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Genetic and Non-genetic Effects on Productive and Reproductive Parameters of Arsi Cattle and Their Holstein Friesian Crosses in Ethiopia

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Abstract

Data collected from 1968 to 1998 on 12 breed groups of crossbreds of Arsi cattle with Holstein Friesian were used to estimate crossbreeding parameters for lactation milk yield and reproductive traits in a dairy herd of Asella station, Arsi Zone, Ethiopia. Two methods were used in data analysis. The least squares analysis of variance was used for evaluation of various breed groups and environmental effects, and the linear regression approach for estimating crossbreeding parameters. The non-genetic (environmental) effects considered were year group, parity and season of calving. It was estimated that the high grade Holstein Friesian crosses (93.75%) produced about 1854 kg (proportionally 1.81) and 87.75% Holstein Friesian crosses about 1671 kg milk (proportionally 1.61) above Arsi breed during their lactation period. Individual breed additive effect of Holstein Friesians as a deviation from Arsi breed was highly significant and estimated to be 2297 kg for lactation milk yield, +213 days for calving interval and +198 days for lactation length. The individual heterosis effect was estimated to be 313 kg for lactation milk yield, -77 days for calving interval and 9.6 days for lactation length, while maternal recombination effects were estimated to be 603 days and negative for lactation milk yield and 60 days and negative for lactation length. It was concluded that milk production performance of crossbreds of Holstein Friesian with Arsi breed was mainly determined by breed additive genetic effects. The heterosis effect was low relative to additive genetic effect. Under the observed management level, cows with above 75% Holstein Friesian inheritance could be recommended provided that sound reproductive management and mating system are put in place to maintain the desired blood level.

Keywords: Crossbreeding; milk production; tropics, Ethiopia; additive genetic effects; heterosis effects

Introduction

In the tropics, dairy herds often consist of a crosses between improved European dairy breeds and indigenous or adapted breeds. Such crossbreeding in tropical areas has been widely used as a method to combine the high milk yield of *Bos taurus* breeds with the adaptability of local breeds to heat stresses, diseases, low quality feed and poor management. Apart from the additive contribution of each breed to overall performance, there are also large non- additive heterosis effects in milk yield and fertility traits which combine to give a large advantage in total production to the first generation (F_1) of these crosses (Mackinnon *et al.,* 1996). However, further upgrading by back crossing to the European breed gave variable and often rather disappointing results. In a review of dairy cattle cross-breeding experiments in the tropics, Syrstad (1989) concluded that most of the decline in productivity from F_1 to F_2 generations was due to loss of heterozygosity, i.e. dominance effects were the most important contributor to heterosis, with perhaps a small negative effect of recombination on milk yield.

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Although crossbreeding or upgrading of indigenous cattle with exotic breeds in Ethiopia has been done for the last 30 years or so, the performance and adaptability of crossbred cattle is not yet clearly described. The lack of reliable estimates of crossbreeding parameters remains a hindrance to the choice of the optimal crossbreeding system for milk production in the country. In this study, milk production data from a crossbreeding program in an experimental dairy herd from the highlands of Ethiopia were analyzed to identify breed combinations for superior performance. The data allowed estimation of the breed additive and non-additive effects and estimation of the performance of different breed groups.

Material and Methods

Description of experimental herd

Data for this study were obtained from herd at Asella station that is situated 180 km southeastern of Addis Ababa in a highland plateau of Ethiopia. Chilalo Agricultural Development Unit (CADU) established the herd in 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 used to produce 50%F_2, 75%, 87.5% Holstein Friesian crosses (Table 1). Only data from Holstein Friesian and Arsi crosses were used in this study. Most of the mating was done by artificial insemination (AI).

Climate of the study area

The climate is characterized 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 precipitation of 1300 to 1350 mm. Short rains occur from March to April, followed by long rains from July to September. The long dry season lasts from November to February, and a short dry spell is experienced between March and May (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 concentrate feed (48% Niger seed cake, 48% wheat bran, 3.5 bone meal and 0.5% salt) was fed to all animals at the rate of 2 to 4 kg per cow day, depending on the levels of milk yield (Kiwuwa *et al*., 1983). 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. Vaccinations and treatments against identified ailments were recorded. No individual supplementary feeding records were kept, except for animals on feeding trials. Milk recording was initially carried out daily, but in 1973 this practice was changed to either twice monthly or once every 3 weeks.

Statistical analysis

Using data collected between 1968 and 1998 lactation milk yield, lactation length (LL) and calving interval (CI) were analyzed using General Linear Model (GLM) of SAS (1987). Two methods were used in data analysis: for method one, the least squares analysis of variance was used to compare the performance level of breed groups, and for method two, the multiple regression analysis was used to estimate the contribution of breed additive, heterosis and recombination effects. For comparison of breed groups (method one), the effects included in the model were breed group (12), lactation number (5), season of calving (5), and year group of calving (7). Year of calving ranged from 1968 to 1998 and was grouped into 7 year groups; period one from 1968 to 1971, period 2 from 1972 to 1975,

period 3 from 1976 to 1979, period four from 1980 to 1984, period five from 1985 to 1989, period six from 1990 to 1994 and period seven from 1995 to 1998. This grouping was based on similarity of significance difference of lactation milk yield during preliminary analysis. For evaluation of the effects of season on milk production and calving interval, the months of calving were grouped into five seasons, first part of dry season from October to December, second parts of the dry season from January to February, short wet season from March to May, first part of wet season from June to July and second parts of the longer wet season from August to September (Kiwuwa et al, 1983). For milk yield, parity of dam classes consisted of the first through fifth lactation number. But for calving interval the estimated least square means for lactation number greater than two were almost similar and was decided to make these lactation classes in the final analysis one and greater than one. The statistical model for analyzing milk yield, lactation length and calving interval was:

$y_{ijklm} = M + L_i + S_j + P_k + B_l + e_{ijklm}$ (model 1)

Where: y_{ijklm} = Lactation milk yield, lactation length or calving interval of an individual cow 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 and lactation length and = 1 or > 1 for calving interval

S_j = the effect due to j^{th} season of calving (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 l^{th} breed

group (l = 1...12)

e_{ijklm} = random residual effect.

The multiple regression approach developed by Robison *et al*. (1980, 1981) was used to estimate the contribution of breed additive genetic and heterosis effects to differences between breed group with respect to lactation milk yield, lactation length and calving interval, using the following model

$y_{ijkl} = M + L_i + S_j + P_k + g^I_F X_1 + h^I X_2 + g^M_F X_3 + h^M X_4 + R^I X_5 + R^M X_6 + e_{ijkl}$ (Model 2) Where: M =

intercept (general level of local Arsi breed)

L_i = the effect due to the i^{th} lactation number (i = 1...5 for milk and lactation length and = 1 or > 1 for calving interval

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

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

g^I_F = individual genetic effect of Holstein Friesians as deviation from Arsi breed. h^I = individual

heterosis effect.

g^M_F = maternal additive genetic effect of Holstein as deviation from Arsi 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.

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 X_1 to X_6 of the different breed groups see Table 1.

Results and Discussions

Non-genetic effects

Least square mean milk yield and lactation length by lactation number is presented in Table 2. Milk yield increased from first to fifth lactation with a slight decline on the fourth lactation. There was a marked increase in milk yield from the fourth to the fifth lactation partly because animals with low milk yield were culled by about the fifth lactation in order to retain high producer cows in the herd. Hirooka and Bhutyan (1995) also reported a similar rise in milk yield on the seventh and eighth lactation. Goshu and Mekonnen (1997) reported higher milk yield for the fourth and fifth lactation in Fogera-Friesian crosses at Gonder Breeding Station, Ethiopia, whereas Mackinnon *et al*. (1996) reported a decrease in milk yield and lactation length after the third parity on crosses of indigenous cows with Ayrshire, Brown Swiss and Sahiwal in Kenya. Martinez *et al*. (1988) also reported that age difference, i.e. difference of lactation number, is one of the most important non-genetic sources of variation in milk yield.

Lactation length was significantly highest for cows in lactation number one than other lactations. There is no significance difference between the second to the fifth lactations (Table 2). The estimated least square mean lactation milk yield and lactation length by season were higher for June to July (first parts of wet seasons) than other seasons (Table 3). This might be attributed to the availability of feed and improved management system. The estimated least square mean lactation milk yield and lactation length by year group are presented in Table 4. Lactation milk yield increased from year group 1 to 3 (1968 to 1979) and decreased thereafter to 1994 and increased slightly to the group ending in 1994. Cows that calved during the period 1976 to 1979 had significantly the highest lactation milk yield. A similar pattern was observed on lactation length. Although there was no consistent trend, estimated least square mean calving interval was highest for cows that calved during the period 1976 to 1979 and lowest for the period 1990 to 1994. This inconsistent trend might be attributed to changes in level of management such as changes in feed and feeding systems. Poor heat detection and time of insemination increase postpartum anestrus interval and days-open which in turn influence calving interval. Efforts to control these interrelated factors must be a regular part of dairy management.

Breed group effect

Breed group effect was highly significant ($p < 0.0001$) for lactation milk yield. Estimated least square means of lactation milk yield increased as proportion of Holstein Friesian blood increased (from 0 to 15/16 (Table 5). The 93.75% cross Holstein Friesian cows produced significantly the highest lactation milk yield followed by 87.5% Holstein Friesian crossbred cows. The local Arsi cows produced significantly the lowest lactation milk yield. Syrstad (1984) observed that a striking feature in some *Bos taurus* X *Bos indicus* crossbreeding project in the tropics is an increase in milk yields of higher grade *Bos taurus* crosses as environmental level improved. Given the tropical environment of the study area, the better milk production performance of high-grade crosses over the other crosses in this herd where management levels were good is supportive of this conclusion.

A similar result was reported in another crossbreeding experiment between local and Holstein Friesian breed at Debre Zeit Agricultural Research Center, where the pure Holstein Friesian and grade cows produced the highest lactation milk yield than the other breed groups (Million Tadesse, 2001). Mason and Buvanendran (1982) and Hirooka and Bhutyan (1995) also reported high milk yield by exotic breed in tropics when animals were well fed and managed indicating that the genetic potential of genotype depends on the level of management.

The high grade Holstein Friesian crosses (> 75%) had significantly ($p < 0.05$) longer calving intervals while F_1 and the Arsi breeds had shorter calving intervals (Table 5). The mean calving interval for Arsi breed was 403 ($\pm$40) days which is lower than 474 days reported for Horro breed in Ethiopia by Goshu and Mekonnen (1997). Similarly Kiwuwa *et al* (1983) reported 439 days of calving interval for the Arsi breed at Asella station of Arsi livestock breeding farm. The longer calving interval for high grade Holstein Friesian crosses is related to environmental effect such as heat stresses, which affect postpartum estrus interval and days to conception negatively. Good reproductive management together with appropriate feeding system is needed for better performance.

Crossbreeding parameters

Estimates of individual breed additive, individual heterosis and maternal recombination effects for lactation milk yield, lactation length and calving interval are shown in Table 6. Individual breed additive effects were large ($p<0.001$) for all traits. The individual additive genetic effect of Holstein Friesian cows was estimated to have 2297 kg significantly more milk yield, 231 days longer calving interval and 198 days longer lactation length above the contemporary Arsi cows. This estimated additional lactation milk yield is greater than the similar breed additive difference of 1345 kg reported in crosses between Sahiwal and Brown Swiss (Mackionnen et al., 1996) but in agreement with breed additive difference of 2860 kg milk yield reported for crosses between Holstein Frisian and Gir breed in Brazil, (Madalena 1982) and close to the 2220 kg lactation milk yield for crosses between Holstein Friesian and Barca breed at Debre Zeit Agricultural Research Center in Ethiopia (Million Tadesse, 2001).

Estimate of individual heterosis with respect to Holstein Friesian and Arsi breed genes had positive effects and approached significance ($p< 0.05$) for milk production, not significant for lactation length, while negative and significant ($p < 0.01$) for calving interval (Table 6). The estimate of 313 kg heterosis effect on lactation milk yield for full heterozygosity is similar with estimate from other studies. For instance, Syrstad (1984) reported heterosis effects of 295 kg for total milk yield on crossbreeding of *Bos taurus* and *Bos indicus* breeds in the tropics; Million Tadesse (2001) also reported a similar 295 kg heterosis effect on milk yield on crossbreds of Barca and Holstein Friesian at Debre Zeit, Ethiopia. However, Mackinnon *et al*. (1996) reported a much larger estimate of 616 kg for total milk yield in crossbreds of Ayrshire and Sahiwal in Kenya.

A reason for lower heterosis effects in *Bos taurus* x *Bos indicus* crosses may be a good production environment (Barlow, 1981; Kahi, *et al*., 1995). Cunningham (1981) suggested that when there is a substantial difference between the F_1 and the local breed, it is likely that there is genotype by environmental interaction where production in poor environment is influenced heavily by heterosis. Production in a good environment is largely determined by breed additive effects and small heterosis effects. The large breed additive effects and small effects of heterosis obtained in this study, according to this suggestion, are indicative of a good production environment at the Asella station.

Estimate of maternal recombination effect was negative and large ($p < 0.05$) for milk yield and negative ($p > 0.05$) for lactation length (Table 6). This result is contrary to the estimate of large and positive value for milk yield in crosses of Ayrshire, Brown Swiss and Sahiwal cattle in Kenya (Mackinnon et al., 1996). Evidence for recombination loss in *Bos indicus* x *Bos taurus* crosses in tropical environments has always been based on the decline in performance from F_1 to F_2 or back cross generations (McDowell, 1985; Cunningham and Syrstad, 1987; Syrstad, 1989). But according to Syrstad (1989), such a decline could have a variety of causes other than recombination. The evidence for large and negative value of maternal recombination effect on lactation milk yield in this study is not strong because the effect of genotype is confounded with the effect of year of calving as indicated by the small average value and narrow range of coefficients of recombination.

Despite the uncertainty in magnitude of the contribution of recombination, the results presented here clearly support the conclusion reached by Cunningham (1981) that in crossbreeding between *Bos taurus* and *Bos indicus* breeds in the tropics additive effects could be more important than heterotic effects in suitable environments on the premise that the level of management of this experimental herd in Asella was good during the study period.

Table 1. Number of records (N) and genetic composition of crossbreeds between Arsi breed (A) and 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.

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

Table 2. Least squares means and standard errors (s.e) for lactation number on milk yield and lactation length (LL)

Lactation	Milk yield (kg)		LL (days)	
	Mean	s.e	Mean	s.e
1	1903.55C	74.43	431.62A	10.12
2	2044.16B	85.38	395.27B	12.19
3	2071.24B	116.06	396.69B	17.37
4	2056.18B	171.14	378.34B	28.22
5	2551.84A	236.06	371.46B	41.37

Within variable groups, row means followed by the same letter do not differ significantly

Table 3. Least squares means and standard error (s.e) of season of calving for lactation milk yield and lactation length

Season	Milk yield (Kg)		LL (days)	
	mean	s.e	Mean	s.e
January-February	2050.93C	130.12	389.80A	19.76
March-May	2041.18C	119.08	389.58A	16.83
June-July	2320.95A	116.77	420.48A	19.22
August-September	2018.50C	121.94	373.39A	19.05
October-December	2195.43B	102.79	400.14A	15.39

Within variable groups, row means followed by the same letter do not differ significantly

In general, the crossbreeding experiment utilizing Holstein Friesian and Arsi breeds resulted in large variations in milk yield among the breed groups. The high grade Holstein Friesian crosses had higher lactation milk yield but longer lactation length and calving interval over other crosses, which indicate poor reproductive management. The importance of individual heterotic effects relative to the individual additive genetic effects was low.

Table 4. Least Squares means and standard error (s.e) for year groups of calving on lactation milk yield, lactation length (LL) and calving interval (CI).

Yg	Milk yield (kg)		LL (days)		CI (days)	
	Mean	s.e	Mean	s.e	Mean	s.e
1	1738.37G	310.05	394.13AB	38.40	523.01BA	51
2	1915.60FC	259.92	406.43A	30.27	507.08B	40
3	2658.05A	164.48	435.78A	29.62	584.23A	31
4	2433.53B	142.08	401.81A	22.88	564.99A	32
5	2079.18C	93.31	369.55B	17.82	503.16B	17
6	1995.28D	99.89	367.31B	17.40	458.20C	22
7	2057.75ECD	109.50	387.72B	19.21	514.29B	26

Within variable groups, row means followed by the same letter do not differ significantly

Due to the unbalanced structure of the data, it is difficult to have definitive conclusions. However, based on lactation milk yields alone upgrading to higher Holstein Friesian blood appears worthwhile to the type and level of environment and management in Asella farm, but with careful management of reproduction to keep lactation length and calving interval within reasonable good limits. It is also important to put an appropriate mating system in place to ensure maintenance of the desired blood level in the crossbreds

Table 5. Least squares means, proportion of Holstein Frisian and Standard error (s.e) for breed groups (BG) on lactation milk yield, lactation length (LL) and calving interval (CI)

BG	Prop. of HF	Milk yield (Kg)		LL (days)		CI (days)	
		Mean (kg)	s.e	LL	s.e	CI	s.e
1	0	1026.37I	209.71	286.72E	39.54	403D	40
2	0.5 (F_1)	2246.80F	128.46	389.25C	24.08	441C	28
3	0.5 (F_2)	1722.71H	181.18	429.78B	34.68	527B	35
4	0.25	1131.31I	188.49	321.85D	35.63	425CD	41
5	0.75	2496.60D	131.47	435.52B	24.71	509B	22
6	0.75	2087.35G	221.64	396.29C	41.57	529B	50
7	0.625	2075.37G	144.00	406.76BC	27.01	501B	28
8	0.75	2272.88EF	193.67	404.55BC	36.30	532B	38
9	0.875	2340.10E	158.20	413.66BC	29.67	616A	35
10	0.875	2697.40B	192.63	487.77A	36.11	614A	42
11	0.9375	2883.95A	302.43	503.82A	56.66	587A	63
12	0.875	2583.95C	246.94	450.99A	46.27	579A	57

Within variable groups, row means followed by the same letter do not differ significantly

Table 6. Estimated individual genetic effect, individual heterosis effect and the maternal recombination effect of Holstein dam for lactation milk yield, lactation length and calving interval

Parameters	Milk yield (Kg)		CI (days)		LL (days)	
	Mean	s.e	Mean	s.e	Mean	s.e
GL	1015.79***	290.98	390.29***	43.34	262.19 ***	54.52
G^I_F	2297.02***	238.43	213.00***	49.00	197.69***	44.89
H^I_{LF}	312.90*	150.17	-77.00**	28.94	9.56NS	28.15
R^M_{LF}	-602.00*	283.58			-60.07	52.98

*** p < 0.001; ** p < 0.01; * p <0.05 NS= Not significant

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