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Article

Estimation of Variance Components on Number of Kids Born in a Composite Goat Population

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Abstract

Records on 1,487 parturitions from a composite population of Anglo-Nubian, Saanen, Native and crossbred goats at Yala Livestock Research and Breeding Center, Department of Livestock Development during the years 1995 and 2005 were estimated for variance components and parameters for number of kids born using REML procedure. Single-trait analysis included parity, year-season at kidding, covariates of additive and heterosis breed effects, direct genetic effects, permanent environmental and residual effects. The results showed that direct additive breed effects for Anglo-Nubian and Saanen as a measure of deviation from Native goats for the number of kids born were 0.02 and –0.09 heads, respectively. Heterosis breed effects in Anglo-Nubian × Native and Saanen × Native crosses were positive with increasing numbers of kids born at 0.11 and 0.31 heads, respectively. Direct heritability and permanent environmental variance as a proportion of phenotypic variance for number of kids born were found to be 0.04 and 0.02, respectively.

Keywords: Breed effects, variance component, direct heritability, permanent environmental effects, number of kids born, goats

Introduction

Crossbreeding is a widely accepted and common practice in livestock and poultry around the world. The objective of crossbreeding is to improve efficiency of reproduction traits and survival rate. Several approaches to crossbreeding have been practiced in goat production: two-breed cross derived from exotic breeds and indigenous goats; three-breed cross by mating the crossbred dams with purebred sires; backcross of two-breed cross dams to male parent; combination of specific breed cross to form composite populations [1]. Some studies have shown that estimation of genetic variances in crossbred population is important to account for breed additive and non-additive effects by fitting linear regression on breed composition, heterozygosity and recombination. Application of this procedure provides breed additive and non-additive effects, corrected heritability and genetic correlation estimates for use in breeding value prediction within a target population [2-4].

The profitability of goat production depends primarily on the efficiency of offspring production and the most important factor affecting flock efficiency is reproduction. Reproduction efficiency in female goats can be measured and expressed as kidding rate, weaning rate, kidding interval and number of kids born. The number of kids born should be included in selection programmes, although its inclusion has been limited, probably due to its low heritability. Furthermore, there is still limited information on estimation of variance components and parameters for this trait in a composite population when including breed additive and non-additive effects. Therefore, the aim of this study was to estimate variance components and parameters for number of kids born in a population of Anglo-Nubian, Saanen, Native and crossbred goats.

Materials and methods

Data Description

Data were obtained from Yala Livestock Research and Breeding Center, on the east coast of southern Thailand (5 to 7°N, 100 to 102°E). The climate is tropical monsoon with an average ambient temperature, relative humidity and annual rainfall of 28.14 °C, 74.89 % and 2,386.10 millimeters in the year 2007 [5]. The data set was collected from 1,487 parturitions of 476 female goats during the years 1995 and 2005. The trait of interest was the number of kids born. This trait was defined as the number of live kids at birth either single (1 head), twins (2 heads) or triplets (3 heads). The performance in terms of the number of kids born to the female goats from the 13 breed groups is shown in **Table 1**.

Table 1 Number of kids born to the female goats from 13 breed groups.

Breed group[1]			No[2]	NK[3] (head)	
Female	Sire	Dam		Mean	SD[4]
Pure breed					
A	A	A	259	1.31	0.49
S	S	S	23	1.35	0.57
N	N	N	757	1.34	0.50
Two-breed cross					
$\frac{1}{2}A\frac{1}{2}N$	A	N	36	1.19	0.40
$\frac{1}{2}A\frac{1}{2}N$	$\frac{1}{2}A\frac{1}{2}N$	$\frac{1}{2}A\frac{1}{2}N$	146	1.32	0.51
$\frac{5}{8}A\frac{3}{8}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{1}{2}A\frac{1}{2}N$	33	1.55	0.56
$\frac{3}{4}A\frac{1}{4}N$	A	$\frac{1}{2}A\frac{1}{2}N$	76	1.46	0.58
$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	71	1.30	0.49
$\frac{1}{2}S\frac{1}{2}N$	$\frac{1}{2}S\frac{1}{2}N$	$\frac{1}{2}S\frac{1}{2}N$	20	1.35	0.49
$\frac{5}{8}S\frac{3}{8}N$	$\frac{3}{4}S\frac{1}{4}N$	$\frac{1}{2}S\frac{1}{2}N$	9	1.44	0.53
$\frac{3}{4}S\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	43	1.39	0.49
Three-breed cross					
$\frac{3}{8}A\frac{3}{8}S\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	9	1.33	0.50
$\frac{5}{8}A\frac{1}{8}S\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{1}{2}A\frac{1}{4}S\frac{1}{4}N$	8	1.13	0.35
Total			**1,487**	**1.34**	**0.50**

[1]A is Anglo-Nubian, S is Saanen, N is Native
[2]No is the number of records
[3]NK is the number of kids born
[4]SD is the standard deviation

Management

Replacements were usually recruited from within the herd (10 % of sires and 90 % of dams) and some of them were purchased from other livestock and breeding centers of the Department of Livestock Development. Young males and females were performance tested at the age of three to nine months old using body weight and pedigree information as selection criteria. The selected goats remained in the station for breeding and replacement while unselected ones were sold to farmers for further breeding in the production herds. Young females were mated to males for the first time at at least nine months of age. They produced their first kid at between 15 and 18 months old. The mating period usually occurred from 3.00 pm until 9.00 am on the next day and one male was penned with 15 females. Females were rotationally grazed from 9.00 am to 3.00 pm and were offered cut-and-carry forage in the evening. Roughage was mainly *Brachiaria decumbens*, *Paspalum plicatulum*, *Panicum maximum* and *Pennisetum purpureum* ad libitum. Concentrate feed containing approximately 16 % crude protein and 2,600 kcal ME/kg as fed-basis for sires, dams and replacements at 1 % of body weight once a day in the morning. Lactating dams were fed twice a day (morning and evening) at 1.5 % of body weight. New born kids were fed with colostrums for three days. After that, they were fed with dam milk and milk replacer from 1 to 12 weeks of age. Dry grasses, bush leaves, dry fodder and concentrate feed were introduced to the kids at four weeks.

Statistical Analysis

Estimation of variance components were obtained by using a derivative-free restricted maximum likelihood algorithm [6]. The maximum likelihood value was found by the Simplex method. The convergence criterion was considered to be reached when the variance of the function values used in the Simplex method was less than 10^{-8}. Analyses were restarted from the converged values to check that a global rather than a local maximum had been reached. When estimates did not change, convergence was assumed.

Single-trait analysis for number of kids born was conducted with the model that included fixed and random effects. Fixed factors were parity, year-season at kidding and covariates of additive and heterosis breed effects. Direct additive breed effects for Anglo-Nubian and Saanen breeds were expressed as deviation from the Native breed. The crossing types for which heterosis breed effects fitted were: Anglo-Nubian × Native, Saanen × Native and Anglo-Nubian × Saanen. The effects were fitted in the models as linear regression covariates across all breed groups. Coefficients of direct additive breed effects were related to breed contents in animals as a proportion of genes contributed by each breed. Heterosis breed effects were based on the assumption that a linear relationship existed between dominance and degree of heterozygosity. Heterozygosity was calculated as $\sum ps_i pd_j$, where ps_i and pd_j were the proportion of breed i in sire and breed j in dam, respectively [3]. **Table 2** presents coefficients of additive and heterosis breed effects in 13 breed groups. Random effects were direct genetic, permanent environmental and random residual effects.

Table 2 Coefficients of additive and heterosis breed effects in 13 breed groups[1].

Breed group			Additive			Heterozygosity		
Female	**Sire**	**Dam**	**A**	**S**	**N**	**A×N**	**S×N**	**A×S**
A	A	A	1	0	0	0	0	0
S	S	S	0	1	0	0	0	0
N	N	N	0	0	1	0	0	0
$\frac{1}{2}A\frac{1}{2}N$	A	N	$\frac{1}{2}$	0	$\frac{1}{2}$	1	0	0
$\frac{1}{2}A\frac{1}{2}N$	$\frac{1}{2}A\frac{1}{2}N$	$\frac{1}{2}A\frac{1}{2}N$	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0
$\frac{5}{8}A\frac{3}{8}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{1}{2}A\frac{1}{2}N$	$\frac{5}{8}$	0	$\frac{3}{8}$	$\frac{1}{2}$	0	0
$\frac{3}{4}A\frac{1}{4}N$	A	$\frac{1}{2}A\frac{1}{2}N$	$\frac{3}{4}$	0	$\frac{1}{4}$	$\frac{1}{2}$	0	0
$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}$	0	$\frac{1}{4}$	$\frac{3}{8}$	0	0
$\frac{1}{2}S\frac{1}{2}N$	$\frac{1}{2}S\frac{1}{2}N$	$\frac{1}{2}S\frac{1}{2}N$	0	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	0
$\frac{5}{8}S\frac{3}{8}N$	$\frac{3}{4}S\frac{1}{4}N$	$\frac{1}{2}S\frac{1}{2}N$	0	$\frac{5}{8}$	$\frac{3}{8}$	0	$\frac{1}{2}$	0
$\frac{3}{4}S\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	0	$\frac{3}{4}$	$\frac{1}{4}$	0	$\frac{3}{8}$	0
$\frac{3}{8}A\frac{3}{8}S\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{3}{4}S\frac{1}{4}N$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{9}{16}$
$\frac{5}{8}A\frac{1}{8}S\frac{1}{4}N$	$\frac{3}{4}A\frac{1}{4}N$	$\frac{1}{2}A\frac{1}{4}S\frac{1}{4}N$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{16}$	$\frac{3}{16}$

[1]A = Anglo-Nubian, S = Saanen, N = Native

The animal model in matrix notation is expressed as follows,

$$y = X_1b + X_2g + X_3h + Za + Spe + e$$

where

y is the vector of observations for number of kids born

b is the vector of fixed effects

g is the vector of direct additive breed effects

h is the vector of heterosis breed effects

a is the vector of direct genetic effects

pe is the vector of permanent environmental effects

e is the vector of random residual effects

X_1 was an incidence matrix relating records to fixed effects. X_2 and X_3 were the matrices of coefficients relating records to direct additive breed effects and heterosis breed effects, respectively. Z and S were incidence matrices relating records to direct genetic effects and permanent environmental effects, respectively.

First moment for number of kids born was

$$E[y] = X_1b + X_2g + X_3h$$

The variance structure for random effects of number of kids born was

$$V\begin{bmatrix} a \\ pe \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & 0 & 0 \\ 0 & I_{pe}\sigma_{pe}^2 & 0 \\ 0 & 0 & I_n\sigma_e^2 \end{bmatrix}$$

where A was a numerator relationship matrix, σ_a^2, σ_{pe}^2 and σ_e^2 were direct genetic variance, permanent environmental variance and residual variance, respectively. I_{pe} and I_n were identity matrices of order equal to the number of females and number of records, respectively.

Estimates of parameters were derived from estimates of variance components in single-trait analysis. Direct heritability (h^2) and permanent environmental effect (pe^2) were calculated as ratios of σ^2_a and σ^2_{pe} to phenotypic variance (σ^2_p), respectively [7].

Results

Breed Effects

Solutions for breed effects for number of kids born from single-trait analysis are shown in **Table 3**. The solutions for direct additive breed effects were relative to Native effect. Heterosis effects observed upon Anglo-Nubian × Native, Saanen × Native and Anglo-Nubian × Saanen crosses. These effects were estimated by generalized least squares (GLS) simultaneously with other fixed and random effects in the model. Estimates of direct additive breed effects for Anglo-Nubian and Saanen for number of kids born were 0.02 and −0.09 heads, respectively. Heterosis breed effects in Anglo-Nubian × Native and Saanen × Native crosses were positive with the amount of 0.11 and 0.31 heads, respectively, while a cross between Anglo-Nubian and Saanen were negative (−0.18 heads).

Table 3 Estimates of breed effects for number of kids born from animal model.

Effect	Number of kids born (head)
Direct additive breed	
Anglo-Nubian	0.02
Saanen	−0.09
Heterosis breed	
Anglo-Nubian × Native	0.11
Saanen × Native	0.31
Anglo-Nubian × Saanen	−0.18

Table 4 Estimates of variance components and parameters for number of kids born.

Parameter[1]	Number of kids born
σ^2_a	0.01
σ^2_{pe}	0.01
σ^2_e	0.21
σ^2_p	0.23
h^2	0.04 (0.03)
pe^2	0.02 (0.03)
e^2	0.94 (0.02)
−2logL	60.86

[1] σ^2_a = direct genetic variance, σ^2_{pe} = permanent environmental variance, σ^2_e = residual variance, σ^2_p = phenotypic variance, h^2 = direct heritability, pe^2 = permanent environmental variance as a proportion of phenotypic variance, e^2 = residual variance as a proportion of phenotypic variance. Figures in parentheses are standard errors of estimate.

Variance Components and Parameters

From **Table 4**, estimate of phenotypic variance for number of kids born was 0.23 head^2. Direct heritability estimate obtained for number of kids born was 0.04. Permanent environmental variance as a proportion of phenotypic variance was very small (0.02), while residual variance as a proportion of phenotypic variance was large (0.94) for number of kids born.

Discussion

Breed Effects

Direct additive breed effects for number of kids born in the current study were positive for Anglo-Nubian and negative for Saanen relative to Native female goats. The favorable effect of Anglo-Nubian could be due to the fact that Anglo-Nubian breed is of mixed origin between the Prick eared goats indigenous to Britain and Nubian-type goats from Africa and India (Zaraibi, Chitral and Jamnapari). The higher prolificacy of the Anglo-Nubian was associated with its Zaraibi ancestry, one of the most prolific seasonal breeders [8]. The number of kids born of Zaraibi dams under Egyptian environmental conditions averaged 2.9 heads [9]. On the other hand, the unfavorable effect of Saanen for the same trait might be that Saanen female goats were not able to ovulate more ova and also a low survival rate of fetuses under the harsh environmental conditions of the tropics. According to [8], Saanen is commonly believed to be less suited to the tropics than other European breeds.

The positive values for heterosis breed effects obtained from Anglo-Nubian × Native and Saanen × Native crosses for number of kids born were in agreement with [10] who reported significant heterosis effect at 0.35 from a cross of Ile de France × Finnish Landrace sheep. The favorable effects indicated possible compatibility between genetic diversity of Anglo-Nubian and Native or Saanen and Native for this trait. The crossing breeds that are genetically different from each other, but have complementary attributes should provide an adequate amount of heterosis [11]. A higher level of heterosis effect for Saanen × Native when compared to Anglo-Nubian × Native might be due to genetic differences between the breeds involved. The Saanen breed originated from West Switzerland [8], while Native goats are similar to the Malaysian Kambing Katjang [12]. Saanen and Native represent a wider range of genetic diversity than Anglo-Nubian and Native and therefore when crossed, produce more heterosis. The unfavorable effect observed from a cross between Anglo-Nubian and Saanen might be due to a lack of compatibility between the genetic diversity of these two breeds for this trait.

Genetic Parameters

Estimate of heritability for number of kids born was at the lower end of the range reported in the literature (−0.001 to 0.35, [13-17]). [18] summarized 53 reported estimates of heritability for number of lambs born and obtained a mean estimate of 0.10 with a standard error of 0.07. Estimates of heritability for the same trait by using the REML procedure ranged from 0.05 [19] to 0.14 [20]. The low estimate of heritability for number of kids born in the current study may be due to categorical expression of this trait [21,22] and the REML procedure in analyses. The analysis of a trait exhibiting a discrete distribution of phenotype with threshold model resulted in greater heritability estimates for the number of lambs born in Rambouillet and Finnsheep (0.45 and 0.14, respectively, [23]). In theory, threshold models seem appropriate for discrete data and thus may capture a higher portion of genetic variation than is possible with a linear methodology [24]. It was also noticed that the fraction of residual variance of number of kids born was high (0.94), indicating that the major source of variation in this trait appeared to be due to temporary environmental effects. For example, age and body condition of the dam, feeding and management of the dam and the buck [17]. So, there is a need for improved and uniformed management over the years to increase performance.

Estimate of permanent environmental variance as a proportion of phenotypic variance for number of kids born was in agreement with the findings of [25] in Targhee sheep. The low estimate indicating that a dam with a large litter in one kidding year might produce a small litter the next year.

Conclusions

Direct additive breed effects in terms of deviation from Native goats for the number of kids born were positive for Anglo-Nubian and negative for Saanen. Positive values of heterosis breed effects were observed for Anglo-Nubian × Native and Saanen × Native crosses. Estimates of direct heritability and permanent environmental effects were low.

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