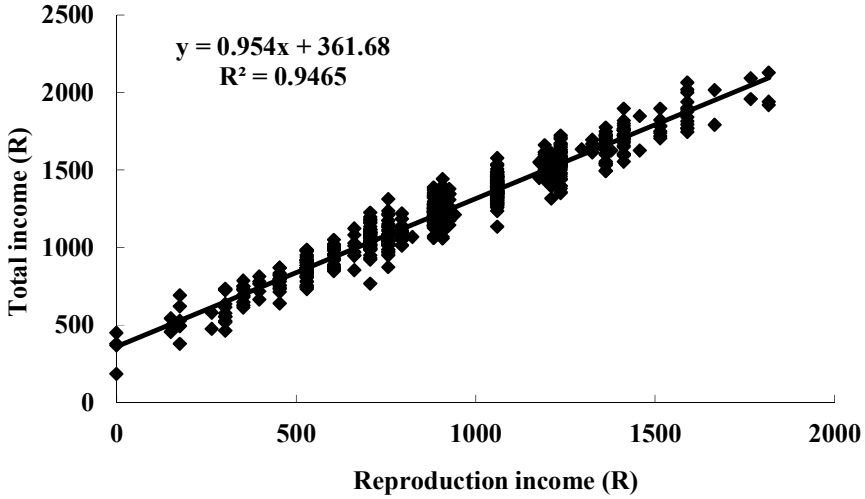

Figure 3. Relationship between total yearly income and yearly reproduction income

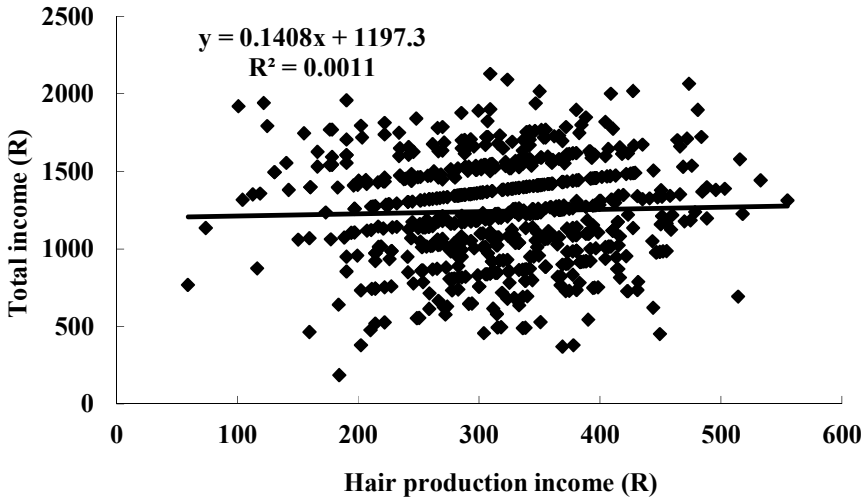

Figure 4. Relationship between total yearly income and yearly hair production income

The ewes that had 6 kidding opportunities were also divided into 4 categories on the basis of their total yearly income. The relative sources of income for these ewes are depicted in Figures 5 and 6. When comparing the relative sources of income among the top and bottom income category ewes, it is obvious from Figures 5 and 6 that the main difference in total yearly income could be ascribed to differences in yearly reproduction income. Yearly hair production income was nearly the same for ewes in all categories. From Figure 6 it is further evident that reproduction income contributed more to total income in ewes in the top 25% income category compared to ewes in the bottom 25% category.

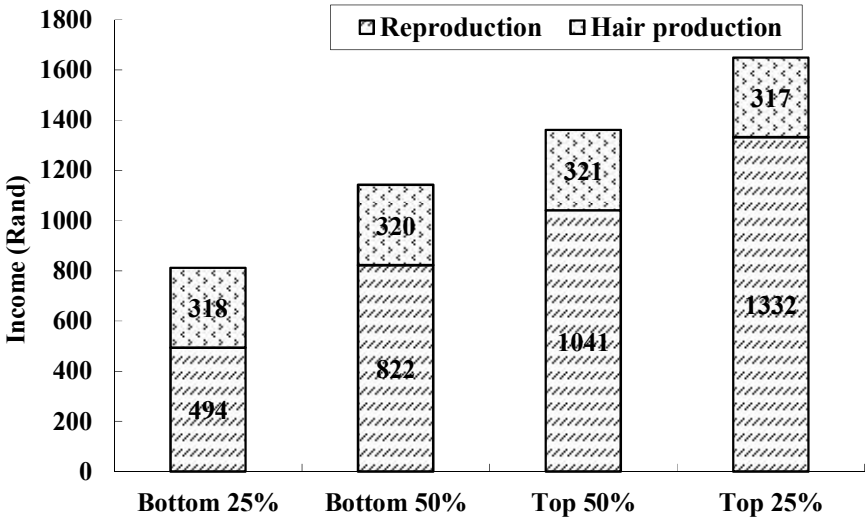

Figure 5. Income sources from ewes in the various income categories

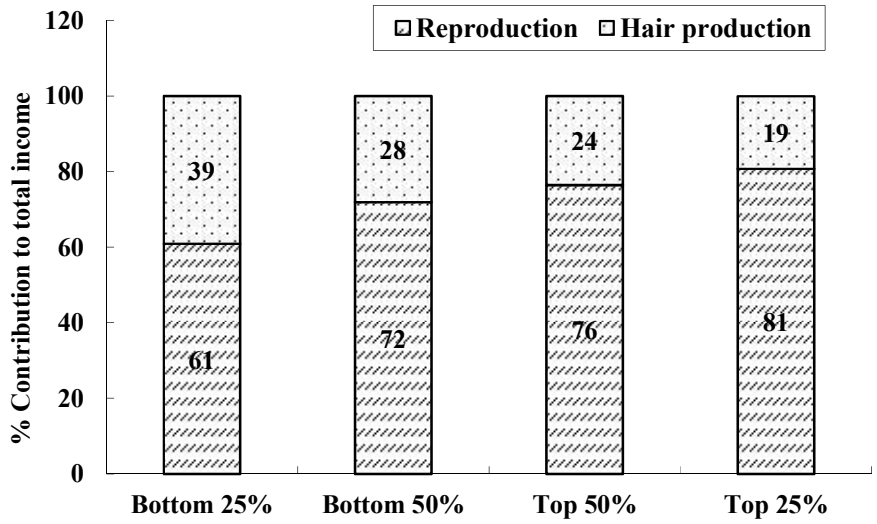

Figure 6. Percentage contribution to total yearly income of income sources from ewes in the various income categories

Data sets C: Early and adult production and reproduction traits of the Top 100 NLB and Bottom 100 NLB ewes hat had 5 or 6 kidding opportunities

Early and adult production and reproduction traits of the ewes in the Top 100 NLB and Bottom 100 NLB categories are presented in Table 9. Fibre diameter at second and third shearing of the Top 100 ewes that had 5 kidding opportunity were higher than that of the Bottom 100 ewes. Variable results were obtained for the other early fibre diameter traits. Early, as well as adult body weights of the Top 100 ewes that had 5 kidding opportunity were higher than that of the Bottom 100 ewes. TWW, NKB and NKW at their first parity were also significantly higher for the Top 100 ewes.

For ewes that had 6 kidding opportunities, the same applied for W12, W16, ABW, TWW1, NKB1 and NKW1, where the Top 100 NLB ewes had higher values than the Bottom 100 NLB ewes.

Table 9. Early and adult production and reproduction traits (± s.e.) of the Top 100 NLB and Bottom 100 NLB ewes that had 5 or 6 kidding opportunities (Traits where significant differences occurred are highlighted in grey)

	5 Kidding opportunities			6 Kidding opportunities		
Trait	**Top 100**	**Bottom 100**	**P value**	**Top 100**	**Bottom 100**	**P value**
FW2	1.38 ± 0.13	1.27 ± 0.11	0.3607	1.24 ± 0.13	1.30 ± 0.07	0.6481
FD2	26.1 ± 0.9	24.8 ± 0.7	0.0872	25.9 ± 1.1	24.5 ± 0.6	0.1435
CV2	22.6 ± 1.8	26.4 ± 1.7	0.0083	24.6 ± 1.7	29.7 ± 1.0	0.0033
SD2	6.0 ± 0.5	6.6 ± 0.5	0.0737	6.5 ± 0.5	7.4 ± 0.3	0.0568
CF2	76.9 ± 4.6	79.6 ± 4.5	0.4793	79.1 ± 7.4	86.1 ± 6.2	0.3317
SDA2	1.57 ± 0.34	1.51 ± 0.33	0.8218	1.30 ± 0.51	1.47 ± 0.42	0.7229
SF2	26.1 ± 1.1	26.6 ± 1.1	0.5941	26.5 ± 1.9	25.8 ± 1.6	0.6897
SL2	157.6 ± 10.3	150.4 ± 7.1	0.4455	140.8 ± 13.4	146.3 ± 7.5	0.6653
ST2	30.5 ± 5.5	28.2 ± 3.4	0.7139	39.8 ± 7.2	31.3 ± 4.3	0.3912
CH2	27.2 ± 2.4	29.8 ± 1.5	0.3521	27.8 ± 1.8	31.2 ± 1.1	0.2011
FW3	1.56 ± 0.10	1.43 ± 0.08	0.1156	1.54 ± 0.09	1.18 ± 0.07	0.4007
FD3	30.0 ± 0.7	28.2 ± 0.6	0.0046	29.0 ± 0.8	28.2 ± 0.7	0.2640
CV3	23.0 ± 1.3	24.6 ± 1.0	0.1811	23.6 ± 1.5	26.1 ± 0.9	0.0943
SD3	6.8 ± 0.4	6.9 ± 0.3	0.6520	7.1 ± 0.5	7.6 ± 0.3	0.3082
CF3	51.8 ± 6.0	62.2 ± 4.5	0.0559	50.7 ± 10.7	66.2 ± 8.5	0.1128
SDA3	1.50 ± 0.22	1.57 ± 0.17	0.7155	1.40 ± 0.35	1.60 ± 0.28	0.5329
SF3	30.1 ± 1.1	29.4 ± 0.8	0.4793	30.8 ± 1.9	30.0 ± 1.5	0.6176
SL3	123.2 ± 7.4	124.5 ± 4.4	0.8397	133.3 ± 9.2	131.4 ± 5.2	0.8362
ST3	35.4 ± 4.7	35.8 ± 3.8	0.9281	38.6 ± 5.1	44.3 ± 4.2	0.2884
CH3	28.4 ± 3.5	29.5 ± 2.8	0.7240	24.5 ± 5.2	28.1 ± 4.3	0.4978
BW	2.84 ± 0.16	2.91 ± 0.14	0.6368	3.00 ± 0.20	3.08 ± 0.18	0.6137
WW	17.3 ± 0.6	15.8 ± 0.4	0.0627	17.2 ± 0.9	16.2 ± 0.8	0.2087
W8	20.1 ± 0.9	18.3 ± 0.8	0.0213	19.4 ± 0.9	18.8 ± 0.8	0.4217
W12	22.3 ± 0.9	19.4 ± 0.8	0.0002	21.2 ± 0.9	19.7 ± 0.8	0.0628
W16	28.9 ± 1.1	24.0 ± 0.9	0.0001	26.6 ± 1.3	23.3 ± 1.1	0.0116
ABW	39.5 ± 0.6	37.4 ± 0.5	0.0240	39.4 ± 0.6	37.5 ± 0.5	0.0399
AFW	1.39 ± 0.05	1.40 ± 0.05	0.9894	1.40 ± 0.05	1.34 ± 0.04	0.3899
AFD	33.0 ± 0.5	31.9 ± 0.5	0.1475	33.0 ± 0.5	32.4 ± 0.4	0.4549
CV	28.6 ± 0.6	28.5 ± 0.5	0.9774	28.8 ± 0.7	28.9± 0.5	0.9141
SD	8.9 ± 0.2	8.8 ± 0.2	0.6766	9.2 ± 0.2	9.1 ± 0.2	0.7447
CF	44.2 ± 2.9	48.8 ± 2.4	0.2919	42.6 ± 3.1	45.6 ± 2.3	0.4661
SDA	1.49 ± 0.07	1.41 ± 0.05	0.4353	1.46 ± 0.08	1.46 ± 0.06	0.9708
SF	34.4 ± 0.6	33.6 ± 0.5	0.3313	34.8 ± 0.6	34.5 ± 0.5	0.6909
SL	123.9 ± 2.7	123.4 ± 2.3	0.9117	123.6 ± 1.6	120.4 ± 1.3	0.1265
CY				79.2 ± 2.2	79.6 ± 0.5	0.8861
ST	27.9 ± 0.8	26.7 ± 0.8	0.2977	29.4 ± 1.1	28.2 ± 1.1	0.4500
CH	27.8 ± 0.7	29.7 ± 0.7	0.0939	28.4 ± 0.9	29.9 ± 0.9	0.2193
TWW1	13.7 ± 1.4	3.2 ± 1.1	0.0001	13.9 ± 1.3	3.0 ± 1.0	0.0001
NKB1	0.99 ± 0.08	0.25 ± 0.06	0.0001	0.97 ± 0.08	0.22 ± 0.06	0.0001
NKW1	0.81 ± 0.03	0.13 ± 0.06	0.0001	0.86 ± 0.08	0.14 ± 0.06	0.0001

	5 Kidding opportunities			6 Kidding opportunities		
Trait	**Top 100**	**Bottom 100**	**P value**	**Top 100**	**Bottom 100**	**P value**
LTTWW	95.0 ± 2.6	47.7 ± 2.1	0.0001	110.0 ± 3.4	58.0 ± 2.9	0.0001
LTKB	7.27 ± 0.09	2.95 ± 0.07	0.0001	8.61 ± 0.13	3.54 ± 0.11	0.0001
LTKW	5.94 ± 0.13	2.47 ± 0.11	0.0001	6.91 ± 0.17	3.03 ± 0.14	0.0001
TWW/KO	19.0 ± 0.5	9.5 ± 0.4	0.0001	18.3 ± 0.6	9.7 ± 0.5	0.0001
KB/KO	1.45 ± 0.02	0.59 ± 0.01	0.0001	1.43 ± 0.02	0.59 ± 0.02	0.0001
KW/KO	1.19 ± 0.03	0.49 ± 0.02	0.0001	1.15 ± 0.03	0.51 ± 0.02	0.0001

For trait abbreviations, please see Table 3

Data sets D: Early and adult production and reproduction traits of the Top 100 Income and Bottom 100 Income ewes that had 5 or 6 kidding opportunities

Early and adult production and reproduction traits of the ewes in the Top 100 Income and Bottom 100 Income categories according to yearly income are presented in Table 10. The traits that differed significantly are highlighted in grey. For both 5 and 6 kidding opportunities, FW3, FD2, FD3, SL2, SL3, BW, WW, W8, W12, W16, TWW1, NKB1 and NKW1 of the early traits differed between the Top 100 and Bottom 100 ewes. It is noteworthy that adult fleece weight and yearly fleece income did not differ between the Top 100 Income and Bottom 100 Income ewes.

Table 10. Early and adult production and reproduction traits (± s.e.) of the Top 100 Income and Bottom 100 Income ewes that had 5 or 6 kidding opportunities for ewes in all flocks (Traits where significant differences occurred are highlighted in grey)

Trait	**5 Kidding opportunities**			**6 Kidding opportunities**		
	Top 100	**Bottom 100**	**P value**	**Top 100**	**Bottom 100**	**P value**
FW2	1.24 ± 0.04	1.29 ± 0.03	0.3458	1.14 ± 0.05	1.29 ± 0.03	0.0084
FD2	26.8 ± 0.3	25.4 ± 0.2	0.0005	26.9 ± 0.4	25.3 ± 0.3	0.0006
CV2	27.5 ± 0.5	28.2 ± 0.5	0.3039	28.0 ± 0.7	28.6 ± 0.7	0.5231
SD2	7.2 ± 0.2	7.2 ± 0.2	0.9677	7.5 ± 0.2	7.2 ± 0.2	0.3133
CF2	75.3 ± 1.5	79.6 ± 1.4	0.0307	74.2 ± 1.9	79.6 ± 1.8	0.0436
SDA2	1.45 ± 0.07	1.19 ± 0.07	0.0140	1.37 ± 0.10	1.23 ± 0.10	0.3085
SF2	27.6 ± 0.4	26.7 ± 0.3	0.0670	28.2 ± 0.5	26.6 ± 0.5	0.0196
SL2	99.7 ± 5.8	149.2 ± 3.7	0.0001	93.9 ± 7.6	157.0 ± 7.6	0.0001
ST2	33.8 ± 1.9	34.0 ± 2.1	0.9298	36.5 ± 2.1	35.0 ± 2.5	0.6609
CH2	30.4 ± 1.1	29.5 ± 1.2	0.5727	30.6 ± 1.2	28.3 ± 1.4	0.2372
FW3	1.53 ± 0.03	1.38 ± 0.03	0.0001	1.54 ± 0.03	1.41 ± 0.03	0.0037
FD3	29.8 ± 0.2	28.0 ± 0.2	0.0001	30.1 ± 0.3	28.0 ± 0.3	0.0001
CV3	24.3 ± 0.5	25.7 ± 0.5	0.0424	24.0 ± 0.7	25.7 ± 0.6	0.0750
SD3	6.9 ± 0.1	7.2 ± 0.1	0.1397	6.9 ± 0.2	7.2 ± 0.2	0.1967
CF3	62.6 ± 1.9	67.3 ± 1.5	0.0555	61.7 ± 2.5	65.0 ± 2.0	0.3053
SDA3	1.51 ± 0.08	1.47 ± 0.07	0.6837	1.57 ± 0.11	1.34 ± 0.09	0.1098
SF3	29.5 ± 0.3	29.0 ± 0.3	0.2280	29.7 ± 0.4	29.4 ± 0.3	0.5375

Trait	5 Kidding opportunities			6 Kidding opportunities		
	Top 100	Bottom 100	P value	Top 100	Bottom 100	P value
SL3	107.2 ± 2.7	124.7 ± 1.7	0.0001	106.6 ± 3.4	131.4 ± 2.0	0.0001
ST3	33.6 ± 1.5	32.2 ± 1.4	0.5117	36.8 ± 1.9	33.0 ± 2.1	0.1941
CH3	29.0 ± 0.9	29.3 ± 0.8	0.8118	28.8 ± 1.2	29.0 ± 1.4	0.9146
BW	3.19 ± 0.04	3.36 ± 0.04	0.0016	3.21 ± 0.05	3.39 ± 0.05	0.0075
WW	18.4 ± 0.2	16.5 ± 0.2	0.0001	18.8 ± 0.3	16.5 ± 0.3	0.0001
W8	22.6 ± 0.3	18.7 ± 0.3	0.0001	22.9 ± 0.3	19.0 ± 0.3	0.0001
W12	25.6 ± 0.3	19.6 ± 0.3	0.0001	25.5 ± 0.4	19.6 ± 0.4	0.0001
W16	29.3 ± 0.4	22.9 ± 0.4	0.0001	29.4 ± 0.4	22.5 ± 0.4	0.0001
ABW	41.6 ± 0.3	35.3 ± 0.3	0.0240	41.5 ± 0.4	35.6 ± 0.4	0.0001
AFW	1.37 ± 0.02	1.39 ± 0.02	0.5253	1.38 ± 0.03	1.37 ± 0.03	0.6900
AFD	33.5 ± 0.2	32.6 ± 0.2	0.0010	33.8 ± 0.2	32.6 ± 0.2	0.0003
CV	27.4 ± 0.2	28.6 ± 0.2	0.0009	28.1 ± 0.3	29.3 ± 0.3	0.0053
SD	8.7 ± 0.1	9.0 ± 0.1	0.0457	8.9 ± 0.1	9.1 ± 0.1	0.2235
CF	39.9 ± 1.1	44.6 ± 1.1	0.0020	38.8 ± 1.3	45.1 ± 1.3	0.0005
SDA	1.38 ± 0.03	1.48 ± 0.03	0.0146	1.41 ± 0.03	1.52 ± 0.04	0.0255
SF	35.2 ± 0.2	34.6 ± 0.2	0.0862	35.7 ± 0.3	34.8 ± 0.3	0.0119
SL	101.0 ± 1.3	123.8 ± 1.3	0.0001	100.4 ± 1.6	128.8 ± 1.6	0.0001
CY	79.4 ± 1.6	79.1 ± 0.3	0.8294	80.7 ± 2.7	79.5 ± 0.3	0.6575
ST	29.3 ± 0.5	28.1 ± 0.6	0.1178	29.3 ± 0.6	27.3 ± 0.7	0.0272
CH	30.1 ± 0.5	30.3 ± 0.5	0.8105	30.0 ± 0.5	30.0 ± 0.5	0.9486
TWW1	13.0 ± 0.5	2.4 ± 0.5	0.0001	14.5 ± 0.6	2.5 ± 0.6	0.0001
NKB1	0.82 ± 0.03	0.34 ± 0.03	0.0001	0.94 ± 0.04	0.32 ± 0.04	0.0001
NKW1	0.74 ± 0.03	0.17 ± 0.03	0.0001	0.84 ± 0.03	0.18 ± 0.03	0.0001
LTTWW	111.6 ± 1.6	37.7 ± 1.6	0.0001	132.9 ± 2.2	45.6 ± 2.2	0.0001
LTKB	6.80 ± 0.08	3.62 ± 0.08	0.0001	8.23 ± 0.10	4.19 ± 0.10	0.0001
LTKW	6.24 ± 0.06	2.30 ± 0.06	0.0001	7.48 ± 0.07	2.78 ± 0.07	0.0001
TWW/KO	22.3 ± 0.3	7.5 ± 0.3	0.0001	22.1 ± 0.4	7.6 ± 0.4	0.0001
KB/KO	1.36 ± 0.02	0.72 ± 0.02	0.0001	1.37 ± 0.02	0.67 ± 0.02	0.0001
KW/KO	1.25 ± 0.01	0.50 ± 0.01	0.0001	1.25 ± 0.01	0.46 ± 0.01	0.0001
INC-REP	1350.13 ± 11.49	488.29 ± 11.49	0.0001	1333.78 ± 12.59	494.07 ± 12.59	0.0001
INC-FW	314.35 ± 5.08	322.39 ± 5.08	0.2636	317.17 ± 6.06	317.61 ± 6.06	0.9585
INC-TOT	1664.48 ± 10.25	810.68 ± 10.25	0.0001	1650.94 ± 11.65	811.68 ± 11.65	0.0001

For trait abbreviations, please see Table 3

DISCUSSION

When compiling lists of the top and bottom producing ewes for the adult productive traits, it was evident that it would be difficult to get ewes that are top performers in all traits. There were 179 top and 118 bottom performing ewes that produced more than 8 and fewer than 4 kids respectively over 6 kidding opportunities. Although there were 179 ewes that produced 8 or more kids, not all of these ewes were in the top categories for the other traits. The same applied for the ewes in the bottom category. The ewes

that were top performers with regard to reproduction were not top performers with regard to fleece production.

The negative relationship between reproduction and fleece production was further illustrated by the relative sources of income. There was more variation in yearly reproduction income than in hair production income among the ewes. There was a slight negative relationship between yearly hair production income and yearly reproduction income. Consequently, there was no discernable relationship between yearly hair production income and total yearly income. The relationship between yearly reproduction income and total yearly income on the other hand, was significantly positive. When comparing the relative sources of income among the top and bottom income category ewes, it was obvious that the main difference in total yearly income could be ascribed to differences in yearly reproduction income. Yearly hair production income was nearly the same for ewes in all categories. It was further evident that reproduction income contributed more to total income in ewes in the top 25% income category compared to ewes in the bottom 25% category.

Early reproduction

Early reproduction (TWW1, NKB1 and NKW1), as well as lifetime reproduction, of the Top 100 ewes that had 5 or 6 kidding opportunities were higher than that of the Bottom 100 ewes (Top and Bottom 100 ewes categorised on NKB). Furthermore, for ewes that had both 5 and 6 kidding opportunities, all reproductive parameters were higher for the Top 100 ewes than for the Bottom 100 ewes (Top and Bottom 100 ewes categorised on total yearly income). Selection of top performing young ewes after their first parity would therefore increase ewe lifetime income.

Early body weight

Early, as well as adult body weights of the Top 100 ewes that had 5 kidding opportunities were higher than that of the Bottom 100 ewes (Top and Bottom 100 ewes categorised on NKB). The same applied for W12 and W16 for ewes that had 6 kidding opportunities, where the Top 100 ewes had higher values than the Bottom 100 ewes. For both 5 and 6 kidding opportunities, BW, WW, W8, W12 and W16 were higher for the Top 100 ewes than for the Bottom 100 ewes (Top and Bottom 100 ewes categorised on total yearly income). Saoud & Hohenboken (1984) also found that heavier ewe lambs were more efficient producers. Ewes that had 6 kidding opportunities that produced the highest TWW also had a higher ABW than ewes that produced less TWW. The same trend was observed for NKB. Furthermore, ewes that had higher early body weights were kept in the flock for a longer period. Selection of young replacement ewes could be done on increased early body weight.

Early fleece weight

The favourable genetic correlations of early fleece weight with reproduction (0.41 FW2 and TWW; 0.36 FW3 and TWW; Snyman, 2018) did not seem to realise phenotypically in the adult ewes. Ewes that had 6 kidding opportunities that produced the highest TWW had a lower AFW than ewes that produced less TWW. The same trend could be observed for NKB over 6 kidding opportunities. These trends differed from the following, where the Top 100 ewes that had both 5 and 6 kidding opportunities had higher FW3 than the Bottom 100 ewes. Contrary to this, and more in agreement with the adult situation, FW2 was lower for the Top 100 than the Bottom 100 ewes (Top and Bottom 100 ewes categorised on total yearly income) for ewes that had 6 kidding opportunities. This could most probably be explained through the fact that hair production contributes from 20% to 40% to yearly income, compared to 60% to 80% of reproduction. From these results it follows that too much emphasis on fleece weight at selection age of young replacement ewes should be avoided.

Early fibre diameter

The unfavourable genetic correlations of early fibre diameter with reproduction (0.57 FD2 and TWW; 0.57 FD3 and TWW; Snyman, 2018) were manifested phenotypically where FD2 and FD3 of the Top 100 ewes that had 5 kidding opportunities were higher than that of the Bottom 100 ewes (Top and Bottom 100 ewes categorised on NKB). For ewes that had both 5 and 6 kidding opportunities, FD2 and FD3 were also higher for the Top 100 than the Bottom 100 ewes (Top and Bottom 100 ewes categorised on total yearly income). There were negligible correlations of TWW with AFD. This implies that selection for low early fibre diameter should not be done in the young ewes.

CONCLUSIONS

There are large differences in hair production, reproduction and income among ewes that had 5 or 6 kidding opportunities. These differences could be exploited by placing selection emphasis on those traits that contribute most to yearly income and for which high levels of production can be maintained until an older age. Reproduction contributes the most to total yearly income and fortunately ewes are able to maintain high reproductive levels up to the age of 7 years. Unfortunately, the reproductive traits have the lowest heritability of all the economically important traits. Body weight indirectly contributes to reproduction through favourable genetic correlations with reproduction. Selection of young ewes should therefore be focussed on early body weight, number of kids produced and weight of kids weaned at the first parity.

The negative relationship between reproduction and fleece production in the adult ewes emphasises the fact that positive selection pressure on early fleece weight should not be done at the cost of reproduction. Only young ewes with unacceptably low fleece weights should be culled, while too much selection

pressure on early fibre diameter in the ewes should also be avoided. Selection for fleece production and fleece traits should rather be addressed through ram selection.

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