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A NOTE ON DIVERGENT SELECTION FOR TOTAL FLEECE WEIGHT IN ADULT ANGORA RABBITS: DIRECT RESPONSE TO SELECTION ON TOTAL FLEECE WEIGHT AT FIRST AND SECOND HARVEST

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Abstract: In order to explore the genetic variability of wool production and other quantitative traits, an 8-cohort divergent selection experiment for total fleece weight (TFW) was carried out in French Angora rabbits. Studies were made on the wool production of a total of 669 female rabbits born between 1994 and 2001 and having produced wool from first to 12th harvests. The aim of the selection experiment was to obtain two divergent lines (low and high) on TFW. From preliminary analysis, the dataset was separated into three subsets according to the harvest number: one for each of the first two harvests and one for the third to the 12th harvests. In this paper, wool production data of the first and second harvests was analysed separately. Response to selection for total fleece weight at 3-12 harvest (TFW3-12) on this trait at first and second harvest was the aim of this paper. The second objective was to study the possibility of utilising values of the first or second harvest to estimate breeding values and as selection criteria for total fleece weight in the French Angora rabbit. Preliminary analysis of the data for non-genetic factors was done by the GLM procedure of SAS. Genetic parameters and breeding value estimates were carried out using a BLUP animal model using ASReml. A linear mixed model for a bivariate analysis of total fleece weight at first or second harvest and TFW3-12 was used. Heritability estimates of total fleece weight at first and second harvests were 0.36 and 0.38, respectively, and were similar to that observed at later harvests (0.35). The genetic correlation between TFW3-12 and fleece weight at first harvest was close to zero indicating that wool production at first harvest is a different trait from that of subsequent harvests. Genetic correlation estimates observed at second harvest were high (0.76) and response to selection at second harvest was similar to that observed for TFW3-12. These observations confirm that total fleece weight at first harvest is a different trait from TFW3-12. In French Angora rabbits, the high genetic correlation between TFW3-12 and total fleece weight at second harvest suggests the possibility of selection at this time for TFW3-12.

Key Words: Angora rabbit, divergent selection, heritability, fleece.

INTRODUCTION

The Angora rabbit is exploited to produce a fleece, which is then valued by the textile industry. The genetic improvement and the breeding of this animal have been studied by INRA (Institut National de la Recherche Agronomique) for more than thirty years (Thébault, 1977; Thébault and De Rochambeau,1989). To analyze the efficiency of selection on the total fleece weight and the correlated response on the other

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traits, an experiment of divergent selection was initiated in 1994. Previous studies have shown that total fleece weight in first and second harvests is a different trait from further harvests (Thébault *et al.*, 1992). Therefore, the dataset was separated into three subsets according to the harvest number: one for each of the first two harvests and one for the third to the 12th harvests. Histogram charts of fleece weight showed that the first two harvests were different from the rest of the data set. Previous studies also showed this difference (Thébault *et al.*, 1992). The results derived from the third to the 12th harvests have been published (Rafat *et al.*, 2007a, 2007b, and 2007c). These results showed a divergence of three genetic standard deviations between the high and low lines after eight years of selection. Selection for total fleece weight significantly increased bristle length, the secondary to primary follicle ratio and comfort factor and decreased compression, resilience, bristle diameter, and average fibre diameter. These changes resulted from moderate to high genetic correlations between total fleece weight and bristle length, and between fibre dimensions and secondary to primary follicle ratio, comfort factor, compression and resilience (Rafat *et al.*, 2007b). Thus, selection for increasing total fleece weight results in an increase of both quantitative and qualitative traits of wool production in the French Angora rabbit. Measurement of total fleece weight is simple and easy at farm level. Selection for this trait has positive effects on fleece characteristics such as bristle length, follicle population and fibre diameter.

The number of the harvest is important (at least at the first harvest) for all rabbit strains and for the second and third harvests in French strains. In the French Angora, young rabbits still produce woolly fur, even after depilation at second and third harvests. The total weight of wool harvested in the French breed increased rapidly up to the fifth harvest. Total fleece weight at the first harvest is about five times lower than that observed at the fourth or fifth harvest (Thébault and De Rochambeau, 1988). Previous studies have shown that total fleece weight in first and second harvests is a different trait from subsequent harvests. In this paper, fibre data of the first and second harvests was analysed separately. The objectives of this paper were to address the following questions: what is the response of selection for total fleece weight at 3-12 harvest on this trait at the first and second harvest? Is it possible to utilise the first or second harvest for estimation of breeding values for total fleece weight in French Angora rabbits?

MATERIALS AND METHODS

Animals and experimental design:

Data was obtained from the Angora experimental rabbit farm of INRA at Le Magneraud, France. The experiment took place in a naturally lighted semi-open building with no heating and no forced ventilation. Allain *et al*. (1999) described the management, reproduction and housing of these rabbits. Studies were made of the wool production of Angora females born between 1994 and 2001 under a divergent selection experiment that was initiated in 1994. The aim of the selection experiment was to obtain two divergent lines on total fleece weight. A high line and a low line were made up of 80 females and 20 males each. Sorensen *et al*. (2003) showed where a control line may seem a superfluous inclusion of a control line and can result in minor gains in efficiency if a high selection intensity is practiced in the selected line of a divergent experiment. Therefore in this selection experiment we did not consider a control line. Rabbits were distributed between the lines in order to have the same demographic structure and the same distribution of genetic values. Generations were overlapping. Owing to the fact that selection experiments with rabbits are generally carried out in separated generations, it is useful to obtain the results in a population that has been selected in overlapping generations. Moreover, most natural and artificial populations have overlapping generations. In addition, breeding organisations are interested in utilizing overlapping generations (Rafel *et al*. 1990; Rafat *et al*., 2009). The renewal of the next generation after selection was composed each year of 36 females and 5 males alive at the second harvest in each line. The selection criterion was the total fleece weight of the does measured for the third and later harvests. Genetic values were estimated with the BLUP animal model. The evaluation of the animals was done each year. Twenty does and five bucks having the highest and the lowest genetic values in the high and low lines, respectively, were selected. By 2001, two large cohorts were available from the high and low lines. The selection method has been described extensively by Rafat *et al*. (2007a).

Statistical Analysis:

Data from total fleece weight at the first and the second harvest was analysed separately. Initially, the significance for fixed effects was determined using the least squares means option of the GLM procedure of SAS (version 9.1.3; SAS Institute, 2002). Analyses for genetic parameters and breeding values were carried out with ASReml (Gilmour *et al*., 2002).

The following linear mixed models for a bivariate analysis of total fleece weight at first (TFW1) or second harvest (TFW2) and total fleece weight at 3-12 harvests (TFW3-12) were used:

$$Y_i = X_i\beta_i + Z_i a_i + W_i p_i + e_i$$

Where:

N is the total number of animals (3351),

N_i is the number of animals measured for the ith trait (762 and 669 at the first or the second harvest, respectively),

Y_i (N_i) is a vector of animal records for the ith trait at the first or the second harvest, and TFW3-12

βi (f_i) is a vector of fixed effects for the ith trait consisting of:

- Year (8 levels) from 1994 to 2001,
- Harvest number (10 levels) from the third to the twelfth harvest for TFW3-12,
- Birth season effect (4 levels),
- Harvest season effect (4 levels) for TFW3-12,
- Reproduction (3 levels: females which had litters and females which had been inseminated or not) from the third harvest onwards for TFW3-12,

a_i (N) is a random vector of direct additive genetic effects of animals for the ith trait,

p_i (N_i) is a random vector of permanent environmental effects of animals for the ith trait.

The variance-covariance structures for the animal genetic effects were:

R	$TFW3\text{-}12_1$	$TFW3\text{-}12_2$	$TFW3\text{-}12_3$	TFW3-12n	TFW1
$TFW3\text{-}12_1$	Ve1				
$TFW3\text{-}12_2$	Cov11	Ve1			
$TFW3\text{-}12_3$	Cov11	Cov11	Ve1		
TFW3-12n	Cov11	Cov11	Cov11	Ve1	
TFW1	Cov12	Cov12	Cov12	Cov12	Ve2

Lastly, the means of the estimated breeding values (EBV) for all traits were calculated per cohort of animals born the same year and per selected line.

Table 1: Number of records (N), mean, standard deviation (SD) and coefficient of variation (CV) for traits: total fleece weight at first harvest (TFW1), total fleece weight at second harvest (TFW2), total fleece weight at 3rd to 12th harvests (TFW3-12).

	Unit	N	Means	SD	CV
TFW1	g	762	31.31	8.56	27.34
TFW2	g	669	143.80	34.02	23.66
TFW3-12	g	3351	214.3	57.20	26.66

RESULTS AND DISCUSSION

Means and standard deviations (SD) for TFW1, TFW2 and TFW3-12 are shown in Table 1. Significance levels of fixed effects for fibre traits are shown in Table 2. Results of bivariate analysis for TFW1, TFW2 and TFW3-12 are shown in Table 3. Heritability estimates of TFW at first and second harvests were similar to values observed at harvests for TFW3-12. Genetic correlation between TFW3-12 and TFW1 is close to zero, which indicates that wool production at first harvest is a trait affected by additive genes different from those of following harvests. Similar to our results, the genetic correlation between birth coat and clean fleece weight in superfine Merino sheep was found to be zero and the authors concluded that birth coat does not increase economic gains when included in the selection criteria (Kemper *et al*., 2003). In French Angora rabbits, the high genetic correlation between TFW3-12 and TFW2 suggests the possibility of using TFW2 as a selection criterion.

Response to selection on TFW1 and TFW2 are shown in Figure 1. There was no response to selection at first harvest, while at second harvest, a difference of 2.54 genetic standard deviation was observed between the two divergent lines in 2001. This response to selection at second harvest was similar to that observed for harvests 3 to 12. These observations confirm that TFW1 is a trait affected by different additive genes as was to be expected because hair follicle development in the rabbit is not complete at 8 weeks of age when the first harvest occurs. Rougeot *et al*. (1984) studying the development of the coat in the growing Angora rabbit from birth, indicated that the number of derived hair follicles per hair follicle group increased in the growing animal from 10-12 at birth to 50-70 at the age of 20 weeks when the second harvest occurs. They concluded that the multiplication of derived hair follicles was independent of age but occurs up to a weight of 2 kg, which was reached between 8 and 14 weeks, depending on the growth potential of the animals.

CONCLUSIONS

Our results obtained in French Angora rabbits show: i) a high genetic correlation between total fleece weight at 3-12 harvests and total fleece weight at second harvest and ii) a significant response to selection

Table 2: Significance levels of fixed effects for traits: total fleece weight at first harvest (TFW1), total fleece weight at second harvest (TFW2), total fleece weight at 3rd to 12th harvests (TFW3-12).

	Year	Harvest number	Birth season	Harvest season	Reproduction
TFW1	***	-	***	ns	-
TFW2	***	-	***	ns	-
TFW3-12	***	***	***	***	***

*** $P < 0.001$; ns: non-significant

Table 3: Estimates of heritability, genetic and phenotypic correlations (± standard deviations) from bivariate analysis between total fleece weight at harvests 3-12 (TFW3-12) and first (TFW1) or second (TFW2) harvest.

Trait 1	Trait 2	h^2 Trait 1	h^2 Trait 2	r_g [1]	r_p [1]
TFW3-12	TFW1	0.35±0.05	0.36±0.08	0.01±0.11	0.14±0.03
TFW3-12	TFW2	0.33±0.05	0.38±0.08	0.76±0.10	0.34±0.03

[1] rg : genetic correlation; rp: phenotypic correlation.

for total fleece weight in the adult animal at the second harvest. Therefore, we propose selection for wool production at the second harvest.

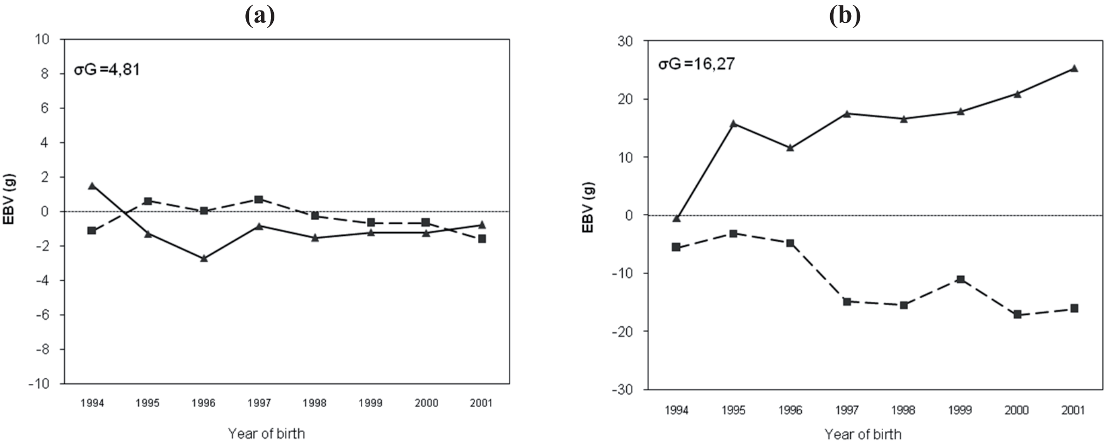

Figure 1: Change of mean breeding value estimates (EBV) of total fleece weight at: (a) first harvest and (b) second harvest over the eight years of selection for both the high (▲) and low (■) lines. Genetic standard deviation (σG) is given.

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