ESTIMATES OF PHENOTYPIC AND GENETIC PARAMETERS FOR WEANING AND YEARLING WEIGHTS IN BALI BEEF CATTLE

Y. Djegho[1], H. T. Blair[2] and D. J. Garrick

Department of Animal Science, Massey University,
Palmerston North, New Zealand

Summary

Records on weaning (3803) and yearling weight (2990) of beef cattle (Bibos banteng) from the Bali Cattle Improvement Project were examined. A mixed model analysis involving all main non-genetic effects (village, year of birth, season of birth, age of dam, sex of calf, all significant interactions and age at weighing as a covariate) as fixed effects and sire nested within village as a random effect was undertaken. Variance components were estimated by Henderson's Method III. Paternal half-sib components of variance and covariance were used to estimate heritabilities of weaning and yearling weights, as well as their genetic and phenotypic correlations. Heritability estimates (± standard error) obtained by Henderson's Method III for weaning and yearling weights were .11 ± .03 and .13 ± .04, respectively while the phenotypic and genetic correlations were estimated as .32 and .64 ± .10, respectively. The parameters estimated in this study were at the lower end of the range of reported values from various breeds. It is concluded that further information should be gathered to assist in estimating genetic parameters for other economic traits of Bali beef cattle and to provide more accurate estimates for weaning and yearling weights. These parameters should then be used to formulate a selection program to enable the genetic improvement of Bali Beef cattle.
(**Key Words**: Heritability, Correlation, Weaning/Yearling Weight, Bali Cattle)

Introduction

The main objective of animal genetic improvement is to increase the net profit of farmers through the genetic component of the operation. To achieve this purpose, breeders should identify all economically important traits of the chosen breed for inclusion in the selection objective. Breeds used in the tropic regions should include the native genetic resources which may have been well adapted to environment stresses.

Bali beef cattle that were derived from the wild banteng (Bibos banteng or Bos sondaicus) are popular with Indonesian farmers because of their draught ability, high fertility, ability to thrive under poor conditions (heat, low quality of roughage) and the production of a carcass with good dressing percentage and a low fat content. The Indonesian government decided to improve this tropical native cattle through establishing a Bali Cattle Improvement Project. The objectives of the project are to develop and increase Bali cattle as a valued resource by improving their productivity through genetic selection, and thereby increasing farmer's incomes. Since 1981, New Zealand has participated in the project by assisting with technical developments to identify and utilise superior Bali cattle through performance- and progeny-testing of bulls (Packard, 1983). The information recorded in the program includes the pedigree of all calves, date of calving, and age and weight at weighing for weaning and yearling weight. The reproductive performance of cows is also recorded. The objective is to increase growth rate under the traditional farming system in Indonesia.

A number of studies have reported heritability estimates for weaning and yearling weight and correlations between them for beef cattle. Values of these parameters are generally moderate to high (Schaeffer and Wilton, 1981; Alenda and Martin, 1987; Robinson, 1990). Packard et al. (1990) reported heritability estimates of .15 ± .05 and .31 ± .08 for weaning weight and yearling

[1]Current address: Department of Agriculture, Jln Sanur 175, Denpasar, Bali, Indonesia.

[2]Address reprint requests to Dr. H. T. Blair, Massey University, Palmerston North, New Zealand.

Received September 27, 1991

Accepted May 20, 1992

weight, respectively, based on data from calves born between 1983 and 1987 in the Bali Cattle Improvement Project.

Falconer (1981) suggested that genetic parameters should be derived from the population that is to be improved. The purpose of this study is to estimate the heritabilities of weaning and yearling weight and their phenotypic and genetic correlations in Bali beef cattle.

Materials and Methods

Data collection

Data was collected as part of the Bali Cattle Improvement Project during a five year period from 1983 to 1987. Records were grouped by village, year, season, age of dam and sex of calves. Calves were born throughout the entire year. For the purposes of analysis, each year was divided into a wet season (October-March) and a dry season (April-September). A large proportion (50.0%) of calvings occurred at the end of the dry season i.e. June to September. The oldest dams were 7 years, as selected heifers were first mated at 18 to 24 months and were used for a maximum of 5 years. Sires were selected on the basis of growth rate from weaning to rising two year old and were only used in one village for up to two years. Therefore, it was not possible to compare villages due to the lack of genetic links.

TABLE 1. NUMBER OF RECORDS IN EACH CLASS OF THE NON-GENETIC EFFECTS FOR WEANING WEIGHT AND YEARLING WEIGHT

Classes		Weaning weight	Yearling weight
Year	1983	1201	1127
	1984	1049	707
	1985	666	434
	1986	496	487
	1987	390	235
Season	Dry	2523	2057
	Wet	1279	933
Dam age	2 year	128	108
	3 year	1068	897
	>3 year	2606	1985
Sex	Bull	1966	1564
	Heifer	1836	1426

Weaning weights of calves were recorded at a mean age of 205 days (range from 135 to 275 days) while yearling weights were recorded at an average age of 365 days (range from 276 to 455 days). 3803 paternal half-sib records from 98 sires and 2990 records from 87 sires were used to estimate the heritability of weaning and yearling weight, respectively. There were 2679 records from 87 sires available to examine the phenotypic and genetic correlation between these traits. The number of records in each class of non-genetic groups (year, season, dam age and sex) for weaning and yearling weight is shown in table 1. The reason for the decline in the number of records per year between 1983 and 1987 is that reduced publicity about the benefits of the project apparently resulted in fewer cows being mated to bulls from the scheme (P.M. Packard, pers. comm.). The number of records per village ranged from 30 to 393.

Statistical analysis

A preliminary analysis was conducted to examine non-genetic effects and their first order interaction effects. Age of dam was classified into 3 groups (2, 3 and more than 3 years at calving). All non-significant interaction effects ($p > 0.05$) were excluded from the model.

A mixed linear model analysis for weaning weight including all main effects (village ($n = 24$), year of birth, season of birth, age of dam and sex of calf), significant interactions from the preliminary analysis (village by year, village by season, year by season, year by calf sex, dam age by season and dam age by sex of the calf) as fixed effects, age of the calf as a covariate and sire nested within village as a random effect was fitted. For yearling weight, the mixed model included the same main effects as for weaning weight and interactions of village by year, village by season of birth, village by age of dam, village by sex of the calf, sex by year of birth, sex by age of dam and season of birth by age of dam. In both models sire and error terms were assumed to be uncorrelated random variables with zero means.

The sire nested within village and residual variance components were derived using Henderson's Method III (Henderson, 1953). Mean squares of sire nested within village were generated using the ANOVA procedure of the SAS computing package (SAS, 1985). Sire variance components were obtained by equating the sire (nested within village) mean square to its expected value. Covariance components were calculated from analysis of the sum of weaning and yearling weight records for each individual. REML estimates of the variance components were also derived using the VARCOMP procedure of the SAS computing package.

Heritabilities, genetic and phenotypic correlation and their standard errors (except for the phenotypic correlation) were estimated from paternal half-sib analysis following Becker (1984). The significance of the phenotypic correlation was tested using critical values originally derived by R. A. Fisher and cited by Snedecor and Cochran (1967).

Results

Non-genetic effects

Several of the first-order interactions amongst main effects were statistically significant for both weaning and yearling weight (see Materials and Methods section). In the presence of interactions, main effects least squares means (LSM) are not informative. However, to convey the magnitude of liveweights, the mean values (± standard errors) of weaning weight and yearling weight (adjusted for year and dam age) were 89.8 ± .5 kg (bull), 80.5 ± .5 kg (heifer) and 145.5 ± .8 kg (bull) and 130.9 ± .8 kg (heifer), respectively. Mean weaning weights and yearling weights by village contemporary groups ranged from 79.4 ± 1.2 kg to 94.4 ± 1.1 kg and from 124.1 ± 1.7 kg to 153.8 + 1.7 kg, respectively. The linear models containing the fixed main effects, their interactions and the covariate of weight on age resulted in R^2 values of 67% and 62% for weaning and yearling weight, respectively. The regressions of weight on age yielded coefficents of .30 kg/day and .20 kg/day for weaning weight and yearling, respectively.

Heritabilities and correlations

Phenotypic standard deviations for weaning and yearling weight were 19.2 kg and 22.4 kg, respectively. Paternal half-sib estimates of heritabilities for weaning and yearling weight by Henderson's Method III are shown in table 2. The genetic correlation between weaning and yearling weight was highly positive with the phenotypic correlation between the two traits also being positive but smaller than the comparable genetic correlation (table 2).

TABLE 2. PATERNAL HALF-SIB ESTIMATES OF HERITABILITIES ± STANDARD ERRORS FOR WEANING WEIGHT (WW) AND YEARLING WEIGHT (YW) (DIAGONAL) AND THEIR GENETIC (ABOVE DIAGONAL) AND PHENOTYPIC CORRELATIONS (BELOW)

Traits	Henderson's Method III	
	WW	YW
Weaning weight (WW)	.11±.03	.64+.10
Yearling weight (YW)	.32**	.13±.04

** $p < .01$.

Discussion

Non-genetic effects

Age at weighing as a linear covariate has a highly significant effect on both weaning and yearling weight of Bali cattle in the present study. Age at weighing controls the largest proportion of variation in both weaning and yearling weight. Most other studies have also indicated that age at weaning has a significant effect on weaning weight (Nicoll and Rae, 1977; Barlow and Dettman, 1978; Buvanendran, 1990) and post-weaning weight (Baker et al., 1974; Nicoll and Rae, 1977).

Both weaning and yearling weight of Bali cattle were significantly affected by various interactions between the non-genetic effects. The most likely explanation of these interactions is the different yearly management among villages and the possibility of different seasonal distribution of rainfall between years in the region. Several studies have indicated that herd might interact with year of birth and significantly affect beef cattle weaning and post-weaning weight (Trail et al., 1985). Furthermore, there may be preferential treatment of different classes of stocks.

Several studies have reported the interactions between year of birth by sex of the calf on weaning weight (Baker et al., 1974; Buvanendran, 1990), post-weaning growth (Tewolde, 1988) and of sex by age of dam on weaning weights (Baker et al., 1974; Sharma et al., 1982).

The presence of several significant non-genetic effects, and interactions amongst those effects, emphasises the need for an effective recording scheme. All weaning and yearling weights should be adjusted for these effects when attempting to rank animals based on their genotype, thereby increasing the accuracy of selection and enhancing the rate of genetic gain.

Heritabilities

The heritability estimates for weaning weight and yearling weight in the present study tend toward the lower values quoted in the literature. The heritability estimates from this study are lower than the average of values from *Bos indicus* breeds reviewed by Plasse (1978 and 1979), which were .28 and .51 for weaning and yearling weight, respectively. The heritability estimate for weaning weight obtained in this study (.11) is in close agreement with the value (.15) reported by Packard et al. (1990). However, the estimate for yearling weight (.13) is substantially smaller than the value (.31) of Packard et al. (1990). When the village by year interaction is included in the model used by Packard et al. (1990), the yearling weight heritability reduces to .14 (D. L. Johnson, *pers comm*). Clearly, the inclusion of the village by year interaction causes a marked reduction in the between-sire variance. Since sires were nested within village, it is likely that the village by year interaction includes a genetic component. Thus, the heritability estimate for yearling weight of .13 found in this study is likely to be an underestimate of the true heritability, while the value of .31 reported by Packard et al. (1990) is probably an overestimate. The structure of the data (sires nested within village and small numbers of observations in sub-groups) has made it difficult to select an appropriate linear model. Accordingly, consideration should be given to using sires across several villages to provide genetic links between locations. This could be achieved through natural mating by following the procedures used in ram circles in Norway (Steine, 1982). By interchanging bulls between "circles" they too could be linked. In addition, administrators of the Bali Cattle Improvement Project must encourage the collection of as many records as possible in each village to ensure that sub-group numbers are near the maximum possible. In the absence of larger subgroup numbers, the removal of effects such as village by calf sex interactions by statistical methods will be inefficient, thereby resulting in less accurate estimates of the genetic parameters.

A further explanation of the low heritability estimates in the present study is the consequence of large environmental variation. In particular, this would be contributed to by the lack of genetic linkages between villages and the year round calving pattern. Field data often exhibit large environmental variation which result in the heritability estimate being underestimated (Kennedy and Henderson, 1975). Lubout and Swanepoel (1990) reported a low heritability of weaning weight in Sanga cattle due to a large effect of the environment on the performance of animals. Large unexplained environmental effects result in linear models that are inadequate in explaining variation in the data. R-square values of models for weaning and yearling weight in the current analysis are 67% and 62%, respectively. Oni et al. (1989) also found low heritability estimates for body weight in Bunaji cattle and suggested the model was inadequate to explain most of the variation of body weights. A large proportion of unexplained residual variation leads to an inflation of error variance and thus decreases heritability estimates.

Restricted maximum likelihood (REML) estimates of the heritabilities of weaning weight and yearling weight (.13 ± .04 and .17 ± .04, respectively) were similar to those obtained via Henderson's Method III. Other studies have also reported that similar estimates of the parameters yielded by Henderson's Method III and REML would be expected if there was no selection operating on the population (Lin and McAllister, 1984; Hayes and Cue, 1985). Although selection has been operating in the population reported here, it is likely to have had little impact given the short time horizon. Colleau et al. (1989) noted that estimates of genetic parameters and sampling variances provided by Henderson's Method III might be similar to those of REML if the number of progeny per sire was relatively homogeneous. However, REML is the preferred method if selected populations are to be analysed (Henderson, 1986).

Correlations

The positive phenotypic and genetic correlation estimates between weaning and yearling weights in this study were at the lower end of the range of the various literature values (Schaeffer and Wilton, 1981; Alenda and Martin, 1987; Robinson, 1990). The REML estimate of the genetic correlation between these 2 weights (.60 ± .11) was similar to that given by Henderson's Method III. The lower correlation estimates in this study are also likely to be caused by the large environmental variation due to the problems suggested previously. Furthermore, compensatory growth of individuals during the post-weaning stage may cause a downward bias of the phenotypic covariance between weaning and yearling weights (Francoise et al., 1973). DeNise and Torabi (1989) also reported that the phenotypic correlation between weaning and yearling weight might be low in poor conditions due to the stressful environment experienced by animals.

Implications for genetic improvement

Genetic parameters obtained from this study can be utilised to further enhance the selection program in the Bali Cattle Improvement Project. Low heritability estimates for both weaning and yearling weights suggest a need to improve the model specification in an attempt to account for more environmental variation. However, the adequate genetic variation in both weaning and yearling weights indicates that selection for both traits is justifiable. Moreover, the existence of a favourable genetic correlation between the two traits indicates that selection for weaning weight will enhance the improvement in yearling weight of Bali cattle. For future improvement of Bali beef cattle, there is a need to collect information on traits such as birth weight and rising two year old weights, reproduction traits, carcass traits and feed efficiency so their phenotypic and genetic parameters can be estimated. These parameters are needed to establish an appropriate selection objective and to choose selection criteria to enable the genetic improvement of Bali beef cattle.

Literature Cited

Alenda, R. and T. G. Martin. 1987. Genetic parameters and consequences of selection for growth traits in a beef herd selected for yearling weight. J. Anim. Sci. 64:366-372.

Baker, R. L., A. H. Carter, E. H. Cox and H. A. Templer. 1974. Influence of birth date and dam's age on early growth of beef cattle. Proceedings of the New Zealand Society of Animal Production. 34:115-130.

Barlow, R. and E. B. Dettman. 1978. Genetic and phenotypic parameters for pre weaning growth and weaning conformation of Angus cattle. Australian J. Agri. Res. 29:373-379.

Becker, W. A. 1984. Manual of quantitative genetics. Fourth edition. Academic enterprises. Pullman, Washington.

Buvanendran, V. 1990. Adjustment factors for weaning weights of Mashona cattle in Zimbabwe. J. Agri. Sci., Cambridge 114:35-40.

Colleau, J. J., C. Beaumont and D. Recaldo. 1989. Restricted maximum likelihood (REML) estimation of genetic parameters for type traits in Normande cattle breed. Live. Prod. Sci. 23:47-46.

DeNise, S. K. and M. Torabi. 1989. Genetic parameter estimates for postweaning traits of beef cattle in a stressful environment. J. Anim. Sci. 67:2619-2626.

Falconer, D. S. 1981. Introduction to quantitative genetics. Second edition. Longman, London and New York.

Francoise, J. J., D. W. Vogt and J. C. Nolan, Jr. 1973. Heritabilities of and genetic and phenotypic correlations among some economically important traits of beef cattle. J. Anim. Sci. 36:635-639.

Hayes, J. F. and R. I. Cue. 1985. Comparison of achieved responses to selection using multi trait selection indices constructed from parameter estimates obtained by three methods of estimation. Z. Tierz. Zuchtungsbiol. 102:321-330.

Henderson, C. R. 1953. Estimation of variance and covariance components. Biometrics 9:226-252.

Henderson, C. R. 1986. Recent development in variance and covariance estimation. J. Anim. Sci. 63:208-216.

Kennedy, B. W. and C. R. Henderson. 1975. Components of variance of growth traits among Hereford and Aberdeen Angus calves. Canadian J. Anim. Sci. 55:493-502.

Lin, C. Y. and A. J. McAllister. 1984. Monte carlo comparison of four methods for estimation of genetic parameters in the univariate case. J. Dairy Sci. 67:2389-2398.

Lubout, P. C. and F. C. J. Swanepoel. 1990. Genetic parameters of Sanga cattle in developing areas. Proceedings of the Fourth World Congress on Genetics Applied to Livestock Production. XIV: 386-387.

Nicoll, G. B. and A. Rae. 1977. Adjustment factors for Hereford and Angus cattle weights. I. Weight at weaning. New Zealand J. of Agricultural Research. 20:269-278.

Oni, O. O., V. Buvanendran and N. I. Dim. 1989. Estimates of genetic and phenotypic parameters for body weight in Bunaji cattle. Tropical Agriculture, Trinidad. 66:369-371.

Packard, P. M. 1983. The improvement and export potential of Bali cattle (Bos Bibos-banteng). Proceedings, New Zealand Society of Animal Production. 43:183-184.

Packard, P. M., I. Pane and C. A. Morris. 1990. *Improvement programmes for Bali cattle.* Proceedings 5th Asian-Australasian Association of Animal Production. 3:269.

Plasse, D. 1978. Aspectos de Crecimiento del *Bos indicus en el Tropico Americano (primera parte).* World Review of Animal Production. 14(4):29-48.

Plasse, D. 1979. Aspectos de Crecimiento *Bos indicus* en el Tropico Americano (segunda parte). World Review of Animal Production. 15(1)21-38.

Robinson, D. L. 1990. Genetic variances and covariances for live-weight in Queensland beef cattle. Proceedings of the Eighth Conference of Australian Association of Animal Breeding and Genetics: 435-438.

SAS Institute Inc. 1985. SAS user's guide: statistics version 5 edition. Cary. North Carolina.

Schaeffer. L. R. and J. W. Wilton. 1981. Estimation of variances and covariances for use in a multiple trait beef sire estimation model. Canadian J. Anim. *Sci.* 61:531-538.

Sharma, A. K., L. Willms, R. T. Hardin and R. T. Berg. 1982. Sex of calf and age of dam adjustments for some performance traits in two populations of beef cattle. *Canadian J. Anim. Sci.* 65:699-708.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Lowa State University Press, U.S.A. p. 557.

Steine, T. A. 1982. *Fifteen years' experience with a* cooperative sheep breeding scheme in Norway. In: R. A. Barton and W. C. Smith (Eds). Proceedings of the World Congress on Sheep and Beef Cattle *Breeding.* 2:144-148.

Tewelde, A. 1988. Genetic analysis of Romosinuano cattle: selection possibilities for beef in Latin American Tropics. Proceedings of the Third World Congress on Sheep and Beef Cattle Breeding. II: 275-292.

Trail, J. C. M., K. Sowes, J. M. C. Jibbo, J. Durkin, D. E. Light and M. Murray. 1985. Productivity of Boran cattle maintained by chemoprophylaxis under trypanosomiasis risk. International Livestock Centre for Africa. No. 9.