Genetic Parameters of Milk Yield and Adjustment for Age at Calving in Nili-Ravi Buffaloes

M. S. Khan[1], G. E. Shook[2], A. A. Asghar[3], M. A. Chaudhary[3] and R. E. Mcdowell[4]
Department of Animal Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan

ABSTRACT : Data were from four institutional herds and four field data collection centers involved in a progeny testing program for Nili-Ravi buffaloes in Pakistan. The REML with a single trait animal model, employed on 2,353 lactations, from 901 daughters of 66 sires, gave a heritability estimate of 0.18 for milk yield with repeatability (between lactations) of 0.43. Estimated milk yield was highest at 65 months of age for the first parity and 81 months for later parities. Correction factors for age at calving, standardized to 60 months in the second and later parities, were developed.
(**Key Words**: Buffaloes, Genetic Parameters, Milk Yield, Calving Age, Animal Model)

INTRODUCTION

Water buffalo contributes greatly to the availability of animal protein in many developing areas of Asia and Africa. Low productivity per animal does not reflect the potential of this species. For example, nineteen million buffaloes mostly owned by small farmers produce 70% of the total milk supply and 25% of the total meat produced in Pakistan (FAO, 1994). Nili-Ravi is one of the highest milk producing breeds of buffalo. It is raised in central part of the Punjab province of Pakistan and has been incorporated as a vital component of the sustainable integrated farming system. Pressure to increase milk production from buffalo through selection is increasing with increasing human population.

Genetic studies on this animal are limited due to less developed recording systems in villages where the majority of buffaloes reside. A progeny testing program in this breed, which started in 1979, was initially limited to government farms. In 1985, the program was extended to include private farms, selected village populations, and military farms (Asghar, 1987). Utilization of these progeny test data for genetic evaluation of the animals require estimates of genetic parameters and adjustment factors for age at calving and lactation length.

Most estimates of genetic parameters available for buffalo populations involve small data from institutional herds and least squares estimation procedures (Tulloh and Holmes, 1992). Some recent studies have used BLUP procedures for the estimation of genetic and environmental (co) variances. Cady et al. (1983) used Henderson's Method 1 for estimating heritability of milk yield in Nili-Ravi buffaloes using records from two institutional herds in Pakistan. Sire variance decreased as minimum record length increased. Heritability estimates for >60, >250 and 300 days in lactation were .25, .18 and .07, respec-tively. Repeatability estimates had a similar trend: .31, .28 and .24 for the three data sets, respectively. Salah-ud-Din (1989) analyzed performance records of Nili-Ravi buffaloes from two military farms using mixed model methodology (Harvey, 1987). Milk yield had 6% heri-tability with repeatability of 41%. In Indian buffaloes, Raheja (1992a, 1992b) used REML procedures, ignoring relationships, to estimate genetic (co) variances. Estimates of heritability ranged from .21 to .28 with repeatability from .43 to .52 for the 1st three lactations. So far, the only estimate for heritability of milk yield in buffaloes employing animal model is available for Italian buffaloes. Pilla and Moioli (1992) reported animal model evaluation of buffaloes for milk yield. Data on 9,409 Italian buffaloes were used. For total and standard (270-day) lactations, heritability of milk yield was .28 and .27. Repeatability estimate was. 47 in both cases.

The purpose of this study was to estimate heritability and repeatability of milk yield under an animal model and to develop factors to adjust milk yield records for age at calving.

[1] Address reprint requests to M. S. Khan.
[2] Department of Dairy Science, University of Wisconsin, Madison, USA.
[3] Livestock Production and Research Institute, Bahadurnagar (Okara), Pakistan.
[4] North Carolina State University, Raleigh, USA.
Received October 28, 1996; Accepted December 26, 1996

MATERIALS AND METHODS

Data for this study were from Nili-Ravi buffaloes at the Livestock Prduction and Research Institute, Bahadurnagar, Okara District, Pakistan. Data on the daughters of the bulls being progeny tested were also available from three other institutional herds and four field data collection centers (progressive private farms and village populations) involved in the project. A total of 3,892 lactations of 1,235 buffaloes were recorded. Records were edited to remove those lactations that ended by abortion or sickness. Lactations in which the first part of lactation was not recorded or the lactation length was less than 180 days also were not included. Dates of birth of the offsprings were matched with the dates of calving of the dams to confirm the pedigrees where possible. Most buffaloes in the field data and some purchased buffaloes in the farm data did not have date of birth and were not used in the analyses. After editing, 2,353 lactations from 901 daughters of 66 sires had information on milk yield, lactation length and age at calving. The single trait linear model was

$$\mathbf{Y} = \mathbf{X b} + \mathbf{Z}_1 \mathbf{a} + \mathbf{Z}_2 \mathbf{P} + \mathbf{e}$$

where **Y** is a vector of observations of unadjusted milk yield; **b** is vector of fixed effects; **a**, **p**, and **e** are random animal, permanent environmental and temporary environmental effects; **X**, $\mathbf{Z}_1$ and $\mathbf{Z}_2$ are incidence matrices for vectors **b**, **a**, and **p**. Fixed effects included two parity groups (1st or later parities), 89 herd-year-season combinations, and covariables of age at calving and lactation length. Linear and quadratic regression coefficients were estimated for deviations of age at calving from 60-months, and days in milk from 305-days, both for 1st and 2nd parity groups. Estimation of effects for age and lactation length through regression, was due to the limited number of observations for specific ages and stages of lactation.

Eight different populations, four institutional herds and four data collection centers were considered as herds. November through April was designated as one season and May through October the other. Grouping of months into seasons in this study was based on the minimum error variance [$\sigma^2_e = \sum (y_i - \hat{y})^2 / (n-p)$, where n is number of observations and p is the number of parameters; $(y_i - \hat{y})$ is difference between observed and predicted values of milk yield] of the fitted model (Khan, 1994). This was different than most commonly used four season (spring, summer, autumn and winter) scenario (Khan, 1986; Salah-ud-Din, 1989; Shah et al., 1989). The combinations of months was slightly different from that used by Cady et al. (1983) who used grouping (April through September as hot weather and October through March as cool weather) to take into account the difference in number of observations in addition to seasonal differences. Expectations and variances for random effects were assumed to be: **A** and **I** are additive relationship and identity matrices; σ^2_a, σ^2_p, and σ^2_e are additive genetic, permanent environmental, and residual variances; q_1, q_2 and N are 1,030, 901, and 2,353.

$$E\begin{bmatrix} a \\ p \\ e \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad Var\begin{bmatrix} a \\ p \\ e \end{bmatrix} = \begin{bmatrix} A_{q1}\sigma^2_a & 0 & 0 \\ 0 & I_{q2}\sigma^2_p & 0 \\ 0 & 0 & I_N\sigma^2_e \end{bmatrix}$$

For the relationship matrix, when one or both parents of any buffalo with a production record were missing, phantom parents were assigned which were assumed to be average representatives of the genetic groups of similar animals selected to be parents at the same time (Westell and Van Vleck, 1987). The time period for the genetic groups was defined by subtracting the average generation interval from the year of birth of the animal with the missing parent to estimate the year of birth of the missing parent. The generation intervals used were calculated from these data for four selection paths, i. e., sire to sire, sire to dam, dam to sire and dam to dam and were 7.4, 6.6, 9.6 and 6.9 years, respectively. A single trait restricted maximum likelihood (REML) program using a sparse matrix solver (Misztal, 1992) was used for the variance component estimation.

Results from the single trait model were used to obtain correction factors to adjust age at calving to 60 months in second and later parities. The correction factors for adjusting age at calving to 60 months of age in second parity group were developed using the following equation:

$$F_{ij} = k_2 / (k_i + c_{ij}) \quad \cdots\cdots\cdots\cdots \quad [1]$$

where F_{ij} is correction factor for level j of age at calving in parity group i, c_{ij} is estimate of age effect at level j within parity group i, k_2 is constant for parity group 2, and k_i is constant for parity group i and is calculated as follows:

$$k_i = (\hat{\mu} + \hat{g}_i) + \hat{hys} + \hat{a} \quad [2]$$

where $\hat{\mu}$ is estimate of overall mean, $\hat{g}_i$ is estimate for parity group i, $\hat{hys}$ is average estimate for herd-year-seasons, $\hat{a}$ is average estimate of breeding values.

RESULTS AND DISCUSSION

Genetic parameter estimates

Milk yield averaged 2,013 ± 597 kg for the first parity and 2,173 ± 731 kg for the second and later parity buffaloes. The average lactation length for the two groups was 285 and 281 days, respectively. Standard deviations for breeding values, permanent environment, and temporary environment were 219, 257, and 391 kg, respectively. Milk yield adjusted for lactation length and age at calving had heritability of 0.18 and a repeatability of 0.43. The values for these parameters are within the range of estimates reported for buffaloes (Tulloh and Holmes, 1992). Milk yield was 10-15% heritable in Egyptian buffaloes (Mohamed et al., 1993; Metry et al., 1994) and 17-18% in Indian buffaloes (Cheema and Basu, 1991; Tailor et al., 1992a). Both, higher and lower estimates have also been reported for these breeds in other studies. Heritability is higher than reported by Salah-ud-Din (1989) for Nili-Ravi buffaloes in Pakistan. In that study lactation length of >150 days was considered as the production potential of buffaloes and thus no adjustments were made for records with lactation length between 150 and 300 days. The estimate is, however, similar to that (.179) reported by Cady et al. (1983) for milk yield of >250 days of lactation duration. Estimates of heritability under the animal model are expected to be higher than sire models (Misztal et al., 1992). Inclusion of records from field data collection centers in the present study may have inflated the proportion of environmental variance causing lower heritability estimates.

The repeatability estimate of milk yield was higher than that reported by Cady et al. (1983) but the same as that reported by Salah-ud-Din (1989) for Pakistani buffaloes. The estimates are also similar to some of reports on Indian buffaloes (Ulaganathan et al., 1983; Raheja, 1992a). Ashmawy (1991) reported repeatability of milk yield to be .48 for Egyptian buffaloes while the estimate was .47 for Italian buffaloes in the animal model study of Pilla and Moioli (1992).

Age at calving adjustment

Average age at first calving was 48.8 ± 9.0 months, the range being 27 to 84 months. Out of 855 first lactations, 9.4% had >60 months of age at calving. For second and later parities, average was 99.78 ± 33.6 months, ranging from 44 to 226 months. Only 7% of animals in second parity calved before 60 months of age.

Average at first calving in this study is similar to other reports on Nili-Ravi buffaloes in Pakistan (Cady et al., 1983, Salah-ud-Din, 1989) but is higher than some of the other breeds of buffaloes. Average age at first calving was reported to be 40 months for Murrah buffaloes by Singh and Rathi (1990) but Yadav et al. (1983) reported 54 months for the same breed. Prakash et al. (1988) on the other hand reported average to be 43 months. For Egyptian buffaloes, age at first calving is lower than most of the breeds of buffaloes raised for milk production. Average age at first calving was 38 and 41 months in two recent reports on Egyptian buffaloes (Mohamed et al., 1993; Metry et al., 1994). Genetic differences among breeds do exist for this trait, but nutritional and managemental factors are also responsible for the breed differences. Mostly the sample size is low and data editing can exaggerate these differences.

The linear and quadratic estimates of regression of milk yield on age at calving deviated from 60 months (age-60) were 2.8941 and −0.3050 kg for first parity group, respectively and 1.5886 and −0.0374 kg for 2nd and later parity group, respectively. Estimates for the first parity were higher than those of the second and later parities. Figure 1 shows the relationship between age at calving and milk yield. Estimated milk yield varied from 1,740 kg for buffaloes calving at 27 months of age to 2,175 kg for those calving for the first time at 65 months. For the later lactations, minimum estimated yield (1,590 kg) was for those calving at the age of 226 months while maximum (2,418 kg) was for those calving at 81 months of age. Predicted yield (2,401 kg) for cows calving in second and later parities at 60 months of age (k_2) was chosen as base for developing correction factors for age at calving.

Choice of 60 months as base age was due to simplicity and its correspondence to the end of first lactation when most of the selection decisions of buffaloes can be taken. Also, it was an age observed both in the first and second parity groups. This avoids extrapolation to an age which was not observed in the data. Choice of age of highest production (mature equivalent) would be unrealistic because most of the animals do not produce to that age (Miller, 1973). Adjustment to average age at first calving, average for all calvings or age of average yield could have been some of the other options. Because ranking of animals is not affected by the choice of base age, choice of a base is arbitrary. A younger age base lowers the frequency and magnitude of adjustments of lactation records for selection purposes (McDaniel, 1973).

Correction factors to adjust milk yields to 60 months of age in the second and later parities were developed. Maximum adjustment in the first parity was 661 kg (38%) of milk for buffaloes calving earliest while minimum credit (10%) was given to those calving around 60-65 months of age in this parity group. For later parities, the maximum adjustment was 766 kg of milk (47%) for the oldest buffaloes. Only those calving after 161 months of age got credit for 10% or more for adjusting their records to 60 months in parity group 2. Estimated yields for age at 60 months for the first and later parities were 2,168 and 2,401 kg, respectively.

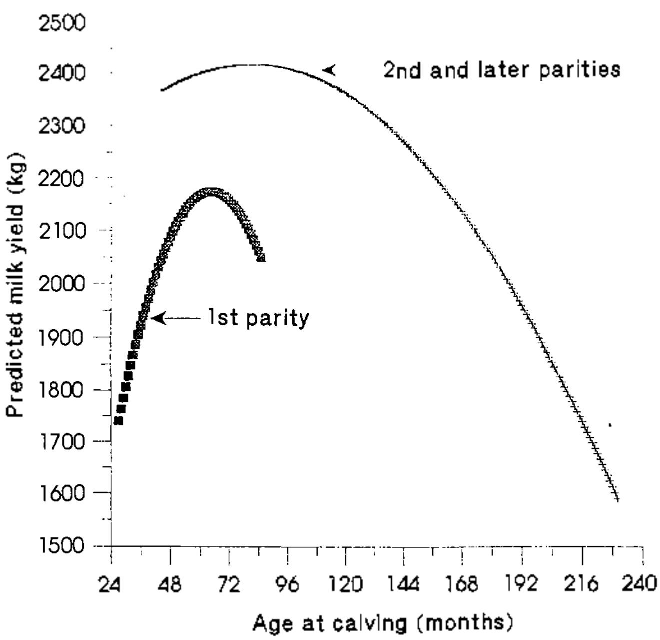

Figure 1. Predicted milk yield by parity group and age at calving.

Comparison of these factors with other studies on buffaloes must be made indirectly becaues of differences in methodology and the choice of different base ages. Records were adjusted to 300 day and base age was 127 months in the study of Salah-ud-Din (1989). If the age base was same as in present study, i. e. 60 months, correction fators in the study of Salah-ud-Din (1989) would be lower for the first parity before 60 months of age but higher when age at calving was >60 months. For the later parity group, this trend would be reversed, i. e., factors would be higher before 60 months and lower after 60 months when compared with factors in the present study. Fourth degree polynomial for first parity and second degree polynomial regression equations for later parities were used in estimating milk yield by Salah-ud-Din (1989). Estimated milk yield at 60 months of age was 1,561 kg for first parity and 1,833 kg for later parities. Duration of lactation and environmental and genetic factors affecting lactation milk yield were ignored in developing the regression equations for age adjustment (Salah-ud-Din, 1989). These may be some of the factors responsible for different behaviour and extent of differences between the two studies. Khan (1986) reported single regression factors (for first and later parities) for adjusting records to mature age. Milk yield was reported to increase by 6.55 kg for each month increase in age at calving until the age of maximum production (88-90 months) correponding to third parity. The decline thereafter was .26 kg for each month increase in age at calving. Records of lactation length between 180 and 305 days were not corrected for lactation length while records of >305 days were reportedly corrected for developing the regression equation. Estimated yield would be 2,047 kg for buffaloes calving at 60 months of age by the reported regression equation which is less than the estimated yield at this age both for first and later parity groups in the present study.

CONCLUSIONS

Estimated milk yield was maximum at 65 months of age for first parity and 81 months for later parities. Milk yield was adjusted to 60 months of age in second and later parities. Choice of base age of 60 months was due to its simplicity and has the advantage of occurring both in first and later parity groups. Milk yield was moderately heritable (0.18) with repeatability estimate of 0.43. As the recording systems in buffalo expand and more herds are involved in the future, estimates of genetic parameters and correction factors can be calculated from larger data sets. More extensive and precise recording at the national level and development of a national data base is suggested for future studies.

ACKNOWLEDGEMENTS

The authors thank Mr. Muhammad Khalil Ahmad, Director, Livestock Production and Research Institute, Bahadurnagar (Okara) Pakistan for permitting the use of data. Appreciation is extended to Dr. Ignacy Misztal for making the computer program available.

REFERENCES

Asghar, A. A. 1987. Studies required for progeny tested bulls to improve buffalo milk production in Punjab. 3rd. Ann. Rep. (1986-87). Livest. Prod. Res. Inst. Bahadurnagar, Okara, Pakistan.

Ashmawy, A. A. 1991. Repeatability of productive traits in Egyptian buffaloes. J. Anim. Breed. Genet. 108:182.

Cady, R. A., S. K. Shah, E. C. Schermerhorn, and R. E. McDowell. 1983. Factors affecting performance of Nili-Ravi buffaloes in Pakistan. J. Dairy Sci. 66:578.

Cheema, J. S., and S. B. Basu. 1991. Factors affecting the components of gamma-type lactation curve in Murrah buffaloes. Indian J. Dairy Sci. 44:137.

FAO. 1994. FAO Production Yearbook. Vol. 47. FAO, Rome.

Harvey, W. R. 1987. User's guide for LSMLMW, mixed model least squares and maximum likelihood computer program. The Ohio State Univ., Columbus.

Khan, M. A. 1986. Genetic analysis of a purebred herd of Nili-Ravi buffalo. Ph. D. Diss., Univ. Agri., Faisalabad (Pakistan).

Khan, M. S. 1994. Adjustment of lactation records for lactation length and age at calving in Nili-Ravi buffaloes and Holstein Cattle. Ph. D. Diss., University of Wisconsin, Madison (USA).

McDaniel, B. T. 1973. Merits and problems of adjusting to other than mature age. J. Dairy Sci., 56:959.

Metry, G. H., H. El-Rigalaty, J. C. Wilk, and R. E. McDowell. 1994. Environmental and genetic factors affecting multiple lactations in Egyptian buffaloes. Trop. Agric. (personnel communication).

Miller, P. 1973. A recent study of age adjustment. J. Dairy Sci., 56:952.

Misztal, I. 1992. JSPFS. Single trait REML program for animal models using sparse matrix solver. In Program notes. Univ. Illinois, Urbana, IL.

Misztal, I., T. J. Lawlor, T. H. Short, and P. M. VanRaden. 1992. Multiple-trait estimation of variance components of yield and type traits using an animal model. J. Dairy Sci. 75:544.

Mohamed, M., A. M. Kawther, and A. S. Khattab. 1993. Genetic relationship of age and weight at first calving with first lactation milk yield in Egyptian buffaloes. Buffalo Bull. 12:38.

Pilla, A. M., and B. M. Moioli. 1992. Genetic evaluation of buffaloes for milk yield using the animal model. Zoot. Nutr. Anim. 18:207.

Prakash, A., V. N. Tripathi, and S. S. Tomar. 1988. Relative importance of age and weight at calving on milk production in Murrah buffaloes. Indian J. Dairy Sci. 41:129.

Raheja, K. L. 1992a. Comparative study of variance-covariance components of economic traits between different lactations estimated from single and multiple-trait procedures. Indian J. Anim. Sci. 62:467.

Raheja, K. L. 1992b. Selection free estimates of genetic parameters of production and reproduction traits of first three lactations in Murrah buffaloes. Indian J. Anim. Sci. 62:149.

Salah-ud-Din. 1989. The genetic analysis of production and reproduction traits in Nili-Ravi buffalo in Pakistan. Ph. D. Diss., The Ohio State Univ., Columbus.

Shah, S. N. H., A. H. Willemse, D. F. M. Van De Wiel, and B. Engel. 1989. Influence of season and parity on several reproductive parameters in Nili-Ravi buffaloes in Pakistan. Anim. Reprod. Sci. 21:177.

Singh, S., and S. S. Rathi. 1990. Relationship among various reproduction and production efficiency traits in Murrah buffaloes. Int. J. Trop. Agri. 8:93.

Tailor, S. P., L. S. Jain, and M. Tusavara. 1992a. Analysis of milk yield, lactation length and dry period in Surti buffaloes. Indian J. Anim. Sci. 62:479.

Tulloh, N. M., and J. H. G. Holmes. 1992. World Animal Science, C6. Buffalo Production. Elsevier, New York, NY.

Ulaganathan, V., K. Venkatarajulu, and S. Balachandran. 1983. Estimation of breeding values in Murrah buffaloes by maximum likelihood method with adjustment for season of calvings. Trop. Vet. Anim. Res. 1:33.

Westell, R. A., and L. D. Van Vleck. 1987. Simultaneous genetic evaluation of sires and cows for a large population of dairy cattle. J. Dairy Sci. 70:1006.

Yadav, K. N., S. S. Rathi, S. Ram, and R. Singh. 1983. Estimates of genetic and phenotypic trends in Murrah buffaloes under progeny testing programme. Indian J. Dairy Sci. 36:330.