Variance components and heritability estimates for first lactation traits of Sahiwal cattle by different statistical methods

RK Pundir*

National Bureau of Animal Genetic Resources, Karnal -132 001 India

ABSTRACT

Variance components and heritability were estimated by Analysis of variance (ANOVA), Minimum Norm Quadratic unbiased estimates (MINQUE/MIVQUE), Maximum likelihood (ML) and Restricted Maximum Likelihood (REML) methods for age at first calving, first lactation milk yield, first lactation peak yield, First lactation length, first dry period, first service period and first calving interval from the first lactation performance records of 597 Sahiwal cows, daughters of 33 sires, spread during 1977 to 2000 and maintained at Government Livestock Farm, Hisar, India. Different methods for estimation of variance components gave similar results i.e., variance components were not statistically different by all the four methods for a particular trait as concluded by homogeneity test of variance and equality of two variances for same trait by two different methods. The moderate to high estimates of heritability for all the traits under study indicated that improvement can be made through direct selection.

Kew Words: First lactation traits, heritability, variance components

INTRODUCTION

Genetic parameters are of paramount importance for any genetic improvement program in livestock. The outcome and accuracy of a program depends on heritabilty estimate of the trait of interest. The magnitude of the heritability provides an idea about the scope for effective genetic improvement through selection. It is also used in estimation of breeding values of sires/cows which help in their ranking. Hence, accurate and precise estimates of heritability are first priority of breeders. Heritabilities are estimated by variance components and numbers of methods are available for estimation of variance components.

The present study was undertaken to estimate variance components and heritabilities by Analysis of variance (ANOVA), Minimum Norm Quadratic unbiased estimates (MINQUE/MIVQUE), Maximum likelihood (ML) and Restricted Maximum Likelihood (REML) methods of various first lactation performance traits of Sahiwal cattle, an important milch breed of India.

MATERIALS AND METHODS

Data: First lactation records of 514 Sahiwal cows daughters of 33 sires spread over a period of 24 years from 1977 to 2000 maintained at Government livestock farm (GLF), Hisar, Haryana, India were used to estimate variance components and heritabilities. Only the sires having records on at least 5 daughters were included in the present study. Cows having abnormal and incomplete records due to sickness, abortion and death of calf within a week of calving were excluded from the study. The total duration of study was divided into six equal periods of 4 years each viz. P1 (1977-1980), P2 (1981 to 1984), P3 (1985 to 1988), P4 (1989 to 1992), P5 (1993 to 1996) and P6 (1997 to 2000). Each year was divided into 4 seasons namely summer (March to June), rainy (July to mid September), autumn (mid September to November) and winter (December to February). The traits considered in the study were age at first calving (days), first lactation milk yield (Kg), first lactation peak yield (Kg), First lactation length (days), first dry period (days), first service period (days) and first calving interval (days).

*Present Address: Principal Scientist, NBAGR, Karnal; E-mail; Pundirrk@nbagr.ernet.in

Statistical Methods: Variance components for first lactation milk yield (FLMY), first lactation peak yield (FPY), First lactation length (FLL), first dry period (FDP), first service period (FSP) and first calving interval (FCI) were estimated by a unit trait mixed model incorporating sire as random and sire genetic group (1-6), season of calving (1-4), period of calving (1-6) as fixed effects and age at first calving as covariable. Age at first calving (AFC) was analyzed by same model except regression part. Using matrix algebra and assuming that all genetic variation is additive, the model can be reprsented as

$$Y = Xb + Zs + e$$

Where y is a Nxl vector of observations, X is the Nxp design matrix for fixed effects, Z is Nxq design matrix for sires, b is px1 column vector of fixed effects, s is qx1 column vector of random effects and e is Nx1 random error vector, distributed normally with mean 0 and variance σ2. The normal equation for this can be expressed as

$$\begin{bmatrix} X'X & XZ \\ Z'X & Z'Z \end{bmatrix} \begin{bmatrix} b \\ s \end{bmatrix} = \begin{bmatrix} X'y \\ Z'y \end{bmatrix}$$

Henderson's method 3 (HM-3, ANOVA)

The ANOVA procedure is used to estimate the sire and error variance components of variance. The estimates of sire and error effects were obtained by equating observed and expected mean squares from analysis of variance and solving the resulting equations (Searle, 1971).

Maximum Likelihood (ML)

The Maximum likelihood, an iterative procedure was proposed by Hartley and Rao (1967) to solve Henderson's mixed model equations. Estimates of ML are sufficient, consistent, efficient and asymptotically normal. However, as the number of fixed effects increases, the ML estimates loose unbiaseness. Under the assumption of normal distribution, ML estimates of variance components were obtained as

$$\sigma^2_e = \frac{y'y - \hat{b}' X'y - \sum_{i=1}^{q} \hat{\sigma}^2_{si}\, Z_i' y}{N}$$

$$\hat{\sigma}^2_s = \frac{s's + \hat{\sigma}^2_e \; tr\left((Z'Z + \hat{\sigma}^2_e / \hat{\sigma}^2_s)^{-1}\right) \hat{\sigma}^2_s}{n_s}$$

Where n_s is the number of sires.

Restricted Maximum likelihood (REML)

Restricted Maximum likelihood (Patterson and Thompson, 1971) like ML is an iterative procedure. In contrast to ML, REML takes into account the loss of degrees of freedom associated with estimation of fixed effects. The main idea behind REML is that all the information used in estimating variance components is combined in any set of N-p linearly independent error contrasts, where p is the number of fixed effects and the error contrast is defined as a linear combination of observations whose expectation is zero.

Minimum Norm/ Variance Quadratic Unbiased Estimator (MINQUE/MIVQUE)

Minimum Variance Quadratic Unbiased Estimator are defined as those obtained from REML equations without iteration, using a priori values of 0 and 1, for σ^2_s and σ^2_e, respectively (Hartley and Rao, 1967). The method was proposed by Rao (1971). MINQUE estimates of variance components are unbiased and ANOVA based. Heritabilities were obtained from variance components by paternal half-sibs correlation method. Heritabilities were estimated as:

$$h^2 = 4\,\sigma^2_s \;/\; (\sigma^2_s + \hat{\sigma}^2_e)$$

Where, σ^2_s is the sire component of variance $\hat{\sigma}^2_e$ is the error component of variance. Standard errors of heritability were computed using the formula developed by Swiger et al. (1964). Variance components were estimated by SPSS 7.5 software for Windows. Heritabilities and their standard error were calculated from variance components obtained in the study.

Estimated variance components were evaluated by using Bartlett (1937) homogeneity test.

$X^2 = M / C$ (X^2 value at (a-1) d.f)

$M = 2.3026\, f\, (a \log s'^2 - \Sigma \log s_i^2)\; (s'^2 - \Sigma \log s_i^2 / a)$

$$C = 1 + \frac{a+1}{3\,a\,f}$$

Where, s_i^2 is an estimate of the same σ^2, a is the number of estimate, and f is the d.f.

Estimated variance components were also evaluated by using criterion of Swallow and Monahan (1984).

Equality of two variances was tested by the procedure of Snedecor and Cochran (1967).

$F = \sigma^2_1 / \sigma^2_2$

Where, σ^2_1 is the larger mean square

RESULTS AND DISCUSSIONS

Sire and error variances, ratio of sire and error variances and heritability with standard error of different first lactation performance traits by ANOVA, MINQUE, ML and REML methods are presented in table-1. No negative sire variance was observed for any of the trait under study by any of the method. Similar observations were made by Bilgin et al., (2004) in lambs. While Raheja et al., (2001) obtained negative estimates of sire variances by ANOVA and MINQUE methods in Murrah buffaloes. The ANOVA based methods i.e. ANOVA and MINQUE can result into negative estimates of sire variances unlike to the ML and REML. The negative estimates of variance components may be either due to sampling variance or model was not able to explain total variance (Smith and Savage, 1992).

The error variance obtained by ANOVA and MINQUE methods was higher as compared to ML and REML in most of the traits. However, differences among variances obtained for different traits by different methods were not significant, statistically. The homogeneity test revealed that sire variances obtained for a particular trait by different methods were not statistically different. This was true for all the traits under study, similar to the results of Bilgin et al., (2004). The σ^2 values for AFC, FLMY, FPY, FLL, FDP, FSP and FCI were 1.65, 1.50, 1.20, 0.075, 3.75, 0.077 and 1.83 respectively.

The equality of two variances obtained for a particular trait by two different methods in all possible combinations was tested by procedure of Snedecor and Cochran (1967). The test revealed that none of the two variances obtained for a particular trait was statistically different and this was true for all the traits under study. The F values ranged from 1.02 to 1.28 for AFC, 1.02 to 1.43 for FLMY, 1.04 to 1.42 for FPY, 1.02 to 1.06 for FLL, 1.01 to 1.59 for FDP, 1.05 to 1.47 for FSP and 1.02 to 1.25 for FCI.

Both the tests revealed that variance components obtained by ANOVA, MINQUE, ML and REML procedures were not statistically different for all the traits under study. The ratio of sire and error variances in all cases was less than 0.15 for all the traits by all the four methods (table-1). Swalllow and Monahen (1984) reported that ML estimates of sire variance have downward bias

Table 1. Sire and error variances, ratio of sire and error variance and heritability with standard error for different first lactation traits of Sahiwal cattle by different methods

Trait/Method	Sire variance	Error variance	Sire/Error variance	Heritability	Standard error
Age at first calving					
MINQUE	1364.8420	27277.8010	.0500	.1908	.0031
ANOVA	1613.0290	26332.7310	.0613	.2308	.0033
ML	1670.1850	27334.8160	.0634	.2384	.0034
REML	1742.2517	26334.1020	.0662	.2484	.0034
First lactation milk yield					
MINQUE	9389.6950	113386.6140	.0828	.3060	.0038
ANOVA	12462.8120	110461.0910	.1128	.4056	.0043
ML	12707.6160	110573.4450	.1149	.4124	.0043
REML	13432.2760	110564.6500	.1215	.4332	.0044
First Peak milk yield					
MINQUE	30.0220	299.1280	.1004	.3618	.0041
ANOVA	36.8155	286.1940	.1286	.4560	.0045
ML	40.9475	287.1440	.1426	.4992	.0047
REML	42.6340	287.0860	.1485	.5172	.0048
First lactation length					
MINQUE	239.6255	2524.3480	.0949	.3468	.0040
ANOVA	224.2195	2553.6810	.0878	.3228	.0039
ML	209.8060	2557.4520	.0820	.3032	.0037
REML	220.3050	2557.2620	.0861	.3172	.0038
First dry period					
MINQUE	626.0210	10355.2160	.0605	.2280	.0033
ANOVA	418.2430	10553.0150	.0396	.1524	.0029
ML	393.8840	10499.4520	.0375	.1448	.0028
REML	424.5050	10503.4290	.0404	.1552	.0029
First service period					
MINQUE	1194.9630	11706.8580	.1021	.3704	.0041
ANOVA	907.0690	11980.9250	.0757	.2816	.0036
ML	810.2960	11922.1660	.0680	.2544	.0035
REML	858.0290	11925.9640	.0719	.2684	.0036
First calving interval					
MINQUE	997.7500	12775.2540	.0781	.2896	.0037
ANOVA	869.5380	12897.3090	.0674	.2528	.0035
ML	796.3920	12868.9220	.0619	.2332	.0034
REML	849.9400	12870.8100	.0660	.2476	.0034

which may be larger when ratio of sire and error variance is more than 0.5. But when it is less than 0.5, the ML estimators of sire variance have small bias, low MSE and are the preferred estimator. It indicated that in the present study estimates of sire variances by likelihood procedures may be of choice.

The heritability estimates are population and time specific. They depend largely on environmental effects. Different workers reported different estimates of heritability for same trait by same method. The h^2 estimates for AFC ranged from 0.1908 to 0.2484 by different methods. The estimates were in close agreement with the reports of Tomar et al., (1974) and lower than Gandhi and Gurnani (1995). Choudhary et al., (2003) and Kothekar et al., (2004) reported higher estimates of h^2 for AFC in Sahiwal cows using ANOVA, ML and REML procedures. But standard error (SE) of the estimate was higher than the present study in said reports. A considerable amount of additive genetic variance with respect to AFC was observed in the present study which will help in selection for the genetic improvement.

The heritability estimates of FLMY ranged from 0.3060 to 0.4332 by the four methods used in the study. Among the four methods REML procedure yielded higher estimates and MINQUE lowest. The SE of heritability in all four methods was almost similar. The estimates obtained in the present study were within the range obtained by Taneja et al., (1978) and Yadav et al., (1992). The lower estimates as compared to the present study were reported by Gandhi and Gurnani (1995). The ML and REML estimates of heritability obtained in the study were higher than the reports of Choudhary et al., (2003) and Kothekar et al., (2004). Higher estimates of heritability for FLMY indicated that trait can be improved through direct selection.

Estimates of heritability for FPY ranged from 0.3618 to 0.5172 by different methods. Lower estimate for this trait (0.15+0.10) was reported by Yadav et al., (1992). The FPY is an important trait which appeared in early stage of lactation and had high genetic correlation with lactation milk yield, the trait of interest. The high estimates of heritability of this trait suggested that it should be considered in selection of animals.

The heritability estimates for FLL ranged from 0.3032 to 0.3468 with SE from 0.0037 to 0.0040. Similar estimates were reported by Gandhi and Gurnani (1995) and lower by Taneja et al., (1978), Reddy and Nagarcenkar (1989), Choudhary et al., (2003) and Kothekar et al., (2004). In the present study a good amount of additive genetic variance was observed with respect to FLL.

The ML and REML procedures resulted heritability estimates with lower SE for FDP as compared to ANOVA and MINQUE. The estimates ranged from 0.1448 to 0.1552, similar to the reports of Taneja et al., (1978). Lower estimate of heritability for this trait was observed by Reddy and Nagarcenkar (1989).

The MINQUE method resulted high estimate of heritability of FSP as 0.3704+ 0.0041 as compared to other methods. The estimates were in close agreement with the reports of Kothekar et al., (2004) and higher than the reports of Taneja et al., (1978) and Reddy and Nagarcenkar (1989).

First calving interval (FCI) is an important trait which decided economy of the animal. It has a major role in selection of cows. The heritability estimates for FCI ranged from 0.2332 to 0.2896 by different methods. Lower estimates of heritability of this trait were reported by Taneja et al., (1978), Reddy and Nagarcenkar (1989) and Gandhi and Gurnani (1995).

Pundir and Raheja (1993) estimated heritability of different first lactation performance traits of Sahiwal cattle using Multi Trait Maximum Likelihood procedure (Scaffer, 1986). Estimates reported for AFC, FLMY, FLL, FDP, FSP and FCI were lower than the present study.

The estimates of heritability obtained by REML were higher than the ML due to higher error variance resulted by ML method. Higher error variance in ML method resulted as it did not account for the loss of degree of freedom for fixed effects in estimation of error variance (Patterson and Thompson, 1971). As the number of fixed effects increased, this bias also increased. This bias can be overcome by using REML as it combines properties of ML witch accounts for loss of degree of freedom. The ML and REML procedures give parameters within space, but estimates are biased. The ANOVA based method ANOVA and MINQUE resulted unbiased estimates but some time they give negative estimates of sire variance and parameters out of the space which is not desirable.

CONCLUSIONS

In the present study a considerable amount of additive genetic variance with respect to different first lactation performance traits was observed which help in selection and genetic improvement. The variance components obtained by different methods of estimation of variance components i. e. ANOVA, MINQUE, ML and REML were not different, statistically as concluded by different tests. By looking the properties of different estimates by different methods it may be concluded that likelihood methods (ML and REML) may be given the priority for estimation of variance components over the ANOVA based (ANOVA and MINQUE) methods.

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