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Estimation of crossbreeding parameters for milk production traits of crosses between Holstein Friesian and local Arsi breed in the highland of Ethiopia

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Abstract

Data on milk production from crossbreeding experiment of Holstein Friesian and Local Arsi breed in highland of Ethiopia was used to estimate breed additive, heterosis and recombination effects for individual and maternal traits of average daily milk yield and milk yield per day of calving interval. The least square analysis of variance was used, for evaluation of the various breed groups, and the multiple regression analysis to estimate the contribution of individual and maternal breed additive, heterosis and recombination effects. The effect of Breed group (p<0.001) and Parity (p<0.001) were significant for both traits, while, season and year group (period) of calving were not significant (P > 0.05). Estimated least square means were highest for 50% F1 cross with 6.00 kg for milk/LL and 5.53 kg for milk/CI and lowest for Arsi breed with 3.11 kg of milk/LL and 1.99 of milk/CI. The individual breed additive genetic and heterosis effects were significant for both traits (P<0.01). Maternal heterosis and recombination effect were not significant (P>0.05) for both traits. The individual breed additive effect was estimated at 3.63 kg milk /day for milk/LL and 2.98 kg milk /day for milk/CI. Individual heterosis effect was 1.08 kg/day (22%) for daily milk yield and 1.48 kg milk/day (45%) for milk/CI. Estimate of individual recombination effect was negative for both traits 0.54 kg/day for milk/LL and 2.75 kg milk/day for milk/CI. The maternal heterosis effects were estimated to be –0.28 kg milk/LL and 0.88 kg milk/CL, while, maternal recombination effect of –1.11 kg/day milk/LL. On the basis of predicted result milk yield increased as proportion of Holstein Friesian inheritance increased up to 50% (F1), and declined from 65.5% to 87.5% and increased above this level. It can be concluded that about equal proportion of genes from the two breeds was optimum.

Keyword: Crossbreeding, Breed additive, Heterosis, Milk yield, Cattle.

Abbreviations: Number of records (N) local Arsi breed (L), Holstein Friesian (F). G^I= Individual additive genetic effect, H^I= individual heterosis effect, G^M= maternal additive genetic effect, H^M= maternal heterosis effect, R^I= individual recombination effect, R^M= maternal recombination effect, Lactation length (LL), Calving interval (CI).

Introduction

Although Ethiopia has large number of indigenous cattle population, their potential for milk production is rather low. At the same time the adaptability of temperate cattle is poor, though their milk yielding capacity is generally good. Crossbreeding between indigenous and temperate cattle where the adaptability of indigenous cattle is combined with high production capacity and good temperament of temperate cattle is considered as the best option to increase milk production. Because of this breed improvement efforts in Ethiopia have so far been limited to crossing zebu with temperate cattle and conduction research to make sound decisions concerning the appropriate level of temperate inheritance (Kiwuwa et al. 1983, Kebede, 1992).

In crossbreeding herds, improvement can be effected by two methods: (1) maximising heterosis and heterosis retention through optimal use of breed combinations and breeding systems, and (2) through utilisation of additive genetic values of the component breeds. In both methods the challenge is to separate the additive and non-additive contribution and partition of the later into within-locus (dominance) and between-locus (epistatic) contributions. In this study data from crossbreeding program in a herd located in highland Ethiopia (Asella station) were used to estimate crossbreeding parameters for average daily milk yield and milk yield per day of calving interval, to identify an optimal breed combination which provides an optimal performance.

Material and Methods

Herd description

Data for this study were obtained from herd at Asella station that is situated 180 km south east of Addis Ababa in a highland plateau of Ethiopia. Chilalo Agricultural Development Unit (CADU) established the herd during 1967. In 1968, crossbreeding in Asella station was started using 200 Arsi, 22 Fogera, 16 Barca and 10 Boran cows purchased from local markets. These cows were mated with pure Holstein Friesian bulls to produce F_1 heifers. The F_1 were later be upgraded to produce 50%, 75%, 87.5% and 93.75% Friesian level. These breeds were also inter se mated with bull of similar blood level. Most mating was by Artificial insemination (AI) using semen from Ethiopian National Artificial insemination Centre.

Only the Friesian * Arsi data are used in this study. The Arsi breed seems to have evolved from the large group of small Abyssinian Short-horned Zebus. They are found the central highlands of Ethiopia, especially in Arsi, east

Shewa and Bale zones. The Arsi cattle are small, short and compact, and are thickset but relatively well proportioned. They are extremely active but temperamental and often very aggressive with an average height at withers of 110 cm live weight is 257 kg and the average carcass yield is 57.4%.

Data collection

Data on 346 records on milk yield and 290 records on calving interval on Local Arsi and Holstein Friesian cross from Asella dairy cattle breeding program was collected and used for this study. Individual records were collected for each cow and each calving. These include breed group, cow number, sire of cow, dame of cow, date of calving, date of dry-off and total lactation milk yield. From these data milk yield per lactation length and milk yield per day of calving interval were analysed. Milk yield per day of lactation length was computed as total lactation milk yield (kg) divided by lactation length (days). Milk yield per days of calving interval was computed as total lactation milk yield (kg) divided by calving interval (days). Calving interval (days) for each lactation was computed as the difference between at start of lactation and next calving. Lactation length (days) was computed as difference between date of start of milking and dry-off date.

A number of factors were identified in the preliminary screening of data that had a bearing on the techniques to be used. The first problem was, the non overlapping years of calving between local Arsi breed and different crossbreds

There was also some deviant observation presented in some of the breed groups, for example very short or long lactations. In the main analysis, these records with lactation length < 200 or greater than 1000 days were discarded in order to avoid possible aberrant results.

Climate

Asela station is located about 180 km southeast of Addis Ababa in the Arsi Region in a highland plateau area rising to a height of 2000-3000 m. Both Arsi Region and Asela station are characterised by mild subtropical weather with maximum and minimum temperatures ranging from 18 to 28 ^{0}C and 5 to 10 ^{0}C, respectively. The station experiences bimodal rainfall, with an annual average precipitation of 1300 to 1350 mm. Short rains occur during March and April, followed by long rains during July to September. The long dry season lasts from November to February, and a short dry spell is experienced in March and June (Kiwuwa et al., 1983).

Herd management

The feeding practice, which varied over the years, was designed to give continuous growth using a moderate plane of nutrition. Natural grazing and concentrate supplement constituted the major feed supply. During dry season hay or concentrates (48% Niger seed cake, 48% wheat bran, 3.5% bone meal and 0.5% salt) were fed to all animals at the rate of 2 to 4 kg per cow per day, depending on the levels of milk yield.

Cows were hand milked twice daily. Newborn calves were taken away from their mothers shortly after birth. They were bucket fed to weaning which occurred between 49 and 79 days. Colostrums and whole milk substitutes were fed to calves twice daily at a rate of 1.0 kg to 2.5 kg milk equivalent per day. Animals were routinely vaccinated against anthrax, rinderpest, blackleg and pleuropneumonia. Regular dosing against internal parasites and measures against mastitis were undertaken. Milk recording was initially carried out daily, but in 1973 was changed to either twice monthly or once every 3 weeks. Vaccinations and treatments against identified ailments were recorded. No individual supplementary feeding records were kept, except for the animals in feeding trials.

Statistical analysis

Data collected from 1968 to 1995, on milk yield/LL and milk yield/CI were analysed using General Liner Model (GLM) of SAS (1987). Two different methods were used in data analysis (Method 1 and method 2), Method 1, the least square analysis of variance was used to compare among breed group, and method 2, the multiple regression analysis to estimate the contribution of breed additive, heterosis and recombination effects. In the first method, the effects included in the model were breed group (12), lactation number (5), season (5) and year group or period of calving (7). Based on result of level of significance from preliminary analysis of the effect of year of calving on milk yield, years of calving were grouped into 7 periods. These period one from 1968 to1971, period 2 from1972-75, period three from 1976-79, period four from 1980-84, period five 1985-89, period six from1990-94 and period seven from1995-1997. For evaluation of the effect of seasons on milk production and calving intervals the months of calving were grouped into five seasons, first part of dry season from October to December, second part of dry season from January to February, short wet season from March to May, first part of wet season June to July and second part of wet season from August to September (Kiwuwa, et al, 1983).

Model one: The statistical model for analysing milk yield/LL and milk yield/CI will be:

$y_{ijklm} = M + L_i + S_j + P_k + B_l + e_{ijklm}$ where:

y_{ijklm} = Lactation milk yield, lactation length or calving interval of an individual animal with

lactation i, in season j, year groups k of breed group l M =

overall mean

L_i = the effect due to the i^{th} lactation number (i = 1...5 for milk/LL and milk/CI)

S_j = the effect due to j^{th} season of calving (j = 1, 2, 3, 4 and 5). P_k = the

effect due to the k^{th} year group of calving (k = 1...7) B_l = the effect due

to the B^{th} breed group (l = 1...12)

e_{ijklm} = random error effect.

Due to many empty cell interaction effects were not evaluated

Model two: The multiple regression approach developed by Robinson et al. (1980) was used (Method 2) to estimate the contribution of breed additive genetic and heterosis effects to differences among breed groups with respect to average milk yield/LL and milk yield/CI.

$y_{ijkl} = M + L_i + S_j + P_k + g^I{}_F X_1 + h^I X_2 + g^M{}_F X_3 + h^M X_4 + R^I X_5 + R^M X_6 + e_{ijkl}$ Where:

y_{ijkl} = Lactation milk yield, lactation length or calving interval of an individual animal with lactation i, in season j, year groups k of breed group l

M = intercept (general level of local Arsi breed)

$g^I{}_F$ = individual genetic effect of Holstein as deviation from local breed. h^I =

individual heterosis effect.

$g^M{}_F$ = maternal additive genetic effect of Holstein as deviation from local breed.

h^M = maternal heterosis effect.

R^I = individual recombination effect. R^M =

maternal recombination effect. X_1 = proportion

of genes from Holstein.

X_2 = proportion of maximum individual heterosis. X_3 = proportion of genes from Holstein in dam.

X_4 = proportion of maximum maternal heterosis.

X_5 = proportion of maximum individual recombination effect. X_6 = proportion of maximum maternal recombination effect. For definition of L, S and P see model 1.

The proportions of Holstein Friesian genes, individual and maternal heterosis, individual and maternal recombination effect (x_1 to x_6) were considered as continuous variables in method 2, for values of X1 to X6 of the different breed groups see Table 1.

Table 1. Proportion of expected additive, breed content in the breed combination with local Arsi breed.

Group	Breed combination {sire}{dam}	N	G^I_F	H^I_{LF}	G^M_F	H^M_{LF}	R^I_{LF}	R^M_{LF}
1	{L}{L}	63	0.0	0.0	0.0	0.0	0.0	0.0
2	{F}{L}	14	0.5	1.0	0.0	0.0	0.0	0.0
3	{F*L}{F*L}	13	0.5	0.5	0.5	1.0	0.5	0.0
4	{L}{F*L}	17	0.25	0.5	0.5	1.0	0.25	0.0
5	{F}{F*L}	42	0.75	0.5	0.5	1.0	0.25	0.0
6	{F(F*L)}{F(F*L)}	7	0.75	0.375	0.75	0.5	0.375	0.25
7	{F}{L(F*L)}	16	0.625	0.75	0.25	0.5	0.1875	0.25
8	{F}{(F*L)(F*L)}	14	0.75	0.5	0.5	0.5	0.25	0.50
9	{F}{F(F*L)}	22	0.875	0.25	0.75	0.5	0.1875	0.25
10	{F}{F[(F*L)(F*L)]}	7	0.875	0.25	0.75	0.5	0.1875	0.25
11	{F}{F[F(F*L)]}	5	0.9375	0.125	0.875	0.25	0.109375	0.1875
12	{F}{[F(F*L)][F(F*L)]}	9	0.875	0.25	0.75	0.375	0.1875	0.375

N=Number of records; L= local Arsi breed; F= Holstein Friesian; GI= Individual additive genetic effect, HI= individual heterosis effect, GM= maternal additive genetic effect, HM= maternal heterosis effect, RI= individual recombination effect, RM= maternal recombination effect.

Results and Discussions

The non genetic environmental effects

The analysis of variance for the traits considered (Model 1) indicated that all effects except season and year group (period) of calving were significant ($p<0.001$) on average daily milk yield/LL and milk yield/CI ($P<0.05$). Result on mean separation (mean contrast) indicated that first and second lactation yields (Milk/LL) were significantly lower, and fifth lactation yields were significantly higher than other lactation yields. Hirooka & Bhutyan (1995) reported similar large significant effects of lactation number and season of calving on average daily milk yield in a cross of Friesian with local tropical breed. The non-significant effect of season of calving was unexpected result. This suggests that even in the tropics, the influence of climatic conditions may be negligible under good management, while age differences (differences of lactation number) are important non-genetic source of variation in milk yield.

Genetic (breed group) effect

Table 2 contains the least square means for breed group. Breed group effect was highly significant for both traits. Although there is no consistent trend, estimated least square means of milk yield per lactation length increased continuously as proportion of Holstein Friesian increased up to (1/2 (F_1) for Milk/LL and up to ¾ (F1) for Milk/CI and above these level a slight decline were observed. A similar decline was observed by Reis (1977) for level of *Bos Taurus* inheritance above 1/2 to 5/8. However, Mason and Buvanendran (1982) reported high milk yield by exotic breed in the seasonally hot climate in the tropics when the animals were well feed and managed.

Table 2. Least Square Means (LSM) and Standard error (SE) of mean by breed group for daily milk yield (milk/LL) and milk yield per day of calving interval (milk/CI)

Breed group	% of HF	Milk/LL			Milk/CI		
		n	Mean	SE	N	Mean	SE
{L}{L}	0	63	3.11	0.46	24	1.99	0.91
{F}{L}	0.5 (F1)	25	6	0.281	20	5.31	0.44
{F*L}{F*L}	0.5 (F2)	21	4.60	0.399	10	3,81	0.75
{L}{F*L}	0.25	22	4.00	0.414	7	4.33	0.95
{F}{F*L}	0.75	71	5.70	0.292	40	5.20	0.49
{F(F*L)}{F(F*L)}	0.75	11	5.54	0.486	6	4.93	0.87
{F}{L(F*L)}	0.625	43	5.00	0.317	29	4.31	0.53
{F}{(F*L)(F*L)}	0.75	17	5.65	0.425	5	4.73	0.95
{F}{F(F*L)}	0.875	36	5.57	0.354	15	4.98	0.74
{F}{F[(F*L)(F*L)]}	0.875	18	5.60	0.425	10	4.38	0.77
{F}{F[F(F*L)]}	0.9375	5	5.73	0.663	-	-	
{F}{[F(F*L)][F(F*L)]}	0.875	8	5.74	0.541	-	-	

L=Local, F=Holstein Friesian, n = Number of observation, SE and Standard error

Crossbreeding parameters

Estimates of G^I_F, H^I_{FL} H^M_{FL}, R^I_{FL} and R^M_{FL} effects are shown in Table 3 for both traits. The individual breed additive difference between Local Arsi and Holstein Friesian breed was highly significant for both traits (p<0.01). The pure Holstein Friesian breed produced about 3.63 ± 0.52 kg more milk/day for milk/LL and 2.98 kg milk/day for milk/CI relative to local breed. This result is lower than breed additive difference of 7.39 kg daily milk yield reported in a cross between Holstein Friesian * local breed Hirooka and Bhutyan (1995), and similar or higher with breed additive difference of 2.39 kg milk/day (milk/LL) and 1.47 kg/day milk (milk/CI) reported between Sahiwal * Brow Swiss crosses, (Mackinnon et al. 1996).

Table 3. Estimates of Breed additive, Heterosis and recombination losses on average daily milk yield (milk/LL) and milk yield per day of calving interval (milk/CI)

Parameter	Milk/LL (kg)		Milk/CI (kg)	
	Estimate	**SE**	**Estimate**	**SE**
Breed additive effect (GIF)	3.63**	0.521	2.98**	1.05
Individual heterosis effect (H^I_{FL})	1.08**	0.344	1.49*	0.64
Maternal heterosis effect (H^M_{FL})	-0.2785NS	0.49	0.88NS	0.68
Individual recombination (R^I_{FL})	-0.541NS	0.21	-2.75NS	2.09
Maternal recombination (R^M_{FL})	-1.11 NS	0.848	-	

Level of significance NS =P> 0.05, *= P<0.05, **= P< 0.01

The next most important genetic effect on average daily milk yield was individual heterosis. Heterosis with respect to Holstein Friesian and local breed genes had significant and positive effects on both traits. The estimate of 1.08 kg/day (proportionally 0.22) on milk/LL and 1.49 kg/day (proportionally 0.45) for milk/CI for full heterozygosity, is in agreement with heterosis effects of 1.04 kg/day on milk/LL and 1.22 kg/day of milk/CI reported on crossbreeding of *Bos Taurus X Bos idicus* (Mackinnon et al. 1996). Madsen & Vinther (1975), and Cunningham and Syrstad (1987) reports positive desirable heterosis for milk yield. However, Hirooka & Bhutyan (1995) reported a small and non-significant estimate of individual heterosis effects for average daily milk yield on crossbreeding between Bos Taurus and Bos indicus cattle in the tropics. These differences on estimates of heterosis for milk yield may be caused by differences of situations where the animals are reared.

Maternal heterosis effects were not significant for both traits (p>0.05). Ahlborn-Breier & Hohenbhoken (1991) reported similar non-significant effect of maternal heterosis on milk yield for crosses of Bos Taurus and Bos indicus breeds. However, Hirooka & Bhutyan (1995) obtained negative and significant estimate of maternal heterosis for average daily milk yield. The non-significance of maternal heterosis effect in this study may imply that recombination loss is not involved.

Estimate of individual and maternal recombination losses were negative but not significant (p>0.05). Taneja and Chawla (1978 b) found indication of large difference in maternal effect on milk yield in their study. However, when the present authors repeated their computations weighting various means according to numbers this indication disappeared. No other authors have been reported evidence of difference in maternal effects between *Bos Taurus* and *Bos indicus* with respect to milk yield.

The findings on additive genetic difference, heterosis and recombination effects were used to predict performance of various breed combinations, which are present or not present in the original data (Hirooka and Bhutyan 1995). Predicted average daily milk yields as a function of coefficients in Table 1 and crossbreeding parameters in Table 3 are presented in table 4. On the basis of these results, the 50% F1 and 15/16 crossbred cows were predicted to have the highest milk, while the 50% F1 cows had the highest observed least square means (table 3). When average daily milk yield and calving interval is combined into milk yield per day of calving intervals again both predicted and observed least square means were highest for 75% cross (F1).

Table 4. Predicted Average daily milk yield using genetic parameters from analysis (method 2)

Breed group	**Predicted milk yield/LL**	**Predicted milk yield/CI**
0% HF	3.11	1.99
25% HF	4.14	3.67
50% HF (F1)	6.00	4.97
50% HF (F2)	4.92	3.29
62.5% HF	5.67	4.89
75% HF	5.96	5.16
87.5% HF	6.03	4.89
93.75% HF	6.31	4.96
100% HF	6.74	4.97

HF= Holstein Friesian

Conclusion

The main aim of this study was to estimate the appropriate crossbreeding parameters and identify the optimum level of Holstein Friesian inheritance in crossbreeding program to genetically improve the herd. It was concluded that the milk production performance of (average daily milk) Arsi x Holstein Friesian crosses were heavily determined by heterosis (dominance effect). The observed and predicted results on both traits are in the same direction in favour of 50% (F1). The contribution of recombination effects in both individual and maternal traits was negligible.

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