A Predicting Measure for Nursing Ability in Beef Cows

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Preweaning performance, especially weaning weight, is one of the most important factors in determining the economic returns from beef cattle. The performance of a calf is strongly influenced by nursing ability or milking ability of its dam (Neville 1962, Wistrand and Riggs 1966, Robison et al,, 1978).

The maternal contribution is environmental to the offspring, but is genetic in the sense that the genotypic differences among cows are expressed in the phenotypic measurements of their offspring. This indicates that some phenotypic measurements of a calf can be utilized as an indicator for genetic nursing ability of the dam.

The relationships between a phenotypic value of a calf (P_c) and the genotypic value for maternal effect of the dam (G_{md}) are illustrated as shown in Fig.1, using a path diagram. Let P, G and E represent phenotypic, genotypic and environmental values, respectively. The subscripts c, s and d mean the values of a calf, the sire and the dam, respectively. The maternal and non-maternal effects are denoted by m for the maternal and o for the non-maternal. The P_c equals ($P_{oc} + P_{mc}$).

Assuming that P_{oc} equals ($G_{oc} + E_{oc}$) and P_{md} equals ($G_{md} + E_{md}$), the phenotypic value of a calf is

$$\begin{aligned} P_c &= P_{oc} + P_{mc} \\ &= (E_{oc} + G_{oc}) + P_{md} \qquad [\because P_{mc} = P_{md}] \\ &= \tfrac{1}{2}G_{os} + \tfrac{1}{2}G_{od} + G_{md} + E_{oc} + E_{md} \quad \cdots\cdots \text{(1)}. \end{aligned}$$

Then, the phenotypic variance of P_c and the covariance between G_{md} and P_c are written as:

$$\begin{aligned} \mathrm{Var}(P_c) &= \left\{\tfrac{1}{4}\sigma_{Gos}^2\right\} + \left\{\tfrac{1}{4}\sigma_{God}^2 + \sigma_{Gmd}^2 + \sigma_{GmdGod}\right\} + \left\{\tfrac{1}{2}\sigma_{GosGod} + \sigma_{Eoc}^2 + \sigma_{Emd}^2\right\} \\ &= \hat{\sigma}_S^2 + \hat{\sigma}_D^2 + \hat{\sigma}_E^2 \quad \cdots\cdots \text{(2)} \end{aligned}$$

$$\mathrm{Cov}(G_{md}, P_c) = \tfrac{1}{2}\sigma_{GmdGod} + \sigma_{Gmd}^2 \quad \cdots\cdots \text{(3)},$$

respectively. The σ_G's^2 and σ_E's^2 are the theoretical causal components for the genotypic and environmental values, respectively. On the other hand, the $\hat{\sigma}$'s^2 in equation (2) are the variance components in ANOVA table computed from data. The σ_{GmdGod} is the covariance between genotypic values for growth and maternal effects. Therefore, regression coefficient of G_{md} on P_c is given from (2) and (3) by:

$$b_{Gmd \cdot Pc} = \frac{\mathrm{Cov}(G_{md}, P_c)}{\mathrm{Var}(P_c)} = \frac{\tfrac{1}{2}\sigma_{GmdGod} + \sigma_{Gmd}^2}{\hat{\sigma}_D^2 + \hat{\sigma}_S^2 + \hat{\sigma}_E^2} \qquad \text{(4)}.$$

The numerator can be rewritten as:

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$$\frac{1}{4}\sigma_{God}^2 + \sigma_{Gmd}^2 + \sigma_{GmdGod} - \frac{1}{4}\sigma_{Gos}^2 - \frac{1}{2}\sigma_{GmdGod} \quad \text{------- (5).}$$

Then from (2) and (5),

$$b_{Gmd \cdot Pc} = \frac{\hat{\sigma}_D^2 - \hat{\sigma}_S^2 - \frac{1}{2}\sigma_{GmdGod}}{\hat{\sigma}_D^2 + \hat{\sigma}_S^2 + \hat{\sigma}_E^2} \quad \text{------ (6).}$$

Estimates of σ_{GmdGod} reported for weaning weight by Koch and Clark (1955), Hill et al.(1966), Deese and Koger (1967), Hohenboken and Brinks (1971) and Koch (1972) were negative in beef cattle. Cundiff (1972) mentioned that the genetic correlation between G_{md} and G_{od} could not be strongly positive or negative. According to the literatures, in general, the covariance seems to be smaller in purebreds than in crossbreds. Consequently, the last term of the numerator in the equation (6), which is a half of σ_{GmdGod}, can be negligible in the trait, particularly that of the purebred, which is strongly influenced by the maternal effect rather than the direct effect of growth. Therefore, the genotypic differences of nursing ability among cows can be predicted from the following regression coefficient of G_{md} on P_c:

$$b_{Gmd \cdot Pc} \doteq \frac{\hat{\sigma}_D^2 - \hat{\sigma}_S^2}{\hat{\sigma}_D^2 + \hat{\sigma}_S^2 + \hat{\sigma}_E^2} \quad \text{------- (7).}$$

Thus, preweaning growth traits which maximize $b_{Gmd \cdot Pc}$ were investigated as the best measure for predicting nursing ability of dams.

Materials and Methods

Data were obtained at the Tottori National Livestock Breeding Station from 1960 to 1981, and comprised 1,407 calf records of 279 cows of the Japanese Black. Average numbers of progeny per sire and dam were 35.77 and 4.86, respectively.

The following model for analysis of variance was constructed from the five classifications, i.e., sire, dam, sex, chronological period and season, and their interaction together with one covariate, i.e., parity of the calf.

$$y_{ijklmn} = \mu + s_i + d_j + X_k + P_\ell + K_m + (XK)_{km} + C_1(c_{ijklmn} - \bar{c}) + C_2(c_{ijklmn} - \bar{c})^2 + e_{ijklmn}$$

where y_{ijklmn} is the single observed growth trait of a calf,
μ is the population mean,
s_i is the effect of the i^{th} sire,
d_j is the effect of the j^{th} dam,
X_k is the effect of the k^{th} sex,
P_ℓ is the effect of the ℓ^{th} chronological period,
K_m is the effect of the m^{th} season of birth class,
c_{ijklmn} is the covariate of parity,
e_{ijklmn} is a random error specific to this observation.

There were two sexes, steer and heifer. The chronological period was grouped into seven classes as follows: 1960 - 1962, 1963 - 1965, 1966 - 1968, 1969 - 1972, 1973 - 1975, 1976 - 1978 and 1979 - 1981. These groupings were made according to the management systems adopted. In the first period, the calf was not creep-fed, while the method was adopted thereafter, with a condition that a calf was creep-fed only in winter in the second and third periods.

As the traits of calf's growth, intact body weight, body weight adjusted by its partial regression on birth weight, cumulative daily gain and daily gain obtained every month before weaning were studied. In the intact body weight of a calf, prenatal influences of the dam are included, while not in the other traits. This means the prenatal influences were removed by taking birth weight into consideration. The cumulative daily gain was expressed as average daily gain from birth until weaning, assuming that the prenatal influences on growth of the calf remain constant. The degree of its influence decreases with age of the calf. The adjusted body weight was the monthly body weight corrected by a function of the birth weight, namely, the regression of body weight on birth weight.

Analysis used was Method III of Henderson (1953). The analysis of variance and estimation of variance components were done by the Mixed Model Least-squares and Maximum Likelihood Computer Program LSML76 written by Harvey (1977).

Results and Discussion

Changing patterns fo regression coefficients of genetic nursing ability of a dam on growth measurements of her offspring according to the age of the calf are shown in Fig.2. The $b_{Gmd \cdot Pc}$'s of the intact body weights were unchanged throughout preweaning life and small, whereas those of the other measures changed substantially as the age of calf advanced. The $b_{Gmd \cdot Pc}$ of the monthly daily gain went down dramatically as the age of calf increased and reached nearly zero at four months of age. In the cases of the adjusted body weight and the cumulative daily gain, the coefficients first went up and down with a peak at two months of age. The largest $b_{Gmd \cdot Pc}$ was obtained at the second month for both traits.

Gifford (1953) described that milk yields declined as the stage of lactation increased in Herefords. Rutledge et al.(1971) and Robison et al.(1978) reported that milk production was similar for the first and second months of lactation and then declined in Herefords. Drewry et al.(1959) estimated milk yields of Angus cows as 6.4, 7.3 and 4.1 kg for the average 18th, 78th and 203rd days of lactation, respectively. Therefore, it is considered that milk production in beef cattle is high for the first two months of lactation and declines thereafter. Which month of the lactation milk production of a beef cow peaks at, however, seems to vary with breeds and feeding practices before calving.

To clarify why the $b_{Gmd \cdot Pc}$'s of the cumulative daily gain and the adjusted body weight were larger at the second month of lactation than at the first month, the magnitudes of additive genetic ($2\hat{\sigma}_S^2$), maternal ($\hat{\sigma}_D^2 - \hat{\sigma}_S^2$) and residual ($\hat{\sigma}_E^2$) variances for the cumulative daily gain were estimated and are shown in Fig.3.

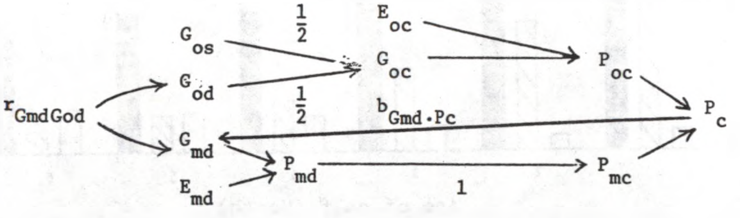

Fig.1 A path diagram showing the relationships between a phenotypic value of a calf and the genotypic value for maternal effect of the dam. See test for symbols.

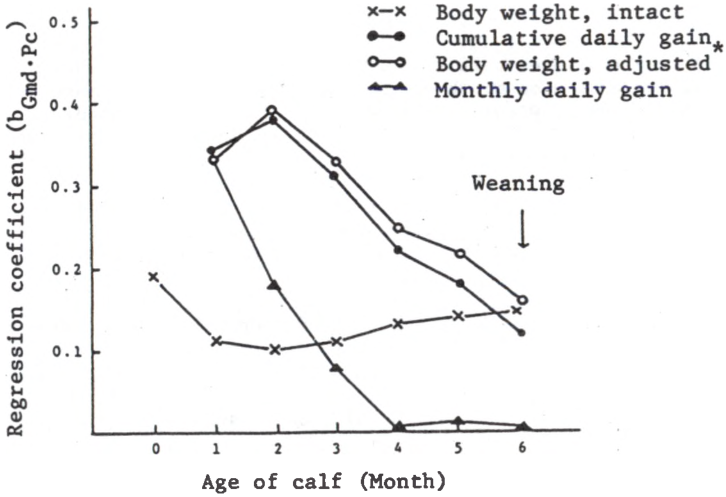

Fig.2 Changing patterns of the regression coefficients of genetic nursing ability of a dam on the phenotypic measurements of a calf according to its age in body weights and daily gains.
*Body weight adjusted by its partial regression on birth weight.

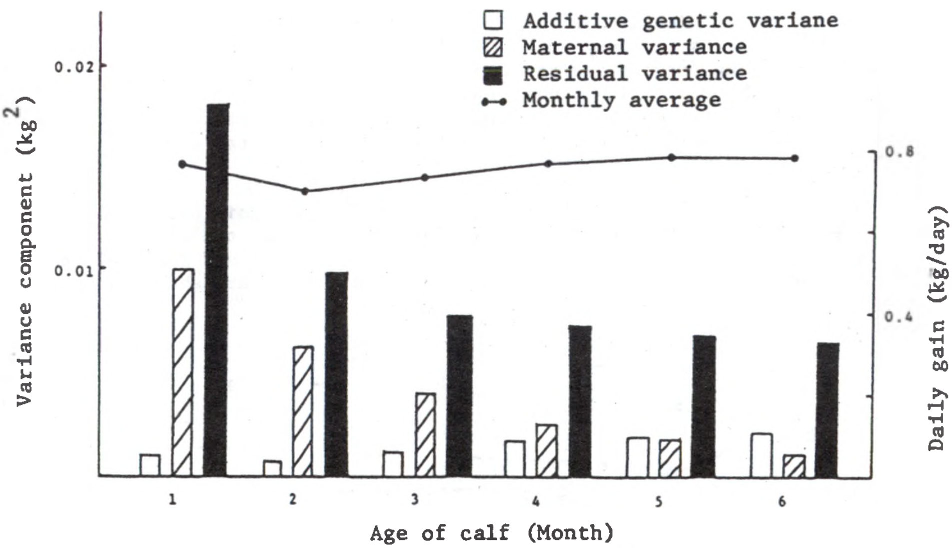

Fig.3 The changes of estimated variance components and monthly average in the cumulative daily gain from birth to weaning by the age of a calf.

Residual variance at the first month was extremely large, compared with that of any other month. Unstability of growth of a newborn calf which has not yet adapted to the new environment could be attributable to the large residual variance. On the other hand, the maternal variance decreased gradually as the age of a calf increased. This indicates that milk production of the Japanese Black cow is highest at the first month and decreases as the month of lactation advances. Therefore, the reason that the $b_{Gmd \cdot Pc}$'s for the two traits were larger at the second month than at the first month, could be explained by the difference of changing patterns in the variances of both residual and maternal effects.

These results suggest that the adjusted body weight and the cumulative daily gain at two months of age are the most sensitive traits in indicating genetic differences for nursing ability between the dams. This agress with the result that the relationship of milk yield and calf weight gains was highest during the first 60-day period of the calf's life (Neville 1962).

Measuring techniques for milk yield of beef cows so far reported (Totusek and Arnett 1965, Rutledge et al. 1972) were rather complicated, and thus more simple techniques are needed to estimate the milk produciton of beef females. In this sense, the cumulative daily gain of calves from birth to two months of age is recommended as the best measure for nursing ability of the dam.

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SUMMARY

Nursing ability of a cow is one of the most important traits in beef cattle. The maternal contribution is strictly environmental to the offspring, but is genetic in the sense that the genotypic differences among cows(G_m) are expressed in the phenotypic measurements of their offspring(P_c). The differences can be predicted from regression coefficient of G_m on P_c ($b_{G_m \cdot P_c}$), if genetic covariance between nursing ability and growth of cows themselves is negligible. Thus, preweaning growth traits which maximize $b_{G_m \cdot P_c}$ were investigated. The data were comprised 1,407 calf records on 279 cows of Japanese Black. Traits studied were intact body weight(IBW), body weight adjusted by its partial regression on birth weight(AWT), cumulative daily gain(CDG) and daily gain(MDG) obtained monthly before weaning. The $b_{G_m \cdot P_c}$'s of AWT and CDG at 2 months of age were largest, which suggests that the AWT and CDG are the best measure for predicting genetic superiority in nursing ability of the dam.

R E S U M E N

La capacidad materna de una vaca es uno de los caracteres más importantes en la producción de vacuno de carne. La contribución materna es estrictamente ambiental para la descendencia, pero es genética en el sentido de que lasdiferenciasgenotípicas entre las vacas (G_m) se expresan

en las medidas fenotípicas de su descendencia (P_c). Las diferencias pueden predecirse del coeficiente de regresión de G_m sobre P_c (b_{G_m} , P_c), si la covarianza entre la capacidad materna y el crecimiento de las vacas mismas es despreciable. Por ello se investigaron los caracteres de crecimiento antes del destete que maximizan b_{G_m} . P_c. Los datos comprendieron 1.407 terneras de 279 vacas de raza Negra Japonesa. Los caracteres estudiados fueron el peso corporal (IBW), el peso ajustado por su regresión parcial al peso al nacer (AWT), la ganancia diaria acumulativa (CDG) y la ganancia diaria (MDG) obtenidas mensualmente después del destete. Los b_{G_m}. P_c de la AWT y CDG a los dos meses de edad fueron mayores, lo que sugiere que el AWT y el CDG son la mejor medida para la predicción de la superioridad genética en la capacidad maternal de las vacas.

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