Genetic and phenotypic parameters of pelt traits in a Karakul control flock

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Genetic parameters of 16 pelt traits and birth mass were calculated in a Karakul control flock (n = 2058; rams = 305) with a half-sib analysis. Moderately high heritabilities were estimated for pelt traits. No antagonistic genetic correlation was found between pattern and hair quality. The genetic correlations between pattern and pelt traits were lower than those estimated for hair quality and the other pelt traits. The expected correlated response from selection for hair quality may be a decrease in the occurrence of brittle hair, hair thickness, metallic, skin thickness, occurrence of feathers, hair stiffness and an increase in hair length, lustre and curl breadth. Selection for pattern may result in a decrease in bandedness, a slight increase in lustre and in the occurrence of feathers, and a moderate decrease in curl type and hair length. Genetic estimates obtained in this study are compared with previous estimates obtained in Karakul sheep.

Genetiese parameters van 16 pelseienskappe en van geboortemassa is in 'n Karakoelkontrole-kudde (n = 2058; ramme = 305) met behulp van die halfsib-metode beraam. Matige hoë oorerflikhede is vir pelseienskappe beraam. Geen antagonistiese genetiese korrelasie is tussen patroon en haarkwaliteit gevind nie. Die genetiese korrelasies tussen patroon en ander pelseienskappe was heelwat laer as dié tussen haarkwaliteit en die ander pelseienskappe. Die verwagte gekorreleerde responsie van seleksie vir haarkwaliteit mag 'n afname in die voorkoms van breekhare, haardikte, metaalagtigheid, veldikte, voorkoms van vere, haarstyfte, en 'n toename in haarlengte, glans en krulgrootte wees. Seleksie vir patroon mag 'n afname in die voorkoms van bande, 'n effense toename in glans en in die voorkoms van vere en 'n matige afname in krultipe en haarlengte veroorsaak. Genetiese parameters verkry in hierdie studie word met ander studies by Karakoelskape vergelyk.

Keywords: Karakul, pelt traits, genetic and phenotypic parameters.

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Introduction

In pelt-bearing animals, the quality of pelts is of great economic importance. The heritability and genetic correlations between economically important characteristics are the basic parameters required for the formulation of breeding plans. The accuracy and magnitude of these parameters will determine the most suitable breeding methods to be applied for the enhancement of genetic gain.

Phenotypic and genetic parameters for pelt traits in Karakul sheep have been estimated by Yao *et al.* (1953), Malan (1959), Nel (1967), Schoeman & Nel (1969), Van Niekerk (1972) and Botma (1981). However, each of these researchers, except Botma *op cit.*, worked with a Karakul population that had been subjected to selection for pelt traits. Since selection changes the gene frequencies of characteristics in a population, the published results may not represent generally acceptable estimates (Falconer, 1981).

Botma (1981) also estimated genetic parameters for birth mass, curl type, curl size, pattern, hair length, hair quality, hair quality at the extremities, hair stiffness, hair thickness and skin thickness for this same flock from records collected from 1970 to 1977. Since then, substantial numbers of records have been collected. This study reports estimates of heritabilities, and of phenotypic and genetic correlations of pelt traits in a genetically stable control flock. Furthermore, additional pelt traits that were not evaluated by the above-mentioned researchers, were also included in this study.

Materials and Methods

Animals

Data were collected from the Karakul control flock at the Karakul Research Station near Upington as was described by Greeff *et al.* (1991). The experimental flock had its origin in 1962 from the purchase of 1200 Karakul ewes from 29 different private breeders. About 3% rams were bought from five different breeders, and it can therefore be assumed that the average inbreeding coefficient of this flock was about zero at the beginning of this experiment. The animals were housed at the Karakul Research Station near Upington. From 1963 to 1969 the population was enlarged and no selection for pelt traits took place, to allow this flock to reach genetic equilibrium. In 1970, 200 ewes were randomly selected for the purposes of a control flock, to provide a continuous measure of environmental effects in an experiment for selection of pelt traits.

Management during mating and lambing

Three mating seasons were applied, i.e. during January, May and August, and depending on the time of the year, mating took place over a period of 51 or 34 days. The control flock was kept on kraal and handmating was applied. During lambing all pregnant ewes were kept on kraal to ensure the positive identification of lambs born, and to ensure that all relevant data were collected within 24 h after birth. The pelts were evaluated and scored as described by Greeff *et al.* (1991) according to the methods proposed by Nel (1967).

Management of the control flock

At the beginning of the experiment, it was proposed that between 45 and 50 rams be used per annum, of which 50% be replaced each year. Every second ewe and every fourth ram lamb born from each ewe were kept for replacement purposes. However, because of sickness, deaths and management procedures, ewes and rams were not replaced as proposed and a more random replacement procedure was practised.

Statistical analysis

The data were analysed with the LSML76 computer program of Harvey (1977) using Henderson's Method 3. Greeff *et al.* (1991) indicated that the scores for most of the pelt traits did not follow a normal distribution, but since Harvey (1982) indicated that a least-squares analysis of discrete values is valid if the values scored are an indication of quantitative differences between classes, characters that did not have a normal distribution were included in the analysis.

As some rams were again used in an ensuing year, the records of the smallest progeny group of such rams in a particular year were also omitted from the analysis. As a number of twin births were recorded, the record of one lamb from each set of twins, was randomly removed from the data file to ensure that the data consisted of records of only half-sibs. This resulted in a total of 2058 records of 305 rams.

Two analyses were carried out. In the first analysis the data were adjusted for known environmental effects, i.e. month of birth, sex of lamb, age of dam at lambing, type of birth and birth mass. In the second analysis, birth mass was excluded in order to calculate the heritability and genetic and phenotypic correlations between birth mass and pelt traits, and to determine the possible effect that adjustment for birth mass has on the estimation of genetic parameters. The environmental effects were discussed by Greeff *et al.* (1991). The following mixed model, with birth mass included as a covariate, was used to calculate the genetic parameters. Where birth mass was not used as a covariate, the bX_{ijk} term was excluded from the model.

$$Y_{ijk} = \mu + a_i + s_j + b_{ijk}X + e_{ijk}$$

where

Y_{ijk} = the adjusted record of the k-th individual of the j-th sire within the i-th year,
μ = the population mean,
a_i = the fixed effect of the i-th year,
s_j = the random effect of the j-th sire,
b = the regression of Y_{ijk} on birth mass,
X_{ijk} = birth mass, and
e_{ijk} = the random error.

The heritability and genetic and phenotypic correlations between traits were calculated with the least-square means and maximum likelihood computer program of Harvey (1977) according to the formulae given by Falconer (1981).

Results and Discussion

The means and coefficients of variation of the different traits relative to the findings of other researchers were discussed by Greeff *et al.* (1991), who indicated that sufficient phenotypic variation exists in most cases for a fairly high selection differential to be applied.

Estimates of heritabilities of the two main composite pelt traits, hair quality and pattern with their component traits, as well as for the different pattern types and birth mass, are indicated in Table 1.

Table 1 Heritabilities (± *SE*) of pelt traits

	$h^2 \pm SE^a$	$h^2 \pm SE^b$
Hair quality	0,301 ± 0,070	0,305 ± 0,070
Hair quality at the extremities	0,250 ± 0,068	0,249 ± 0,067
Hair stiffness	0,330 ± 0,069	0,306 ± 0,070
Brittle hair	0,130 ± 0,062	0,128 ± 0,061
Hair thickness	0,310 ± 0,071	0,330 ± 0,071
Lustre	0,360 ± 0,073	0,368 ± 0,073
Metallic	0,270 ± 0,068	0,270 ± 0,068
Pattern	0,344 ± 0,072	0,336 ± 0,072
Curl type	0,430 ± 0,076	0,444 ± 0,077
Hair length	0,258 ± 0,068	0,282 ± 0,069
Feathers	0,100 ± 0,059	0,098 ± 0,064
Bandedness	0,212 ± 0,065	0,229 ± 0,067
Curl breadth	0,320 ± 0,071	0,314 ± 0,071
Skin thickness	0,194 ± 0,064	0,211 ± 0,067
Pattern types		
Corkscrew	–	–
Peppercorn	–	–
Lyre	0,357 ± 0,073	0,360 ± 0,073
Moiré	–	–
Firtree	–	–
Birth mass (kg)	–	0,156 ± 0,062

[a] Adjusted for birth mass.
[b] Not adjusted for birth mass.

Genetic parameters for corkscrew, peppercorn, firtree and moiré pattern types could not be computed because of the negative estimates of genetic variance, probably due to the discrete nature of the scale of measurement of pelt traits. According to Harvey (1977), the standard errors of both the heritability estimates and the genetic correlations are approximations and should be considered as minimum estimates since these are computed from paternal half-sibs as if the analysis was simply a 'between-family' and 'within-family' analysis with unequal numbers, but with no adjustments for fixed effects.

Table 1 indicates the heritability estimates of pelt traits without adjustment for birth mass and adjusted for birth mass. It is clear that adjustment for birth mass had a very small effect on the heritability estimates. The small differences were probably caused by the narrow range of birth mass values between lambs.

Moderately high heritabilities with relatively small standard errors (*SE* range from 0,06 to 0,08) were found in most cases. The lowest heritability of those calculated was found for occurrence of feathers (h^2 = 0,10) and brittle hair (h^2 = 0,13). The highest heritability was found for curl type (h^2 = 0,43 and 0,44). Hair quality, hair stiffness, hair thickness, lustre, pattern, curl breadth and lyre pattern had heritabilities between 0,30 and 0,36. Heritabilities for the rest of the characteristics varied from 0,19—0,27. Selection on the basis of individual performance for hair quality and pattern should therefore be effective.

Botma (1981) estimated the heritabilities of pelt traits on the same flock for records collected between 1970 and 1977, with both the half-sib and regression of offspring on sire methods, separately for ram and for ewe lambs. He found large differences between the heritabilities estimates for ram and ewe lambs calculated with the same method and also between the two methods. The estimates of heritability for pattern, hair quality, curl type and curl breadth in this study agree reasonably well with those reported by Botma (1981) in ewe lambs calculated with the half-sib method. The same was found for the heritability of hair length of this study compared with Botma's *op cit.* results for ram lambs, also calculated with the half-sib method. Apart from this, no consistent agreement between the estimates in this study and those of Botma (1981) could be found.

Nel (1967) and Van Niekerk *et al.* (1968) estimated the heritabilities for hair quality, pattern, curl type, curl breadth and hair length. The heritabilities of Nel *op cit.* for pattern and curl breadth, calculated by parent offspring regression, agree well with the heritabilities obtained in this study. However, Nel's *op cit.* heritabilities of hair quality, curl type, hair length and birth mass calculated with the same method were somewhat higher. On the other hand, his heritabilities for pattern and curl breadth calculated by the regression method agree well with those found in this study. Of the heritabilities calculated with the half-sib method by Nel *op cit.*, only the heritabilities of hair length and birth mass agreed well with this study. Van Niekerk (1972) found heritabilities for the above-mentioned traits as well as for lustre and metallic, calculated for lambs born to dams two to three years of age and lambs born to dams four to eight years of age with the half-sib method, to be generally lower than in this study. His heritabilities of skin thickness and hair length, however, agree well with this study. As his population (Niemöller stud) was highly selected for pattern and hair quality, this may be an indication that genetic variation decreased during selection in that population, especially in respect of curl type, metallic and hair quality.

Hair quality and pattern are the most important traits which influence the price of the product. Schoeman (1984) stated that one of the most surprising features of genetic and phenotypic parameters of pelt traits is the discrepancy in the estimates concerning the association between pattern and hair quality in the literature. He suggested that this may be the result of different selection policies applied in different flocks. Characteristics which are correlated with hair quality and pattern are thus of special interest, because they can throw light on the mechanisms by which selection can bring about change in hair quality and pattern. Estimates of phenotypic and genetic correlations between pelt traits are given in Table 2.

Table 2 Phenotypic and genetic correlations between pelt traits[a]

	Hair quality	Quality extremities	Hair stiffness	Brittle hair	Hair thickness	Lustre	Metal	Pattern	Curl type	Hair length	Feather	Bandedness	Curl breadth	Skin thickness	Corkscrew	Peppercorn	Lyre	Moiré	Firtree	Birth mass
Hair quality		0,92	–0,64	–0,86	–0,58	0,91	–0,52	0,20	–0,22	0,45	–0,20	–0,13	0,26	–0,20	–	–	0,12	–	–	–0,23
SE		0,04	0,25	0,44	0,20	0,03	0,25	0,16	0,16	0,16	0,27	0,19	0,16	0,21			0,27	–	–	0,23
Quality at extremities	0,85		–0,79	–0,84	–0,50	0,81	–0,33	0,19	–0,33	0,39	–0,19	–0,36	0,51	–0,23	–	–	0,15	–	–	–0,29
SE			0,30	0,47	0,22	0,07	0,24	0,16	0,19	0,17	0,29	0,22	0,14	0,23			0,18			0,25
Hair stiffness	–0,56	–0,62		0,87	0,35	–0,48	0,34	0,01	0,31	–0,49	0,16	0,13	–0,58	–0,00	–	–	–0,10	–	–	–0,36
SE				0,17	0,13	0,21	0,16	0,17	0,14	0,21	0,21	0,19	0,21	0,20			0,16			0,22
Brittle hair	–0,57	–0,58	0,48		0,21	–0,75	0,15	0,04	0,14	–0,61	0,09	–0,25	–0,27	–0,10	–	–	–0,18	–	–	0,25
SE					0,23	0,36	0,24	0,22	0,21	0,34	0,40	0,28	0,29	0,28			0,23			0,32
Hair thickness	–0,27	–0,26	0,37	0,13		–0,48	0,88	0,22	–0,20	–0,25	0,91	–0,12	0,29	0,72	–	–	–0,35	–	–	0,43
SE						0,18	0,11	0,16	0,14	0,17	0,29	0,19	0,15	0,11			0,16			0,19
Lustre	0,83	0,72	–0,53	–0,45	–0,27		–0,63	0,32	–0,23	0,36	–0,20	–0,25	0,29	–0,12	–	–	0,17	–	–	–0,18
SE							0,25	0,15	0,15	0,44	0,26	0,18	0,14	0,19			0,15			0,21
Metallic	–0,55	–0,46	0,43	0,27	0,46	–0,61		0,08	–0,16	–0,09	0,69	–0,06	0,17	0,45	–	–	–0,27	–	–	0,02
SE								0,17	0,16	0,19	0,30	0,20	0,18	0,18			0,17			0,23
Pattern	0,09	0,03	0,08	–0,02	0,04	0,10	–0,02		–0,39	–0,42	0,27	–0,79	0,14	–0,31	–	–	0,33	–	–	–0,72
SE									0,15	0,18	0,26	0,24	0,17	0,19			0,14			0,24
Curl type	–0,26	–0,31	0,24	0,17	–0,03	–0,23	–0,05	–0,09		0,11	–0,13	0,79	–0,71	0,09	–	–	0,02	–	–	0,36
SE										0,17	0,26	0,12	0,21	0,17			0,14			0,16
Hair length	0,26	0,28	–0,30	–0,31	0,12	0,24	–0,07	–0,21	0,07		0,43	0,45	0,45	0,64	–	–	–0,23	–	–	0,49
SE											0,29	0,16	0,14	0,18			0,17			0,06
Feathers	0,08	0,06	0,16	–0,09	0,20	0,03	0,17	0,14	–0,23	0,04		–0,57	0,21	0,81	–	–	–0,26	–	–	0,00
SE												0,40	0,27	0,31			0,22			0,36
Bandedness	–0,02	–0,05	–0,00	–0,01	–0,04	0,00	–0,06	–0,26	0,41	0,38	–0,24		–0,52	0,23	–	–	–0,03	–	–	0,68
SE													0,21	0,22			0,18			0,25
Curl breadth	0,33	0,39	–0,34	–0,28	0,09	0,29	–0,02	–0,10	–0,52	0,41	0,03	–0,12		0,27	–	–	–0,18	–	–	–0,03
SE														0,19			0,16			0,22
Skin thickness	–0,14	–0,15	0,26	0,07	0,56	–0,15	0,24	0,04	0,05	0,20	0,23	0,02	0,07		–	–	–0,66	–	–	0,51
SE																	0,21			0,20
Corkscrew	–0,14	–0,16	0,06	0,10	–0,09	–0,14	–0,04	–0,17	0,44	–0,02	–0,18	–0,04	–0,17	–0,03		–	–	–	–	–
SE																				
Peppercorn	–0,23	–0,24	0,27	0,29	0,02	–0,22	0,10	–0,12	0,26	–0,17	–0,13	–0,04	–0,21	0,01	0,26		–	–	–	–
SE																				
Lyre	–0,06	–0,06	0,05	0,03	–0,08	–0,04	0,01	0,20	0,10	–0,11	–0,05	–0,01	–0,11	–0,08	0,00	0,02		–	–	–0,41
SE																				0,22
Moiré	0,07	0,06	–0,03	0,00	–0,05	0,09	–0,03	0,07	–0,06	–0,01	–0,02	–0,06	0,03	–0,01	–0,01	–0,00	–0,01		–	–
SE																				
Firtree	0,00	0,02	–0,01	0,00	0,02	0,03	–0,01	0,00	–0,07	0,01	0,01	–0,05	0,03	0,02	–0,01	–0,01	–0,01	–0,00		–
SE																				
Birth mass	–0,06	–0,06	0,11	0,01	0,29	–0,07	0,10	0,00	0,13	0,25	0,11	0,10	0,09	0,46	0,03	–0,01	–0,04	0,04	0,04	
SE																				

[a] Genetic correlations above diagonal and phenotypic correlations below diagonal.

Adjustment of pelt traits for birth mass had, in general, only a small effect on the phenotypic and genetic correlations. As in the case of the heritabilities, adjustment did not lead to a significant change in the estimation of the phenotypic and genetic correlations. In some cases the genetic correlation increased slightly, whereas it decreased negligibly in other cases. There was also no clear indication that the accuracy of the prediction increased or decreased if adjustments were made. It would appear that the change in genetic correlation after adjustment for birth mass was not of such an order that this adjustment is warranted. Therefore, only estimates of phenotypic and genetic correlations between unadjusted pelt traits are given in Table 2.

The genetic and phenotypic correlations of hair quality with its component traits were relatively high, as expected. The genetic correlations between pattern and the other pelt traits were much lower than the genetic correlations between these pelt traits and hair quality, except for bandedness. Fairly large standard errors were found for the genetic correlations, except between hair quality and hair quality at the extremities, hair quality and lustre, hair quality at the extremities and lustre, hair thickness and metallic, and hair thickness and skin thickness. The association between the phenotypic and genetic correlation for the same trait was in most cases in the same direction. However, the genetic correlation was much higher than the phenotypic correlation if the correlation was positive, and much lower if the correlation was negative.

Table 2 indicates that hair quality was phenotypically and genetically slightly positively correlated with pattern (r_p = 0,09; r_g = 0,20 ± 0,16). This is in contrast with the results of Botma (1981) and Nel (1967), but agrees with the low genetic correlations of 0,002 and –0,006 found by Van Niekerk (1972) for lambs born from young ewes estimated with the regression method, and for lambs born from two- to three-year-old ewes estimated with the half-sib method, respectively. Schoeman and Albertyn (1991) indicated that genetic correlation estimates in the literature vary from –0,32 to 0,61 but are in most cases negligible. This may be an indication that pattern and hair quality are inherited fairly independently.

Hair quality was highly correlated with hair quality at the extremities (r_p = 0,85; r_g = 0,92 ± 0,04). This underlines the conclusion that poor hair quality at the extremities is associated with poor hair quality on the body. Hair quality on the body was phenotypically and genetically highly correlated with lustre (r_p = 0,83; r_g = 0,91 ± 0,03), but negatively correlated with brittle hair (r_p = –0,57; r_g = –0,86 ± 0,44), metallic (r_p = –0,55; r_g = –0,52 ± 0,25), hair stiffness (r_p = –0,56; r_g = –0,64 ± 0,25) and hair thickness (r_p = –0,27; r_g = –0,58 ± 0,20). This indicate the relative large contribution of these traits to the hair quality score. Relatively low phenotypic correlations were found between hair quality and the other pelt traits and also between pattern score and the other pelt traits. This generally agree with the results of Nel (1967), Schoeman (1968), Van Niekerk (1972) and Botma (1981). A very high negative genetic correlation was found between pattern and bandedness (r_g = –0,79 ± 0,24). This indicates that selection for pattern might eliminate bandedness as a correlated response. The genetic correlation between pattern and hair length was moderate (r_g = –0,42 ± 0,18), and agrees well with the results of Nel (1967), Van Niekerk (1972) and Botma (1981).

A high negative phenotypic and genetic correlation (r_p = –0,61; r_g = –0,63 ± 0,25) was found between metallic and lustre, as expected. Contrary to general belief, a low phenotypic (r_p = 0,27) and low genetic correlation of 0,15 ± 0,24 was found between metallic and brittle hair. The low heritability of 0,13 for brittle hair is probably responsible for this low genetic correlation, which may have been induced by the subjective way of measurement. Skin thickness and hair thickness were positively correlated (r_p = 0,56; r_g = 0,72 ± 0,11), while curl type and curl breadth were phenotypically and genetically negatively correlated (r_p = –0,52; r_g = –0,71 ± 0,21) with each other. This agree well with results reported by Nel (1967), Van Niekerk (1972) and Botma (1981).

No genetic correlations could be calculated between pelt traits and the firtree, corkscrew, peppercorn and moiré pattern types because of negative estimates of genetic variances. Cheverud (1988), however, suggested that when genetic correlations are correctly estimated, they tend not to be very different in either magnitude or pattern from their phenotypic counterparts. He concluded that, when reliable genetic estimates are not available, phenotypic correlations and scaled variances may be substituted for their genetic counterparts. As no genetic correlation could be calculated between pelt traits and the corkscrew, peppercorn and moiré pattern types, the phenotypic correlations provided a fair idea of the association between these traits and the other pelt traits. Lyre, moiré and firtree pattern types generally had a very low phenotypic relationship with pelt traits, while the more over-developed types, i.e. peppercorn and corkscrew patterns, had low phenotypic correlations with pelt traits. The highest phenotypic correlation of 0,44 was found between corkscrew and curl type score.

Estimates of phenotypic correlations between birth mass and pelt traits were generally low, except with skin thickness (r_p = 0,46). Metallic, occurrence of feathers and curl breadth were not genetically correlated to birth mass. Pattern, however, was highly negatively correlated (r_g = –0,72 ± 0,24) and bandedness was highly positively correlated (r_g = 0,68 ± 0,25) with birth mass. The negative genetic correlation of birth mass with hair quality (r_g = –0,23 ± 0,23), lustre (r_g = –0,18 ± 0,21) and hair stiffness (r_g = –0,36 ± 0,22) suggest that an increase in birth mass may have a negative effect on hair quality, and may also reduce pattern substantially. Apart from this, it can be concluded that no unfavourably large genetic correlations exist between birth mass and pelt traits and also between pelt traits *inter alia*.

Conclusions

Heritability estimates of pelt traits were in most cases high to moderately high except for the occurrence of feathers and for brittle hair. No serious antagonistic genetic correlations were found between pelt traits. This is contrary to the results of Van Niekerk (1972), who found a moderate negative genetic correlation between pattern and curl size, and a moderate positive genetic correlation between hair quality and curl size. As Van Niekerk *op cit.* worked with a highly selected population, this may be an indication that these differences were induced by the different selection policies applied for hair quality and pattern. Falconer (1981) indicated that two selected traits which are genetically positively correlated with each other, may, after some time, show a negative association because pleiotropic genes which influence both characteristics in a certain direction, become fixed after which they do not contribute to the variances or covariances of the characteristics.

In general, on the strength of the estimates of parameters found in this study, correlated responses for selection for hair quality may result in a decrease in brittle hair, hair thickness, metallic, hair stiffness, and a slight decrease in curl type, feathers, skin thickness, and a sharp increase in quality at the extremities, lustre and only a slight increase in curl breadth. Selection for pattern may result in a correlated decrease in bandedness, a slight decrease in hair length, curl type, skin thickness and a slight increase in lustre and the occurrence of feathers.

In the early Sixties, pattern had a larger influence on pelt price than hair quality and it was freely advocated that pattern contributes as much as three times more to the monetary pelt value than hair quality (Le Roux, 1979). This resulted in less emphasis being put on hair quality in selection policies with a consequent deterioration thereof. The situation became so serious that a committee was appointed in 1973, on the request of the Karakul Board, to investigate the degeneration in hair quality of the national flock (Le Roux, 1979).

In the early Eighties, however, the fashion changed when reversible garments were introduced. Relatively more emphasis was then put on hair quality rather than pattern, indicating the vagary of the fashion designers with regard to pelt traits. Thus, although pattern is an important trait and plays an important role in the uniqueness of the Karakul pelt, history shows that pattern and hair quality must be improved together. Since a low positive genetic association was found between pattern and hair quality in this study, it is suggested that selection pressure should, to a large extent, be directed only to the improvement of hair quality within a curl type and to the eradication of undesirable pattern types which may influence hair quality. This conclusion is in agreement with that of Le Roux (1979) who suggested that selection should be directed towards a certain curl type with the emphasis on hair quality and lustre in particular. Traits such as curl size and hair length should be allowed to find their own intermediate optimum.

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