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Estimates of genetic parameters of growth traits in Madras Red sheep

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Abstract: *Sheep rearing is an important livelihood for a large number of small and marginal farmers in India as sheep make significant contribution to income generation, supply of animal source of food and serve as financial security to the resource-poor rural households. Growth is an economic trait of interest in domestic animals. The present study was aimed at evaluating growth performance and estimating the genetic parameters for growth traits of Madras Red sheep, a native breed of Tamilnadu state in India, under organized farm conditions. Monthly body weight measurements of 1424 sheep from birth to 2 years of age born during the years 1996 to 2010 were utilized for the analysis. Using least squares analysis, the effects of non-genetic factors namely, sex of lamb, season of birth (Main season(Oct.-Mar.) and off season(Apr.-Sep.)), dam weight at lambing (<25, 25-29.99, 30-34.99, ≥ 35 kg) and year of birth (1996-2000, 2001-2005, 2006-2010) on the observed birth weight and body weight at 3rd, 6th , 9th and 12th months and also on the average daily weight gain during 0-3, 3-6, 6-9 and 9-12 months were studied. The body weight at birth, 3rd, 6th, 9th and 12th month showed significant difference between sex of lamb, dam weight at lambing and year of birth ($P < 0.01$). The body weight, except at birth and 9th month showed significant difference between the seasons ($P < 0.01$). Average daily weight gains showed significant difference between sex of lamb, season of birth and year of birth while it showed significant difference between dam weights at lambing only for the period 3-6 months. Heritability and genetic correlation estimated using paternal half-sib analysis for body weights at various ages and average daily weight gains for different growth periods indicated scope for improvement through selection.*
Keywords: *Average daily weight gain, body weight, genetic correlation, heritability, Madras Red, Sheep*

I. Introduction

Sheep rearing is an important livelihood for predominant small and marginal farmers of India. Sheep are efficient converters of unutilized poor quality grass and crop residues into meat and skin. The Madras Red sheep, a native breed of Tamilnadu state in India is known for valuable quality meat and skin. This medium-sized hairy breed is distributed in the northern districts of the state [1]. Growth, one of the most important traits for farm animals, has been investigated for many years [2, 3, 4, 5]. The performance of Madras Red sheep under farmer's flocks was studied by [6] and the growth efficiency by [7]. In sheep, growth traits such as body weight and average daily weight gains are important response indicators. Thus far, there has been no detailed study on characterizing the growth performance in Madras Red sheep of an organized farm. This work will study the factors influencing the growth performance and also the genetic parameters of growth traits; the results can then be used in designing breed improvement programs.

II. Materials and Methods

2.1 Data description

Monthly body weights from birth to 24 months of age of 1424 sheep born during the period from 1996 to 2010 maintained at the Post Graduate Research Institute in Animal Sciences, Kattupakkam, Tamilnadu, India were used for the analysis. Data on sex of lamb, season of birth (Main season-Oct.-Mar. and off season-Apr-Sep.), dam weight at lambing (<25, 25-29.99, 30-34.99, ≥ 35 kg) and year of birth (1996-2000, 2001-2005, 2006-2010) were also used for the analysis. All births in this study were single and no twinning was recorded. Daily weight gain (g) during the periods 0-3, 3-6, 6-9 and 9-12 months were also calculated and used for the analysis.

2.2 Preliminary environment effects analysis

General Linear Model procedure was used to identify the effect of non-genetic factors on the observed body weights recorded at birth, 3rd, 6th, 9th and 12th month and also on the average daily weight gain (g) during 0-3, 3-6, 6-9 and 9-12 months. The fixed model $Y_{ijklm} = \mu + S_i + G_j + D_k + T_l + \varepsilon_{ijklm}$ was used where Y_{ijklm} is the adjusted monthly weight of the m^{th} lamb, μ is the overall mean, S_i is the fixed effect of the i^{th} season (i=main, off), G_j is the j^{th} gender (j = female, male), D_k is the k^{th} weight group of the dam at lambing (k= <25, 25-29.99, 30-34.99, ≥ 35 kg), T_l is the l^{th} time period (l=1996-2000, 2001-05, 2006-10) and ε_{ijklm} is the error attributed to the m^{th} lamb.

2.3 Estimation of genetic parameters

The scope for genetic improvement in an economically important trait of sheep depends on its magnitude of heritability and genetic variance. Heritability, denoted by h^2, is one of the most important concepts in animal breeding as it is used to help plan breeding programs, determine management strategies, estimate breeding values of individual animals, and predict response to selection. It is a measure of the degree (0 to 1) to which offspring resemble their parents for a specific trait and indicates how much confidence to place in the phenotypic performance of an animal when choosing parents of the next generation. For highly heritable traits where h^2 exceeds 0.40, the animal's phenotype is a good indicator of genetic merit or breeding value. Genetic correlations tell us how pairs of traits "co-vary" or change together. When genetic correlation is different from 0, then more of the same genes affect both traits. Selection for one trait will increase/decrease the other depending on whether the genetic correlation is positive or negative.

Body weights recorded at birth, 3rd, 6th, 9th and 12th month and also the average daily weight gain (g) during 0-3, 3-6, 6-9 and 9-12 months were used to estimate heritability and genetic correlation. Heritability estimates were computed by paternal half-sib correlation method [8]. The standard errors were estimated as per [9]. This method is used when each of a number of sires is mated to a number of females allotted at random and one offspring is produced by each dam. For the analysis, sires having a minimum of 5 progenies were considered. The observation X_{ij} on the j^{th} offspring of i^{th} sire is denoted by the following statistical model

$X_{ij} = \mu + s_i + e_{ij}$, where

X_{ij} is the observation on the j^{th} offspring of i^{th} sire, μ is the population mean, s_i is the effect of i^{th} sire, e_{ij} is the environmental deviations attributed to individuals within sire groups. All the effects are assumed to be random, normal and independent with zero expectation and variance as $E(s_i^2) = \sigma_s^2$ and $E(e_{ij}^2) = \sigma_e^2$. The variance components used for the estimation of heritability and genetic correlation of each trait were obtained by Variance Components Procedure of SPSS software [10] using Restricted Maximum Likelihood (REML) method after adjusting for significant fixed effects.

The formula used for computing heritability is $$h^2 = \frac{4\hat{\sigma}_s^2}{\hat{\sigma}_s^2 + \hat{\sigma}_e^2},$$

where $\hat{\sigma}_s^2$ is the additive genetic variance and $\hat{\sigma}_e^2$ is the environmental variance.

$$SE(h^2) = 4\sqrt{\frac{2(1-t)^2(1+(k-1)t)^2}{k(k-1)(s-1)}}$$, where $t = \frac{\hat{\sigma}_s^2}{\hat{\sigma}_s^2 + \hat{\sigma}_e^2}$ is the intra class correlation,

$$k = \frac{1}{s-1}\left[N - \frac{\sum n_i^2}{N}\right]$$ is the average number of progenies / sire,

s is the number of sires, and N is the total number of progenies.

The formula for genetic correlation between two traits x and y is $$r_g = \frac{\mathrm{cov}_s(xy)}{\sqrt{\sigma_{s(x)}^2 \sigma_{s(y)}^2}}$$

$$SE(r_g) = \frac{1-r_g^2}{\sqrt{2}}\sqrt{\frac{SE(h_x^2)SE(h_y^2)}{h_x^2 h_y^2}}$$ [11]

III. Results and Discussion

3.1 Data description

There were 1224 main season lambs born during October-March and 200 off season lambs born during April-September. As regards sex of the lamb, there were 703 females and 721 males. The overall sex ratio was 50.63% male lambs. More males were born in the off season (55.5%) than in the main season (49.8%). Regarding weight of dam at lambing, 157 (11%) were born to dams less than 25 kgs, 638 (44.8%) to dams weighing between 25-29.99 kgs, 511 (35.9%) to dams weighing between 30-34.99 kgs and 118 (8.3%) to dams weighing more than 35 kgs. With regard to the year of birth, 279 (19.6%) were born during 1996-2000, 634 (44.5%) during 2001-2005 and 511 (35.9%) during 2006-2010. In the present study, the type of all births was single and no twinning was observed.

3.2 Least Squares Analysis

Body Weights

The least squares mean ± standard error along with statistical significance to identify the effect of non-genetic factors on the observed body weights recorded at birth, 3rd, 6th, 9th and 12th months are given in TABLE 1. The overall mean body weights at birth, 3rd, 6th, 9th and 12th month were found to be 2.687, 10.548, 14.943, 17.902 and 20.369 kgs respectively which are in close agreement with corresponding figures reported by [6] in a study with the same breed under farmer's flock maintained in the northern district of Tamilnadu state in India. The mean body weights for males is significantly higher (P<0.01) than the corresponding values for females in all age groups. The body weight, except at birth and 9th month showed significant difference (P<0.01) between the seasons. The means for 3rd, 6th and 12th month for off season is significantly higher (P<0.01) than the corresponding main season values. However, the 9th month main season weight is higher, though not significantly, than the corresponding value for the off season. This may be because the main season lambs reach the winter season at the age of 9 months during which time the growth is conducive. Significant effect (P<0.01) of dam weight at lambing and year was observed in all age groups. The effect of weight of dam at lambing showed an increasing trend in all age groups which may be due to mothering ability and milk yield [12]. The results are in conformity with the findings of [1] and [7] in Madras Red sheep.

Average Daily Gain

The least squares mean ± standard error along with statistical significance to identify the effect of non-genetic factors on the average daily weight gain is given in TABLE 2. The overall average daily weight gains during 0-3, 3-6, 6-9 and 9-12 months were 87.357, 47.894, 31.717 and 25.615 g respectively. Growth during pre-weaning period is rapid compared to other periods. Sex of lamb, season of birth and year of birth showed highly significant (P<0.01) influence on all body weight gains while the weight of dam at lambing showed highly significant (P<0.01) effect on growth efficiency of their offspring only during birth to 3 months. Male kids grew faster than female kids. Off season lambs grew faster during 0-3, 3-6 and 9-12 months while main season lambs grew faster during 6-9 months. The findings are in agreement with [13], [14] and [7]. On the other hand, non significant effect of sex of lamb on average daily weight gain was reported by [6]. Significant variations found over the years could be due to different management conditions and maternal environment experienced by the lambs.

3.3 Genetic parameters

3.3.1 Heritability estimates of body weights and average daily weight gains

The estimates of heritability ± SE for body weights recorded at birth, 3rd, 6th, 9th and 12th months and average daily weight gains during 0-3, 3-6, 6-9 and 9-12 months are given in TABLE 3. The heritability estimates ± SE for birth weight and 9M weight were moderate at 0.25806 ± 0.13804 and 0.20195 ± 0.14983 respectively whereas the estimates for weaning weight (3M), 6M weight and yearling weight (12M) are much better at 0.5084 ± 0.16058, 0.51642 ± 0.16653 and 0.65173 ± 0.19068 respectively. Very low heritability estimate for birth weight in Muzaffarnagari sheep was reported by [14], whereas for other body weight traits, it ranged from 0.18 to 0.26.

Similarly, the estimates of heritability ± SE calculated for average daily weight gains during 0-3, 3-6, 6-9 and 9-12 months are 0.47404 ± 0.15818, 0.41969 ± 0.16009, 0.20515 ± 0.15057 and 0.46108 ± 0.18137 respectively. The finding matches with that of [15] in Sirohi kids.

3.3.2 Genotypic correlation among body weights at different age

The estimated genetic correlations of body weights at different ages are given in TABLE 4. The estimates of genetic correlation between birth weight and 6M, 9M, 12M weight are low at -0.03787 ± 0.36598, -0.31497 ± 0.69571 and 0.17610 ± 0.50488 respectively whereas all other genetic correlation are quite high. The estimate of genetic correlation between 3M and 12M weight is high at 0.96711 ± 0.06946. The high positive genetic correlations between 3M and 12M suggest that the trait 3M bodyweight can be effectively used in the selection program.

IV. Tables

Table 1: Least-squares means ± standard error of body weight (kg) of Madras Red sheep at different stages of growth (Number of observations in parentheses)

Fixed Effect	*Birth Weight (1424)*	*3 Months (1333)*	*6 Months (1164)*	*9 Months (958)*	*12 Months (794)*
Overall Mean	2.687± .019	10.548± .093	14.943± .125	17.902± .165	20.369± .202
Season of Birth	NS	**	**	NS	**
Main	2.669± .016	9.50 ± .077	13.704± .102	18.052± .123	19.788± .145

(1224)	(1224)	(1140)	(996)	(855)	(715)
Off (200)	2.706± .032 (200)	11.595± .154 (193)	16.182± .207 (168)	17.752± .283 (103)	20.950± .349 (79)
Sex of lamb	**	**	**	**	**
Female (703)	2.601± .023 (703)	10.238± .110 (675)	14.179± .146 (610)	16.562± .185 (547)	18.771± .221 (484)
Male (721)	2.774± .022 (721)	10.858± .106 (658)	15.707± .144 (554)	19.241± .190 (411)	21.967± .237 (310)
Dam Weight at lambing (kg)					
< 25 (157)	2.274± .037^{a} (157)	9.902± .186^{a} (139)	14.119± .249^{a} (121)	16.904± .311^{a} (96)	19.255± .379^{a} (79)
25 – 29.99 (638)	2.654± .021^{b} (638)	10.26± .102^{a} (598)	14.583± .137^{a} (517)	17.622± .178^{b} (428)	20.182± .217^{b} (347)
30 – 34.99 (511)	2.836± .022^{c} (511)	10.75± .106^{b} (486)	15.101± .143^{b} (425)	18.060± .186^{c} (351)	20.691± .224^{c} (294)
≥ 35 (118)	2.985± .041^{d} (118)	11.28± .201^{c} (110)	15.969± .265^{c} (101)	19.021± .324^{d} (83)	21.348± .374^{c} (74)
Year of Birth					
1996-2000 (279)	2.649± .030^{a} (279)	11.55± .144^{a} (266)	16.289± .194^{a} (235)	18.928± .248^{a} (177)	22.672± .302^{a} (140)
2001-2005 (634)	2.625± .023^{a} (634)	9.722± .113^{b} (575)	13.894± .154^{b} (468)	17.296± .201^{b} (374)	19.211± .245^{b} (309)
2006 -2010 (511)	2.787± .024^{b} (511)	10.37± .115^{c} (492)	14.646± .152^{c} (461)	17.481± .187^{b} (407)	19.224± .226^{b} (345)

Sub-class means with different superscripts differ significantly ** p<0.01 NS- Not significant

Table 2: Least-squares means ± standard error of average daily weight gain (g) of Madras Red sheep at different periods of growth (Number of observations in parentheses)

Fixed Effect	*0-3 months (1333)*	*3-6 months (1161)*	*6-9 months (958)*	*9-12 months (791)*
Overall Mean	87.357 ± 1.033	47.894± 1.246	31.717± 1.337	25.615± 1.676
Season of Birth	**	**	**	**
Main (1140)	75.921± .856 (1140)	45.352 ± 1.02(994)	45.278± .999(855)	19.371± 1.208(712)
Off (193)	98.794± 1.710 (193)	50.436± 2.069(167)	18.156± 2.294(103)	31.858± 2.897(79)
Sex of lamb	**	**	**	**
Female (675)	84.838± 1.22 (675)	42.905± 1.463(608)	26.173± 1.501(547)	22.185± 1.832(484)
Male (658)	89.877± 1.184 (658)	52.883± 1.437(553)	37.261± 1.542(411)	29.044± 1.967(307)
Dam Weight at lambing (kg)		NS	NS	NS
< 25 (139)	84.821± 2.063^{b}(139)	45.396± 2.494(120)	30.999± 2.522(96)	25.439± 3.145(79)
25 – 29.99 (598)	84.541± 1.134^{b}(598)	47.172± 1.367(517)	31.818± 1.44(428)	27.014± 1.807(345)
30 – 34.99 (486)	87.833± 1.183^{a}(486)	47.749± 1.426(424)	31.998± 1.506(351)	26.240± 1.861(293)
≥ 35 (110)	92.234± 2.229^{a}(110)	51.259± 2.65(100)	32.052± 2.627(83)	23.765± 3.109(74)
Year of Birth				
1996-2000 (266)	98.988± 1.601^{a}(266)	50.375± 1.930^{a}(235)	27.632± 2.015^{a}(177)	37.067± 2.512^{a}(140)
2001-2005 (575)	78.867± 1.257^{b}(575)	46.020± 1.535^{b}(467)	36.476± 1.633^{b}(374)	21.608± 2.032^{b}(308)
2006 -2010 (492)	84.217± 1.281^{c}(492)	47.287± 1.516^{b}(459)	31.042± 1.519^{a}(407)	18.168± 1.875^{b}(343)

Sub-class means with different superscripts differ significantly ** p<0.01 NS- Not significant

Table 3: Heritability estimates ± standard error for
Body weight at several ages and Average Daily Weight Gains for different periods

Trait	*Heritability*	*SE*
Body weight		
Birth weight	0.25806	0.13804
3M weight	0.50840	0.16058
6M weight	0.51642	0.16653
9M weight	0.20195	0.14983
12 M weight	**0.65173**	0.19068

Average Daily weight gain		
0– 3 m	0.47404	0.15818
3 – 6 m	0.41969	0.16009
6 – 9 m	0.20515	0.15057
9 – 12 m	0.46108	0.18137

Table 4: Genetic Correlation ± standard error among body weight at several ages

Trait	*3M weight*	*6M weight*	*9M weight*	*12M weight*
Birth weight	0.40225 ± .31645	-0.03787 ± .36598	-0.31497 ± .69571	0.17610 ± .50488
3M weight		0.68372 ± .19570	0.60774 ± .34613	**0.96711** ± .06946
6M weight			0.54459 ± .53295	0.74043 ± .21629
9M weight				0.77219 ± .24131

V. Conclusion

In Madras Red sheep, sex of lamb, dam weight at lambing and year of birth had a marked influence on all body weight measurements. The body weight, except at birth and 9th month showed significant difference between the seasons. Average daily weight gains showed significant difference between sex of lamb, season of birth and year of birth while significant effect of dam weight at lambing was seen only for the period 3-6 months. Heritability for body weight and average daily weight gain were moderate to high, the highest heritability of 0.65173 obtained for 12M weight. Estimates of genetic correlation between birth weight and 6M, 9M and 12M are low while other correlations were on the higher side with very high positive correlation of 0.96711 observed between 3M and 12M weight. In conclusion, it is possible to show improvement in 12M body weight which comes from the fact that this trait is highly heritable and at the same time genetically correlated to 3M weight. The findings suggest that by selecting potential animals early based on 3M weight, a significant genetic improvement in the 12M body weight in Madras Red sheep can be brought about.

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