ADDITIVE AND HETEROSIS EFFECTS ON MILK YIELD AND BIRTH WEIGHT FROM CROSSBREEDING EXPERIMENTS BETWEEN HOLSTEIN AND THE LOCAL BREED IN BANGLADESH

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Summary

Data from purebred and crossbred cattle involving Holstein and the Local breed in Bangladesh were used to estimate the genetic effects on average daily milk yield and birth weight. A total of 877 records on average daily milk yield for 4 types of breed groups and a total of 418 records on birth weight for 5 breed groups were analyzed. Two different methods were applied in this study; the least squares analysis of variance approach and the linear regression approach. Breed group effects were highly significant for both average daily milk yield and birth weight. The result showed that straightbred Holstein produced the highest milk yield and the 7/8 crosses ranked highest in birth weight. For the two traits, the additive breed effect was highly singificant, whereas the individual heterosis effect was not significant. Furthermore, this study showed a negative maternal heterosis for average daily milk yields and a positive maternal heterosis for birth weight. Comparing the breed least squares means obtained from the linear regression approach revealed that straightbred Holstein produced the highest average milk yield and the 3/4 crosses were predicted to have the largest birth weight. It is indicated that the linear regression approach can adequately separate the genetic component of performance, estimate unknown crossbreeding parameters and predict unknown performance of crosses which are not include in the original data.

(**Key Words** : Additive Effect, Birth Weight, Crossbreeding, Milk Yield, Heterosis Effect)

Introduction

Crossbreeding of the indigenous Zebu breeds with world-famous temperate dairy breeds in the tropics has been widely used as a tool to combine high milk yield and high growth potential of the exotic breeds with the adaptability of the Local breeds to heat and humid stress, serious disease, low quality feed and poor management. Numerous studies have reported high levels of heterosis effects for both individual and maternal traits in crossbreds of European and indigenous Zebu cattle (Cartwright et al., 1964; Koger et al., 1975; Madsen & Vinther, 1975).

However, crossbreeding programs in the tropics are sometimes more indiscriminate than planned (Simon, 1984). Such indiscriminate crossbreeding might lead to serious damages rather than benefits. Therefore, a study of the effects of crossbreeding on economically important traits would seem worthwhile.

In Bangladesh, the crossbreeding experiments by means of Artificial Insemination (AI) programs have been conducted in the government and institutional farms since early 1970. The objective of the study is to estimate additive and heterosis effects on average daily milk yield and birth weight using data available in Bangladesh for purebreds of Holstein and Local cattle and different grades of their crosses.

Materials and Methods

Two kinds of data sets, one for average daily milk yield, another for birth weight, were used in this study. All the data were collected from the records for the Holstein, the Local breed and their crosses kept at the Central Cattle Breeding Station (CCBS), Savar, Dhaka. The data for average daily milk yield included a total of 877 records for four types of breed groups covering a period over 17 years (1973-89) and the data for birth

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weight included a total of 418 records for five types of breed groups covering a period over 8 years (1983-1990). The crossbred grades considered and the number of records for each breed group are shown in table 1 and table 2.

TABLE 1. NUMBER OF RECORDS AND COEFFICIENTS FOR EFFECTS IN BREED GROUPS FOR AVERAGE DAILY MILK YIELD DATA

Breed groups	No. of records	Effects		
		g_I	h_I	h_M
Local breed (L)	200	0	0	0
Holstein (H)	142	1	0	0
F_1 (HxL)	263	0.5	1	0
BC (HxHL)	272	0.75	0.5	1

g_I : Breed additive effects for Holstein expressed as a deviation from the Local breed.
h_I : Heterosis effects for Holstein and Local combination.
h_M : Maternal heterosis effect of F_1 crossbred dam.

TABLE 2. NUMBER OF RECORDS AND COEFFICIENTS FOR EFFECTS IN BREED GROUPS FOR BIRTH WEIGHT DATA

Breed groups	No. of records	Effects			
		g_I	h_I	h_M	g_M
Local breed (L)	11	0	0	0	0
Holstein (H)	20	1	0	0	1
F_1 (HxL)	284	0.5	1	0	0
F_2 (HLxHL)	67	0.5	0.5	0.5	1
7/8H 1/8L	36	0.875	0.75	0.25	0.5

g_I : Breed additive effects for Holstein expressed as a deviation from the Local breed.
h_I : Heterosis effects for Holstein and Local combination.
h_M : Maternal heterosis effect of F_1 crossbred dam.
g_M : Maternal breed effect of Holstein dam.

Local cattle of Bangladesh are indigenous Zebu type (*Bos indicus*). Three main types of local cattle are found in Bangladesh; the large type represented by the Pabna and the North Bengal Gray, the small type which are found predominantly everywhere in the country and the Red Chittagong, found in the Chittagong district of the country. The productivity of these animals is low and it is believed to be due to the un-organized breeding programs, diseases of frequent occurrence, inadequate nutrition, stressful climate and so on.

The animals in CCBS were kept under the typical agro-climantic conditions in Bangladesh. The mean annual temperature in the country is about 26℃. Minimum and maximum temperature is 26.6 and 38.4℃ in summer, and 11.0℃ and 28.6℃ in winter, respectively. The average rainfall varies from 1,179 to 4,017 mm. The periods of heavy rainfall may occur during the rainy season, sometimes giving as much 125-250 mm rainfall in a day. There are three prominent seasons in the year; summer from March to June, rainy from July to October and winter from November to February.

Standard conditions of feeding and management practices were adopted for all animals during whole experimental periods. The animals are given green grass plus concentrate (wheat bran, oil cake, molasses and so on) during milking. After milking they are sent to the grazing land and are kept there for 4-5 hours. Drinking water is always available. The feeding and management conditions were quite good compared with poor conditions in village areas in Bangladesh.

In this study, two types of methods (Method 1 and Method 2) were adopted to estimate additive and maternal breed effects, and individual and maternal heterosis effects.

Method 1 was used for comparisons among breed groups. The statistical model in Method 1 for average daily milk yield was:

$$Y_{ijkl} = M + L_i + S_j + P_k + B_l + e_{ijkl}$$

where:

M = overall mean

L_i = the effect due to the ith lactation number (1 to 8)

S_j = the effect due to the jth season of calving (summer, rainy and winter)

P_k = the effect due to the kth period of calving (1973-77, 1978-81, 1982-85 and 1986-89)

B_l = the effect due to the lth breed group (4 breed groups)

e_{ijkl} = random error effect

The statistical model (Method 1) for birth weight was:

$$Y_{ijkl} = M + S_i + Y_j + SE_k + B_l + e_{ijkl}$$

where:

S_i = the effect due to the ith season of birth (summer, rainy and winter)

Y_j = the effect due to the jth year of birth (1983 to 1990)

SE_k = the effect due to the kth sex (male and female) of calf

B_l = the effect due to the lth breed group (5 breed groups)

On the other hand, the multiple regression approach developed by Robison et al. (1980, 1981) was used as Method 2 to estimate the contributions of breed additive genetic, breed maternal, individual heterosis and maternal heterosis effects to differences among breed groups.

The data for average daily milk yield were analyzed with the following statistical model:

$$Y_{ijk} = M + L_i + S_j + P_k + g_I X_1 + h_I X_2 + h_M X_3 + e_{ijk}$$

where:

g_I = the breed additive effect, expressed as a deviation from the Local breed
h_I = the individual heterosis effect
h_M = the maternal heterosis effect
X_1 = proportion of genes contributed by Holstein
X_2 = proportion of loci occupied by genes from Holstein
X_3 = proportion of loci in dam from Holstein

M, L_i, S_j, P_k and e_{ijk} are as described for the model in Method 1.

The breed maternal effect was not included in this model, because only four breed groups are available for daily milk yield. Thus there may be a partial confounding of maternal heterosis and maternal breed effects.

The data for birth weight were analyzed with the following statistical model:

$$Y_{ijk} = M + S_i + Y_j + SE_k + g_I X_1 + h_I X_2 + h_M X_3 + g_M X_4 + e_{ijk}$$

where:

g_M = maternal breed effect
X_4 = proportion of genes in dam from Holstein

M, S_i, Y_j, SE_k and e_{ijk} are as described for the model in Method 1 and X_1, X_2, X_3, g_I, h_I and h_M are as described for the model for average daily milk yield in Method 2.

The fractions of the additive, heterozygotic, maternal heterosis and maternal breed effects (i.e., X_1 to X_4) were considered as continuous variables in Method 2 and calculated as the deviation of the proportion of Holstein genes from proportion of Local breed genes (Ahlborn-breier & Hohenboken, 1991). The coefficients for expected genetic effects of each breed group are shown in tables 1 and 2. The grandmaternal genetic and recombination loss effects described by Dickerson (1969) were ignored in this study, because available breed groups are limited for both traits and these effects can not be separated.

Results and Discussion

The analysis of variance for the traits considered are presented in table 3. All effects, except season of calving, were highly significant on average daily milk yield.

First and second lactation yields were significantly lower, and seventh and eighth lactation yields were significantly higher than other lactation yields. The higher yield of seventh and eighth lactations appears to be because animals with low milk yield were culled up to reaching the time, and, as a result, only high producers would have been retained in the herd. Martinez et al. (1988) reported that age differences (i.e., differences of lactation number) were large non-genetic source of variation in milk yield. The non-significant effect of season of calving was an unexpected result. This suggests that, even in the tropics, the influence of climatic conditions may be negligible under good management.

TABLE 3. DEGREE OF FREEDOM, MEAN SQUARE, AND TEST OF SIGNIFICANCE FROM THE LEAST SQUARES ANALYSIS OF VARIANCE FOR AVERAGE DAILY MILK YIELD AND BIRTH WEIGHT (METHOD 1)

Average daily milk yield			Birth weight		
Source	DF	MS	Source	DF	MS
Breed group	3	1420**	Breed group	4	1417**
Lactation number	7	31.7**	Season of birth	2	7.8
Season of calving	2	4.6	Year of birth	7	270.7**
Period of calving	3	22.4**	Sex	1	34.8
Error	861	2.7	Error	403	18.5

** : $p < 0.01$

With respect to birth weight, the effects of breed groups and year of birth were highly significant source of variation. Difference between sexes was not important in this study, although sex effects on birth weight were generally reported (e.g., Brinks et al., 1972). Seasonal difference was not also evident. This indicates that the climatic influence on birth weight through their dams' nutrient conditions may be small in this case because the dams were kept in good management under the experimental station.

Breed group effects were highly significant for the two traits (table 3). Table 4 contains the least squares means for the breed groups.

Straightbred Holstein produced the highest average daily milk. Generally speaking, considerably high milk yields are recorded by exotic breeds in the seasonally hot climate in the tropics when the animals were extremely well fed and managed (Mason & Buvanendran, 1982). For birth weight, the 7/8 crossbred calves were ranked highest in the present study.

TABLE 4. LEAST SQUARES MEANS AND STANDARD ERRORS FOR AVERAGE DAILY MILK YEILD AND BIRTH WEIGHT

Breed group	Average daily milk yield (kg / day)	Birth weight (kg)
Local breed (L)	2.93 ± 0.165	13.44 ± 1.782
F_1 (HxL)	6.53 ± 0.139	17.28 ± 0.436
BC (HxHL)	6.03 ± 0.147	·
F_2 (HLxHL)	·	23.28 ± 0.760
7/8H 1/8L	·	28.10 ± 0.849
Holstein (H)	10.32 ± 0.186	26.68 ± 1.051

Method 2 was used to estimate the contributions of breed additive, breed maternal, individual and maternal heterosis effects to differences in the two traits. The method provides a way of separating component parts of performance and gains a clear insight into the biology of crossbreeding (Dillard et al., 1980; Robison et al., 1980).

The estimates of the genetic effects and tests of significance are presented in table 5. The additive breed effect highly significantly influenced both average daily milk yields and birth weight. This indicates the fairy large difference between Holstein and the Local breed. In spite of the fact that milk yield of Holstein shown in this study is 30-40% lower than that in the temperate areas, the Holstein purebred is still maintained with reasonable production level, compared with other crosses and the Local breed.

TABLE 5. LEAST SQUARES MEANS, REGRESSIONS AND STANDARD ERRORS FOR AVERAGE DAILY MILK YIELD AND BIRTH WEIGHT (METHOD 2)

Component	Average daily milk yield	Birth weight
Local[a]	2.93	13.44
g_I	7.39 ± 0.189**	24.97 ± 8.093**
h_I	−0.096 ± 0.217	−8.642 ± 4.596
h_M	−2.397 ± 0.161**	7.540 ± 2.160**
g_M	·	−11.74 ± 8.856

g_I : Breed additive effects for Holstein expressed as a deviation from the Local breed.
h_I : Heterosis effects for Holstein and Local Combination.
h_M : Maternal heterosis effect of F1 crossbred dam.
g_M : Maternal breed effect of Holstein dam.
a : Local breed least squares means.
** : $p < 0.01$.

Heterosis effects were negative, but not significant for the two traits considered in this study. The results differ from those obtained from other reports. High heterosis effects have been generally reported in the literature for milk yield on crossbreding of indigenous Local breeds and European breeds (Madsen & Vinther 1975; Sharma & Pirchner 1991). Cunningham and Syrstad (1987) reviewed many reports on crossbreeding between *Bos Taurus* and *Bos indicus* cattle in the tropics, and gave estimates of the positive desirable heterosis for milk yield using a single weighted least squares analysis across experiments. However, Taneja & Bhat (1974) reported a small and non-significant estimate of heterosis for milk yield. The present result is in agreement with that reported by Taneja & Bhat (1974).

For birth weight, results from crosses among *Bos taurus* breeds reviewed by Long (1980) showed the effects of individual heterosis to range from 1% to 11%. For crosses of *Bos indicus* breeds with *Bos taurus* breeds, Sacker et al. (1971) reported that means of crossbred birth weight were superior to means of purebred birth weight by 9.7% in cross between Red Poll and Boran cattle. However, Thorpe et al. (1980), Trail et al. (1982) and Hirooka et al. (1990) presented results that showed non-significant individual heterosis for birth weight of crosses between *Bos taurus* and *Bos indicus*.

These opposed results on estimates of heterosis for milk yield and birth weight may be caused by differences of situations where the animals are reared. Cunningham (1981) proposed a model for performance of crosses of *Bos taurus* and *Bos indicus* in poor and good environments and suggested that heterosis would be greater in a poor environment than a good environment. In the present study, since straightbred Holsteins can give full play to their ability under a favorable environment (standard management), the performance of F_1 progeny might not differ from average of mid-parents.

Maternal heterosis was highly significant for both average daily milk yield and birth weight. The negative value obtained for maternal heterosis for milk yield may imply that recombination loss is involoved. Ericson et al. (1988) reported the similar negative maternal heterosis effect on milk yield (kg FCM) for crosses among *Bos taurus* breeds, while Ahlborn-Breier & Hohenbhoken (1991) did not find significant maternal heterosis for crosses of *Bos taurus* breeds with *Bos indicus* breeds.

Significant effects of maternal heterosis on birth weight for crosses among *Bos taurus* breeds were reported by Koch et al. (1985). Gregory et al. (1985) reported results that showed the effect of maternal heterosis on birth weight to be 1.6 kg (6%). Moreover, the present result is also in agreement with a result reported by Hirooka et al. (1990) that showed the highly significant effect of maternal heterosis on birth weight.

Maternal breed effect of birth weight was negative but not significant due to large standard error.

Estimating individual heterosis by comparing the average performance of F_1 and the reciprocal cross to the average performance of the straight parents breed appears to be the most reasonable method. Nevertheless, the data for exotic breeds and reciprocal crosses are rarely available in the tropics, because crossbreeding programs have been generally carried out, based on upgrading and criss-cross breeding. That is, the germplasm of exotic breeds is imported through frozen semen and thus the performance of exotic breeds and reciprocal crosses from mating dams of exotic breeds with sires of local breeds necessarily remains unknown under native conditions in tropics. However, Method 2 permits us to estimate heterosis effects from the data where exotic breeds and/or reciprocal crosses are not available.

Jain (1982), Hirooka et al. (1990) and Rege et al. (1993) proposed different procedures for estimating heterosis effects when performance of a parent on one side (ordinary an indigenous Zebu breed) is not known. The linear regression approach seems to be a more advanced procedure than the others, because it allows us to estimate not only individual heterosis effects but also other genetic effects such as additive effects, maternal effects, maternal heterosis effects and so on.

The linear regression approach can be also used to predict performance of various breed combinations which are not included in the original data (Dillard et al., 1980). Predicted average daily milk yield and birth weight, computed as a function of coefficients in table 1 and crossbreeding parameters in table 5, are presented in table 6. The predicted breed group least squares means (LSM) are computed as follows:

LSM = Local breed least squares means
+ (additive effect) (additive coefficient)
+ (heterosis effect) (heterosis coefficient)
+ (maternal heterosis effect) (maternal heterosis coefficient)
+ (maternal breed effect) (maternal breed coefficient)

For example, LSM of the backcross of 75% Holstein genes {H × (HL)} for birth weight were calculated as:

$$\text{LSM of the backcross} = 13.44 + 24.97 \times 0.75 - 8.64 \times 0.5 + 7.54 - 11.73 \times 0.5 = 29.52 \text{ kg}$$

On the basis of these results, the 3/4 crossbred calves were predicted to be heavier birth weight than the 7/8 crossbred calves, while the 7/8 crossbred calves had the highest birth weight for the observed least squares means (table 4). Hirooka et al. (1990) also reported the heaviest birth weight of 3/4 crosses by using the data from crossbreeding between Friesian and the Local dairy breed in Malaysia. It is widely known that backcrosses demonstrate less than desired results in fitness (McDowell, 1985). The heavy birth weight may result in low fitness because of high risk of calving difficult.

TABLE 6. PREDICTED AVERAGE DAILY MILK YIELD AND BIRTH WEIGHT USING GENETIC PARAMETERS FROM ANALYSIS (METHOD 2)

Fraction of Holstein genes	Average daily milk yield (kg / day)	Birth weight (kg)
0.000	2.93	13.44
0.125	2.63	15.23
0.250	2.33	17.04
0.500	6.53	17.28
0.750	6.03	29.52
0.875	8.17	28.10
1.000	10.32	26.68

This study suggested that the linear regression approach (Method 2) may be useful, because it provides a general solution for estimation of unknown crossbreeding parameters and prediction of performance of crosses that have not actually been tested.

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