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Estimation of Genetic Parameters and Influence of Non Genetic Factors on Wool Yields in German Angora Rabbits

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A B S T R A C T

This study was conducted to evaluate the phenotypic profiles, genetic and non-genetic effects on wool production traits in 588 German Angora rabbits maintained at Angora Rabbit Breeding Farm, Kandwari (Himachal Pradesh) from 2000 to 2007. The data were analysed by Harvey's least-squares method of fitting constants. The overall least squares means were 58.77 ± 35.10 g, 169.77 ± 30.38 g, 181.00 ± 21.30 g, 184.73 ± 23.49 g and 594.22 ± 67.13 g for wool yield at first, second, third, fourth clip and annual wool yield, respectively. Year and season of birth significantly affected wool yield at first, third, fourth clip and annual wool yield; however, wool yield at second clip was significantly affected only by year of birth. The heritability estimates for wool yield at different clips and annual wool yield were low to moderate. Hence, improvement of these traits can be attained through better managemental practices, since there is little scope for genetic improvement of the traits through selection. The genetic, phenotypic and environmental correlations among the wool production traits were low to high in magnitude and positive in direction, which indicate that there is possibility of simultaneous improvement of the wool traits.

Introduction

Wool yield is the most important economic trait for determining the economics of breeding Angora rabbits and appears to be affected by a number of genetic as well as non-genetic factors (Thebault *et al.,* 1992; Katoch *et al.,* 1999 and Allain *et al.,* 2004).

German Angora is the largest variety of Angora rabbits with high prolificacy and higher wool production. They yield very fine quality wool (10-15 micron for undercoat fibres) which is used alone or blended with Merino wool to make quality apparels (Gupta *et al.,* 1995). The yield significantly increases from first shearing onward till the animal attains mature body size usually by 9-12 months of age that is the time of third or fourth clip. The initial wool clips are considered important in early selection of rabbits due to their high genetic correlation with annual wool yield (Rafat *et al.,* 2009) and moderate genetic improvement is possible through selection on the basis of initial clips, particularly the first clip due to its high heritability (Niranjan *et al.,* 2011). The present study has been envisaged to determine the influence of genetic and non-genetic factors on wool production traits in German Angora rabbits under sub-temperate Indian conditions to augment the breeding and selection programme.

Materials and Methods

Data collection and location

Data pertaining to first, second, third and fourth clip as well as annual wool yield of German Angora rabbits of either sex where, n = 588, male = 338 and female = 250, over a period of 8 years (2000 to 2007), maintained at Angora Rabbit Breeding Farm, Kandwari, Palampur, Distt. Kangra (Himachal Pradesh), under Department of Animal Husbandry (H.P), which is located at a distance of 8 km from Palampur were utilized in the present study. The data pertained to progenies obtained during subsequent generations of a foundation stock (8 bucks and 32 does) of an improved strain of German Angora rabbit imported from Germany in 1994 for replacing the existing stock at that farm. This farm is located in sub-temperate mid-hill region of Himachal Pradesh at an altitude of 1300 meters above the mean sea level at 32°6$^{/}$ North latitude and 76°32$^{/}$ East longitude. The average maximum and minimum temperature of the location remains 28.4°C in summers (May-June) and 7.2°C in winters (usually in January) with 50-70% relative humidity. The rainfall was recorded more during the end of June due to pre monsoon rains. The entire data were classified into eight years of wool production *i.e.* from 2000 to 2007, where each year further sub-divided into four seasons *viz.*, winter (November-February), spring (March-April), summer (May-August) and autumn (September-October) depending upon the local agro-climatic conditions, and two (male and female) sexes.

Management practices

All the animals were maintained under uniform housing and management conditions throughout the experiment period. The adult animals were housed in individual flat deck standard-sized wire mesh cages fitted with the wall of the house with top entry and provided feeding and watering fixtures in the front sides. For breeding stock and nurseries, nest box (made up of wooden material) of 36 × 36 × 30 centimetre is placed in front of the cages 4-5 days prior to kindling. The advantages of this system of housing include entry of fresh air in the house and easy shifting of the hutch as per the climatic conditions, which is very necessary in that particular climate. For breeding does, the size of the cage was 60 × 60 × 40 centimetre and floor was 250 × 125 centimetre. Apart from feeding of available seasonal green forages *viz.*, oats in winter and, maize and soya bean in summer season to meet approximately 20% of the nutritional requirements, the adult animals (above 6 months of age) were offered pelleted concentrate feed @ 175 gm/doe/day and each lactating doe was offered @ 275gm/doe/day of pelleted feed. The concentrate feed pellets contained 15-17% crude protein, 8% crude fibre, 0.4-0.6% methionine and cystine, 12-14% crude fat, 2-3% ether extract, 0.6% arginine, 1% lysine as well as vitamins and minerals. The water was offered *ad libitum*. Animals were used for breeding only after full growth *i.e.* normally at around 8 months of age and the ratio of male and female was 1:5. Selective breeding was practised to create the next generation. Regarding shearing, hand shearing was done four times in a year at three months interval. Respective ages at first, second, third and fourth clip were 2 months, 5 months, 8 months and 11 months. Immediately after shearing, the quantity of wool clips were stored in polythene bags for short term storage which was further kept in galvanized iron boxes. The wool was sold to

Himachal Pradesh Wool Federation. The rabbits were kept under strict surveillance for all possible health care; culling and medication of affected animals were done whenever needed.

Statistical methods

The data were analyzed at Department of Animal Breeding, Genetics and Biostatistics, Dr. G.C. Negi College of Veterinary and Animal Sciences, Palampur (H.P) using least-squares method of fitting constants (Harvey, 1990) with different fixed and regression effects. The statistical model 1 used to analyze the data was –

$Y_{ijkl} = \mu + P_i + S_j + SX_k + A_{ijkl} + e_{ijkl}$
(model 1)

Where, Y_{ijkl} = the observation on l^{th} individual of the k^{th} sex, which was born in j^{th} season of i^{th} year,

μ = overall population mean,
P_i = the effect of i^{th} year of birth,
S_j = the effect of j^{th} season of birth,
SX_k = the effect of k^{th} sex of individual,
A_{ijkl} = the partial regression on weight at first shearing and
e_{ijkl} = the random error attached to each observation.

Duncan's Multiple Range Test (DMRT) was done to make pair wise comparison among the least squares means wherever significant differences exist by using the modified method of Kramer (1957).

To estimate heritability (h^2), the model 2 (Hazel and Terril, 1945) was used –

$Y_{ij} = \mu + S_i + e_{ij}$ (model 2)
Where, μ = overall population mean,
i = 1, 2,. . .., s (s = number of sires),
j = 1, 2,. .., n_i (n_i = number of observations for the sire),
Y_{ij} = observations under j^{th} progeny belonging to i^{th} sire,
S_i = effect of i^{th} sire and
e_{ij} = the random error attached to each observation.

The estimates of heritability (h^2), phenotypic (r_P) and genetic (r_G) correlations were calculated from the sire component of variance and covariance. The standard errors of heritability were estimated by the method described by Swiger *et al.*, (1964), while the standard errors of phenotypic and genetic correlation were estimated as per the methods of Panse and Sukhatme (1969), and Robertson (1959), respectively.

Results and Discussion

The estimates of least-squares means (LSM) and standard errors (SE) for wool yield at first, second, third and fourth clip as well as annual wool yield along with the results of DMRT are presented in Table 1. Furthermore, least-squares analyses of variance showing the effect of different factors on the traits are presented in Table 2.

Wool yield at different clips

The overall LSM ± SE for wool yield at first clip was estimated to be 58.77 ± 35.10 g with a coefficient of variation of 51.97% (Table 1). The wool yield at subsequent clips (2^{nd}, 3^{rd} and 4^{th} clip) were higher than the first clip (Table 1) increasing sharply by second clip (169.77 ± 30.38 g with a coefficient of variation of 15.49%), third clip (181.00 ± 21.30 g with a coefficient of variation of 11.11%) and attaining the peak yield by fourth clip (184.73 ± 23.49 g with a coefficient of variation of 11.56%). The lower wool yield at first clip was because of the lesser number of wool follicles per unit area which subsequently increased with maturity, wool shedding due to harsh climatic conditions, low availability of fodder etc. The mean values for the traits are in accordance with the findings of Swain *et al.*, (1998) in German Angora and Rafat *et al.*, (2009) in adult Angora rabbits. However, lower estimates than the present finding for wool yield at different clips were reported by Bhasin *et al.*, (1998) in different strains of Angora rabbit. On the other hand, Zhou *et al.*, (1988) reported much higher estimates for the traits in Tanghang Angora rabbits.

Table.1 LSM ± SE along with the results of DMRT for wool yield at different clips and annual wool yield

Effect	N	Wool yield (g) during different clips and annual wool yield				
		1st clip	2nd clip	3rd clip	4th clip	Annual yield
Overall Mean (μ)	588	58.77±35.10	169.77±30.38	181.00±21.30	184.73±23.49	594.22±67.13
CV (%)		51.97	15.49	11.11	11.56	10.12
Year of birth						
2000	118	$76.65±3.03^{c}$	$169.24±2.61^{b}$	$176.68±1.99^{a}$	$191.25± 2.12^{d}$	$616.68±5.97^{bc}$
2001	106	$42.98±3.25^{a}$	$184.35±2.80^{c}$	$184.38±2.14^{b}$	$188.94± 2.27^{d}$	$602.42±6.40^{b}$
2002	53	$57.48±4.30^{b}$	$197.41±3.70^{d}$	$190.91±2.83^{bc}$	$190.64±3.01^{d}$	$635.62±8.48^{c}$
2003	33	$68.33±5.60^{bc}$	$192.52±4.82^{cd}$	$199.29±3.68^{c}$	$171.26±3.91^{ab}$	$630.97±11.02^{c}$
2004	65	$42.35±3.98^{a}$	$155.51±3.43^{a}$	$185.68±2.62^{b}$	$182.21±2.78^{cd}$	$566.15±7.84^{a}$
2005	21	$61.14±6.79^{b}$	$152.91±5.84^{a}$	$181.86±4.46^{ab}$	$173.92±4.74^{ab}$	$571.39±13.37^{a}$
2006	86	$68.73±3.75^{bc}$	$153.41±3.22^{a}$	$176.43±2.46^{a}$	$165.45± 2.62^{a}$	$563.78±7.38^{a}$
2007	105	$39.12±3.39^{a}$	$160.69±2.92^{a}$	$171.81±2.23^{a}$	$174.55±2.37^{bc}$	$547.01±6.68^{a}$
Season of birth						
Winter	250	$68.97±4.02^{b}$	169.00 ± 3.46	$181.69± 2.65^{b}$	$193.45 ±2.81^{c}$	$611.92 ± 7.92^{b}$
Spring	106	$44.36±4.65^{a}$	162.34 ± 4.00	$168.94±3.06^{a}$	$184.16 ±3.25^{b}$	$560.76 ± 9.16^{a}$
Summr	172	$49.22±4.28^{a}$	173.07 ± 3.69	$181.68±2.82^{b}$	$177.53±2.99^{ab}$	$580.76 ± 8.43^{a}$
Autun	60	$56.55±5.59^{ab}$	170.65 ±4.81	$185.79±3.67^{b}$	$168.12±3.90^{a}$	$585.96±11.00^{ab}$
Sex						
Male	338	54.40±3.89	165.67±3.35	178.66± 2.56	179.06± 2.72	578.50±7.67
Female	250	55.15±4.05	171.86±3.48	180.39±2.66	182.57±2.83	591.10±7.97

Means with the same superscripts in a column don't differ significantly (P<0.05)
N = number of observations

Table.2 Least-squares analyses of variance for wool yield at first, second, third and fourth clip as well as annual wool yield

Sources of variation	d.f.	Mean squares				
		Wool yield at first clip	Wool yield at second clip	Wool yield at third clip	Wool yield at fourth clip	Annual wool yield
Year of birth	7	14580.17**	3193.88**	3193.88**	5550.39**	55479.34**
Season of birth	3	16481.16*	42364.68	42364.68*	10817.41*	57320.98*
Sex	1	73.84	390.32	390.32	1618.15	20824.65
Error	575	933.18	404.04	404.04	455.95	3615.23

** P<0.01, * P<0.05

Table.3 Heritability, genetic, phenotypic and environmental correlations among wool production traits

Traits	1st clip	2nd clip	3rd clip	4th clip	Annual yield
1st clip	**0.090 ± 0.020**	0.002 ± 0.002	0.103 ± 0.067	0.036 ± 0.006	0.593 ± 0.102
2nd clip	0.198± 0.026	**0.290 ± 0.010**	0.238 ± 0.003	0.964± 0.014	0.823 ± 0.127
3rd clip	0.081 ± 0.012	0.203 ± 0.017	**0.311 ± 0.018**	0.959 ± 0.105	0.774 ± 0.006
4th clip	0.016 ± 0.010	0.072 ± 0.011 (0.054)	0.171 ± 0.004	**0.312 ± 0.021**	0.911 ± 0.116
Annual yield	0.651± 0.031	0.622 ± 0.088 (-0.616)	0.532 ± 0.073	0.419 ± 0.035 (0.410)	**0.270 ± 0.017**

Figures on the diagonal lines are heritability estimates.
Figures above and below the diagonal are genetic and phenotypic correlations, respectively.
Figures in parenthesis are environmental correlations

Effect of year of birth, season of birth and sex on wool yield at different clips

The analyses of variance revealed significant effect of year of birth (P<0.01) on wool yield at all clips *i.e.* from first to fourth clip (Table 2) with an inconsistent trend in wool production over the years attributable largely to variations in management and feeding practices over the years. The wool yield at first clip during eight years ranged between 39.12 ± 3.39 g (2007) and 76.65 ± 3.03 g (2000); second clip ranged between 152.91 ± 5.84 g (2005) and 197.41 ± 3.70 g (2002); third clip ranged between 171.81 ± 2.23 g (2007) and 199.29 ± 3.68 g (2003), and fourth clip ranged between 165.45 ± 2.62 g (2006) and 191.25 ± 2.21 g (2000). The results are in the line of the reports stated by Gaur *et al.*, (1992) and Thebault *et al.*, (1992) in German Angora and different strains of Angora rabbit. On the contrary, non-significant effect of year of birth on third and fourth clip was observed by Sambher (1992) in German Angora rabbits.

Significant effect (P<0.05) of season of birth was observed for wool yield at all clips under study except at second clip with generally higher wool production in winter born animals (Table 2). In case of wool yield at first clip, lowest yield (44.36 ± 4.65 g) was recorded in spring born animals, while it was the highest (68.97 ± 4.02 g) in winter born animals; In case of wool yield at third clip, rabbits born in spring season had the lowest wool yield (168.94 ± 3.06 g), whereas, the highest wool yield (185.79 ± 3.67 g) was recorded in autumn born animals. The averages for wool yield at fourth clip during the four seasons ranged between 168.12 ± 3.90 g in autumn and 193.45 ± 2.81 g in winter. The differences in wool production due to season of birth may be attributed to changes in feed quality, its intake and other changes in managemental practices. Similar significant seasonal effects on wool yield at different clips have also been reported by Sood *et al.*, (2007) and, Bhatt and Sharma (2009) in German Angora rabbits. The wool yield differed significantly among different seasons with the highest and the lowest during winter and summer, respectively. But certain studies (Gaur, 1989 and Sambher *et al.*, 1999) have reported non-significant effect of season of birth on wool yield at different clips.

The sex of the rabbits did not influence significantly wool yield at any clip in the present study (Table 2). This finding is consistent with the findings of Gupta *et al.*, (1995) and Sambher *et al.*, (1999) in Russian and German Angora rabbits, respectively. On the other hand, significant differences due to sex were reported by Gaur *et al.,* (1992) and Niedzwiadek *et al.,* (1992) in different strains of Angora rabbit.

Annual wool yield

The overall LSM ± SE for annual wool yield was estimated to be 594.22 ± 67.13 g with a coefficient of variation of 10.12%. (Table 1). The result is in accordance with the findings of Assad *et al.,* (2017) in German Angora rabbits. However, higher (Singh *et al.,* 2006) and lower estimates (Sood *et al.,* 2007) of annual wool yields were also reported in German Angora rabbits.

Effect of year of birth, season of birth and sex on annual wool yield

Least-squares analyses of variance revealed that the year of birth significantly affected ($P<0.01$) the annual wool yield (Table 2). The first year wool yield was the highest (635.62 ± 8.48 g) for animals' born in the year 2002 and the lowest (547.01 ± 6.68 g) for animals' born in the year 2007. There is decline of annual wool yield over the years after 2002. This may be due to loss of genetic variation which can be restored by replacement of germplasm through introduction of pure breeding stock from other organized farms or fresh import of German Angora rabbits to this farm to maintain superior genotypes and variability in the farm. Present findings are being corroborated by Sambher *et al.,* (1999) and Sood *et al.,* (2007) in German Angora rabbits. However, non-significant effect of year of birth on annual wool yield was reported by Singh (1987) in Russian, British and crossbred Angora rabbits.

Season of birth exerted significant effect ($P<0.05$) on annual wool yield (Table 2). Among seasons, the highest wool yield (611.92 ± 7.92 g) was observed among the animals born during winter and the lowest (560.76 ± 9.16 g) for the animals born during spring. Higher wool yield from winter born animals may be due to the high temperature during the period of fibre growth, thereby increasing the flow of nutrients to the wool follicles which influenced the wool growth in these animals.

This finding is in accordance with the findings of Sood *et al.,* (2007), Rafat *et al.,* (2007) and, Bhatt and Sharma (2009) in Angora rabbits. However, Sambher *et al.,* (1999) reported non-significant effect of season of birth on the trait in German Angora rabbits.

Though sex was found to have non-significant effect on annual wool yield in the present study but, the wool yield of females were higher than the males (Table 2). Similar non-significant effects of sex on the trait were reported by Sambher *et al.,* (1999) and Assad *et al.,* (2017) in Angora rabbits. In contrast, Sood *et al.,* (2007) reported significant effect of sex on annual wool yield in German Angora rabbits.

Genetic parameters

The estimates of genetic parameters *viz.,* heritability (h^2), genetic correlation (r_G), phenotypic correlation (r_P) and environmental correlation (r_E) along with the standard errors among wool yield at different clips and annual wool yield are presented in Table 3.

Heritability

The heritability estimates for wool yield at different clips and annual wool yield were estimated to be low to moderate in the present study (Table 3). These estimates are mainly governed by non-additive gene action with low additive genetic variance and higher environmental effects. Hence, improvement of these traits can be attained through better managemental practices since there is little scope for genetic improvement of the traits through selection. These estimates agree with the estimates of Allain *et al.,* (2004) and Niranjan *et al.,* (2011) in Angora rabbits. However, lower (Caro *et al.,* 1984) and higher estimates (Singh and Jilani, 2006) of heritability for these traits were obtained in different strains of Angora rabbits.

Genetic, phenotypic and environmental correlation

The genetic, phenotypic and environmental correlations among the wool production traits were low to high in magnitude and positive in direction, which indicate that there is possibility of simultaneous improvement of the wool traits. Wool yield at second clip with fourth clip had the highest genetic correlation (0.964± 0.014). Initial wool clips have been found to be important in early selection due to their high genetic correlation with latter clips (Rafat *et al.,* 2009). The present findings are in consonance with the findings of Singh and Jilani (2006) in German Angora rabbits.

In conclusion this study has revealed the importance of genetic and non-genetic factors for wool production traits in German Angora rabbits. Here, the wool production was the highest in winter and autumn born animals. So, it can be recommended to breed the Angora rabbits in the beginning of autumn and winter season. Low to moderate heritability for wool traits reflects that improvement can only be achieved if selection is accompanied by improved managemental practices at the farm. Pure breeding stock from other organized farms or fresh import of Angora rabbits can be introduced to this farm to maintain superior genotypes and variability in the farm.

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