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Study on Age at First Calving, Calving Interval and Breeding Efficiency of *Bos taurus*, *Bos indicus* and their Crosses in the Highlands of Ethiopia

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Abstract

Data collected from 1968 to 1999 on age at first calving, calving interval and breeding efficiency from Asella, Debre Zeit and Holetta were used for this study. The breed group included in the study were Holestin Friesian, crossbred of Holstein Friesian and Jersey with local breeds (Arsi, Boran, and Barca). The effect of year, season, herd, parity and genetic group and partitioning of the later into additive and non-additive effects were analysed. Results indicate that the effect of breed, herd and season of birth significantly (P<0.05) affected age at first calving. For calving interval, all factors except season were significant (P<0.05). Mean age at first calving was significantly (P<0.05) shortest (32.22 months) for F_3 (½ J × ½ L) and longest (55.44 months) for (¼ HF × ¾ L) crosses. Mean calving interval were significantly (P<0.05) shorter (371.44 days) for (¾ J × ¼ L) and longest 516 days for 7/8 HF × 1/8 L. Breeding efficiency was significantly (P<0.05) highest (102%) for F_3 (½ J × ½ L) crosses and lowest (67%) for ¼ HF × ¾ L. Individual additive and heterosis effects on age at first calving were significant (P<0.05) and estimated at -7.9 and -11, 34 months, respectively. The individual additive, individual heterosis, maternal additive, maternal heterosis and maternal recombination were significant (P<0.01) on calving interval and estimated at 104.77, -72.38, -51.89, -62.66 and -168.25 days, respectively. Breeding decisions aiming to increase herd productivity should be determined not only by lactation milk yield but also by reproductive performance of animals under the production environment.

Keywords: reproductive performance, *Bos taurus*, *Bos indicus*, crosses, Ethiopia

Introduction

The indigenous cattle of Ethiopia are well adapted to the environment in the tropics. This is from the fact that they possess a high degree of heat tolerance and resistance to most of endemic diseases. However, their potential for milk production is poor. One way of improving tropical cattle regarding milk production is by crossbreeding with *Bos taurus* (or European type) dairy breeds. Such crossbreeding of European dairy breeds with indigenous cattle in tropical areas has been widely used as method to combine the high milk yield of exotic breeds with the adaptability of local breeds. Apart from the additive contribution of each breed to meet those requirements, there are also large non-additive heterosis effects in milk yield and reproductive traits which combine to give a large advantage in total productivity to the first generation (F_1) of these crosses (Cunningham and Syrstad, 1987). However, much of this heterosis seems to be lost in subsequent generation (Syrstad, 1989), thus wasting some of the genetic potential of such crosses. In a review of dairy cattle crossbreeding 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 reproductive traits. 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 (Mackinnon et al., 1996). In this study data from crossbreeding experiments in herds located in the highlands of Ethiopia were used to: (1) evaluate the environmental and genetic effect on age at first calving, calving interval and breeding efficiency of crossbred dairy cows; (2) identify a breed combination which provides an optimal performance; and (3) determine breed additive and non-additive effects and their interaction with herd (environment).

Material and methods

Herd description and management

Data collected between 1968 and 1999 on age at first calving and calving interval and breeding efficiency from dairy herd at Asella, Debre Zeit and Holetta, Ethiopia were analysed. Asella station is located in a highland plateau about 275 km south east of Addis Ababa, Ethiopia. Its altitude is 2000 m.a.s.l. and received an average annual rainfall of 1300-1350 mm. Crossbreeding at Asella station was started in 1967/68 with the objective of producing F_1 heifers consisting of 1/2 *Bos indicus* and 1/2 *Bos taurus* genes. The F_1 would later be upgraded to produce animals with varying proportions of *Bos taurus* genes (CADU, 1970). Holetta Research centre is located in highland area about 50 km west of the capital, Addis Ababa town. Crossbreeding involving HF and Jersey with local Boran and Horro breeds to produce different crossbred animals ranging from 25% to 75% of both HF and Jersey has been underway for more than 40 years.

Debre Zeit Agricultural Research Centre is located at an elevation of 1900 m.a.s.l. An average annual rainfall was 851 mm with daily mean temperature varying from 9 to 27°C and an overall mean of 19.1°C. The Debre Zeit dairy herd were established during 1971. In 1972, 28 Barca heifers were bought from Eritrea and were mated to Barca bulls to generate station-born heifers. Subsequently, both parental cows and their first female offspring were assigned to (Holstein Friesian (HF) bulls to generate up graded animals of different Holstein Friesian inheritance. Breeds included in the study were as follows.

Beeed Code	Acronym
HF	Holstein Friesian
L	Local zebu breeds (Boran, Arsi and Barca),
1/4HF×3/4L	(25% Holstein Friesian ×75% Local)
F_1 (½ HF× ½ L))	(50% Holstein Friesian ×50% Local),
F_1 (½ J× ½ L)	(50% Jersey ×50% Local)
F_2 (½ HF× ½ L)	{(1/2 Holstein Friesian ×1/2 Local),×(1/2 HF×1/2 Local)}
F_2 (½ J× ½ L)	{(1/2 Jersey ×1/2 Local),×(1/2 Jersey ×1/2 Local)}
F_3 (½ HF× ½ L)	{{(1/2 Holstein Friesian ×1/2 Local),×{(1/2 Holstein Friesian ×1/2 Local)× (1/2 Holstein Friesian ×1/2 Local)}}
F_3 (½ HF× ½ L)	{(1/2 Jersey ×1/2 Local),×{(1/2 Jersey ×1/2 Local)× (1/2 Jersey ×1/2 Local)}}
5/8HF×3/8L	(62.5% Holstein Friesian ×37.5%Local)
5/8J×3/8L	(62.5% Jersey ×37.5% Local)
3/4HF×1/4L	(75% Holstein Friesian ×25% Local)
3/4J×1/4L	(75% Jersey ×25% Local)
$(3/4H×F1/4L)^2$	{(75% Holstein Friesian ×25% Local)× (75% Holstein Friesian ×25% Local}
$(3/4J×1/4L)^2$	{(75% Jersey ×25% Local) (75% Jersey ×25% Local)},
7/8HF×1/8L	(87.5% Holstein Friesian ×12.5%Local)
1/4HF×1/4J×1/2Local	(1/4% Holstein Friesian ×1/4% Jersey ×1/2 Local),
5/8HF×2/8J×1/8L	(5/8 Holstein Friesian ×2/8 Jersey ×1/8 Local)
5/8J×2/8HF×1/8L	(5/8 Jersey ×2/8 Holstein Friesian ×1/8 Local)

Data analysis

Least squares analysis of variance was carried out using General Linear Model (GLM) procedures of SAS (2000). Three models were used for data analysis, the first model (model 1) was used to compare among breed groups

with respect to age at first calving, calving interval and breeding efficiency. The second model (model 2), multiple regression analysis was used to estimate contribution of individual and material additive genetic effects, heterosis, recombination loss and interaction of additive and heterosis with environment (herd). For comparison among breed groups (model 1) the effects included in the model were herd of cow, breed group, lactation number, season and year (season and year of birth for age at first calving and season and year of calving for calving interval and breeding efficiency). The years of calving/birth ranged from 1969 to 1999 and were grouped into 4 periods each period consisting of 8 years; Period 1 included from 1969 to 1975, period 2 from 1975 to 1982, period
3 from 1983 to 1989 and period 4 from 1990 to 1999.

For season of birth and calving, months of the year were classified into 3 seasons based on rainfall distribution; dry season from October to February, short wet season from March to May and long wet season June to September. Five Parities of dam were considered consisting of the first through fifth.

Statistical model for data analysis

Model 1 for comparison among breed groups:

$y_{ijkl} = \mu + H_n + L_i + S_j + P_k + B_l + e_{ijkl}$, where:

y_{ijkl} = Age at first calving, calving interval and breeding efficiency of an individual animal with lactation I, in season j, year groups k of breed group L and in herd n.

μ = underlying constant common to all animals H_n = the

effect due to n^{th} herd of cow (n=1...3)

L_i = the effect due to the i^{th} lactation number (i = 1...5) for calving interval and breeding efficiency

S_j = the effect due to j^{th} season (J=1...3) season of birth for age at first calving and season of calving for calving interval and breeding efficiency

P_k = the effect due to the k^{th} year group of birth/calving (k = 1...4) year group of birth for age at first calving and year group of calving for calving interval and breeding efficiency

B_l = the effect due to the l^{th} breed group (l = 1...19) e_{ijkl} =

random error effect.

Breeding efficiency is used for comparisons among breed groups with respect to their suitability / adaptability. It is a measure based on the regularity of calving and the age at which cows first calve. If an animal calves late for the first time its maintenance costs as a fraction of total costs tend to increase and its life time production tends to decrease (Kiwuwa et al., 1983). The following method was used for evaluation of breeding efficiency (BE):

$BE = \{(N-1)390 + 960\} / \text{(age at each calving)}$

Where, N-1 = the number of calving intervals with N calving; 390 = is the upper limit of desirable calving intervals (days); 960 = is the upper limit of age at first calving (days). The estimated coefficients were expressed as percentage.

Model 2 for estimation of crossbreeding parameters:

$y_{ijkl} = \mu + L_i + S_j + P_k + H_n + g^I X_1 + h^I X_2 + g^M X_3 + h^M X_4 + R^I X_5 + R^M X_6 + (g^I \times H_i) + (h_I \times H_n) + e_{ijkl}$ Where:

μ = intercept (general level of local breed)

H_n = the effect due to n^{th} herd of cow (n=1…3)

L_i = the effect due to the i^{th} lactation number (i = 1…5)

S_j = the effect due to j^{th} season of birth and calving (1…3). P_k = the effect due to the k^{th} year group (k = 1…4)

g^I = individual 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.

X_1 = proportion of genes from Holstein Friesian. X_2 = proportion of maximum individual heterosis.

X_3 = proportion of genes from Holstein Friesian 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.

$H_n \times G_i$= interaction of breed additive with herd $H_n \times H_i$ =

interaction of heterosis with herd

e_{ijkl} = random error

The proportions of *Bos taurus* genes, individual and maternal heterosis, individual and maternal recombination effect (x_1 to x_6) were considered as continuous variables in model 2.

Results and discussions

Year and season effects

Least square means of year group, season, herd and parity effects on age at first calving (AFC), calving interval (CI) and breeding efficiency (BE) are presented in Table 1. Year of birth had no marked effect on age at first calving. Mean calving interval increased from period one (1969 to 1975) to period three (1983 to 1989) and slightly decreased then after. This shorter calving interval during period 1 and longer one during period 3 attributed to change in management such as feed, health and reproductive management. Similar significant effect of year on calving interval was reported in crossbreeding experiment conducted at Abarnosa ranch, Ethiopia, (Ababu Dekeba 2002). Kiwuwa et al. (1983) also reported significant effect of year of calving on calving interval in crossbreeding HF and Jersey with local breeds at Asella dairy farm.

Mean breeding efficiency was significantly (P<0.05) decreased from period 1 (1969 to 1975) to period 3 (1983 to 1989). The highest breeding efficiency during period 1 was related to the better performance in age at first calving and calving interval of cows during this period. Similar significant effect of year on BE was also reported on crossbreeding HF with local Arsi breed at Asella dairy herd (Million Tadesse 1997). Kiwuwa et al. (1983) also reported significant year effect on breeding efficiency in crossbreeding HF and Jersey with local breeds.

Season effect was significant (P<0.05) for age at first calving but not for calving interval and breeding efficiency. Heifers born during long wet season calved at younger age (41.4 months) and calving interval was slightly shorter for cows calved during this period. In contrast, Melaku Negash (1994) did not find any effect of birth season on age at first calving in HF dairy herd at Holetta. Likewise, Hirooka and Bhutyan (1995) did not find any effect of season of birth on age at first calving in HF and local crosses. The better age at first calving during long wet season could be related to availability of green feed during the mating period and its positive effect to cyclicity in the breeding cows. The non-significant season of calving on calving interval in the present study indicated that the similarity in management across seasons. This finding is in agreement with report by Hirooka and Bhutyan (1995). Singh and Rout (1980), Mekonnen and Goshu (1987), Sharma *et al*. (1988) and Enyew (1992) didn't find difference between seasons of calving on calving interval on the study of different indigenous breeds. On the other hand, significant effect of season was observed by Mekonnen and Goshu (1987) and Alemu et al. (1988) on Boran cattle at Abarnosa ranch and Asheber Sewalem (1992) and Addisu Bitew (1999) on Fogera cattle. These different results on calving interval attributed to different in feeding and breeding management provided to the animal.

Table 1. Least square means on age at first calving (AFC), calving interval (CI) and breeding efficiency (be) for year, season, herd and parity effects

Year group	AFC (months)			No	CI (Days)		BE (%)	
	No	Mean	S.e		Mean	S.e	Mean	S.e
1969-1975	25	40.61a	2.1	49	403.6d	23.27	110a	7
1976-1982	118	43.80a	1.1	213	451.5c	14.61	88b	1
1983-1989	117	42.50a	1.2	238	476.6a	12.11	79c	1
1990-1999	182	42.67a	1.6	837	460bac	11.74	78c	1
Season								
Short wet season	141	42.3bac	1.1	324	449.7ns	11.45	87a	1
Dry season	106	43.5a	1.1	328	453.1ns	11.71	88a	1
Long wet season	195	41.3c	1.0	685	441.3ns	10.47	87a	1
Herd effect								
Asella	102	41.4b	1.4	165	448.1b	15.90	88b	2
Debre Zeit	105	37.6c	1.6	414	429.5b	13.23	96a	2
Holetta	215	48.5a	1.3	758	466.5a	15.38	81c	2
Parity								
1				409	471a	10.22	88c	1
2				339	469ba	10.85	86c	1
3				210	429d	12.75	87c	2
4				146	443cde	14.59	90b	2
5				233	428ed	14.99	92a	2

Means within a column followed by different superscripts are significantly different

Herd effect

Heifers at Debre Zeit herd were produced the first calf significantly ($P<0.05$) at younger age (37.38 months) followed by heifers at Asella herd (41.35 months), while heifers at Holetta herd calved significantly at older age (48.46 months). Mean calving interval was significantly ($P<0.05$) longer (467 days) at Holetta herd, while the difference between Asella and Debre Zeit herds was not significant. This difference in age at first calving and calving interval across herd attributed to the difference in management (feed, health and reproductive) provided to the animal. Mean breeding efficiency was significantly highest 96% at Debre Zeit herd followed by Asella (88%) and significantly ($P<0.05$) lowest (81%) at Holetta herd. The better breeding efficiency of cows from Debre Zeit herd is related to shorter age at first calving and calving interval.

Parity effect

Although there is no consistent trend calving interval slightly decreased from parity one to parity three and increased from parity three to parity four and decreased then after. Bhatnagar et al. (1986), Addisu Bitew (1999) and Wilson and Traore (1988) reported significant effect of parity on calving interval. The shorter calving intervals at later parities are a function of selective culling against repeat breeder cows and were as expected for a well managed herd. Similar result of shorter calving interval for parity 5 and above was reported for HF and Gir crosses (Hirooka and Bhutyan 1995). Shorter calving interval for parity six and above was also reported on crossbreeding HF with local breed at Debre Zeit (Million Tadesse 1997). Kiwuwa et al. (1983) also reported a declined calving interval from parity on to parity 4 on crossbreeding of HF and Jersey with local breeds at Arsi. Melaku Negash (1994) reported shorter calving interval for parity 6 and above on reproductive performance of HF dairy cattle herd at Holetta. The difference in breeding efficiency for parity 1, 2 and 3 were not significant and significantly ($P<0.05$) increased from parity 3 to 5. The better breeding efficiency for latter parities is attributed to shorter calving interval obtained for the same parities.

Breed group effect

Least square means of breed group effect on age at first calving, calving interval and breeding efficiency are presented Table 2. Mean age at first calving was significantly ($P<0.05$) longest 55.44± 2.7 months for 25% HF (1/4HF×3/4L) crosses and significantly shortest 32.22±3.3 months for F_3 (½J× ½ L) crosses). Mean calving interval was significantly ($P<0.05$) longest 516.66±21.68 days for 87.5% (7/8HF×1/8L) crosses and significantly ($P<0.05$) shortest 371.44 ±34.62 days for 75% Jersey (3/4J×1/4L) crosses. Mean breeding efficiency was significantly ($P<0.05$) highest (102%) for F_3 (½J×½L) Jersey crosses and lowest (67%) for 25% HF (1/4HF×3/4L) crosses.

Table 2. Least square means of breed group effect on age at first calving (AFC), calving interval (CI) and breeding efficiency (BE)

Breed	AFC (Months)			CI (Days)			BE (%)	
	No	Mean	S.e	No	Mean	S.e	Mean	S.e
L	5	43.77dcb	4.2	204	419.52h	11.63	84cd	2.2
HF crosses								
1/4HF×3/4L	13	55.44a	2.7	8	429.04fe	49.37	67e	3.4
F_1 (1/2HF×1/2L)	48	35.91fe	1.3	226	438.90fe	10.49	93b	3.3
F_2 (1/2HF×1/2L)	28	41.91dcb	1.8	100	494.66ba	15.45	88c	1.7
F_3 (1/2HF×1/2L)	14	45.60b	2.6	23	457.01dc	29.08	84cd	2.6
5/8HF×3/8L	45	44.36b	1.5	77	466.52dc	17.70	87c	1.8
3/4HF×1/4L	83	40.77dcb	1.2	211	479.23cb	12.92	87c	1.4
$(3/4HF×1/4L)^2$ inter se	11	45.32b	2.7	21	438.72fe	29.97	89c	2.7
7/8HF×1/8L				62	516.66a	21.68	85c	1.9
HF	8	42.59dcb	3.2	77	479.74cb	17.26	80d	2.6
Jersey crosses								
F_1 (1/2J×1/2L)	15	38.61e	2.5	92	417.02	16.35	94b	1.8
F_2 (1/2J×1/2L)	23	44.43b	2.1	83	486.09ba	17.03	89c	1.9
F_3(1/2J×1/2L)	8	32.22g	3.3	5	429.03fe	60.50	102a	4.6
5/8J×2/8L	12	39.74dcb	2.8	22	377.09j	30.07	95b	2.9
3/4J×1/4L	6	46.91b	3.8	16	371.44j	34.62	96b	3.0
$(3/4J×1/4L)^2$ *inter se*	4	34.25fe	4.6	7	440.52ed	51.19	96b	4.4
1/4HF× 1/4J×1/2L	45	43.42cb	1.8	73	447.78dc	18.56	87c	1.9
5/8HF×2/8J×1/8L	9	40.07dc	3.1	12	450.27dc	39.75	94ba	3.3
5/8J×1/4HF×1/8L	11	44.95b	2.9	18	472.91cb	32.88	86c	3.2

Means within a column followed by different superscripts are significantly different

Holstein Friesian crosses: Among Holstein Friesian crosses age at first calving significantly (P<0.05) increased by 4.86 months from F_1 (HF×L) to 75% (3/4HF×1/4L) crosses. The F_1 (½ HF× ½ L) crosses gave the first calf by 4.86 months earlier than 75% (3/4HF×1/4L) crosses. The breed group F_2 (½ HF× ½ L) crosses had significantly longer age at first calving by 6 months than F_1 (HF×L) and the breed group F_3 (½ HF× ½ L) had significantly longer age at first calving by 3.7 months than F_2 (½ HF× ½ L). Shorter age at first calving for 3/4 Exotic 1/4 Arsi crosses was reported in crossbreeding experiment at Asella station Kiwuwa et al. (1983). Rao and Tanega (1980) also reported shorter age at first calving for 1/2HF, 5/8HF and 3/4HF crosses on crossbreeding HF with Sahiwal crosses in India.

Mean calving interval significantly (P<0.05) increased by 40 days from F_1 (HF×L) to 75% (¾ HF×¼ L) and increased by 37 days from 75% (¾ HF × ¼ HF) to 87.5% (7/8 HF × 1/8 L). The F_2 (½ HF× ½ L) and F_3 (½ HF× ½ L) had significantly longer calving interval by 55.7 and 37.6 days than their parent F_1 (½ HF× ½ L) and F_2 (½ HF× ½ L) respectively. The F_1 (½ HF× ½ L) had better breeding efficiency than other breed groups. The breed group produced by inter se mating at 75% crosses (3/4HF×1/4L) had longer age at first calving, shorter calving interval and had better breeding efficiency than the 75% (3/4HF×1/4L) crosses. The relatively longer calving interval for grade HF crosses indicate problem with adaptation in tropical environmental condition. Similar longer calving interval of 525 days was reported for (7/8HF ×1/8 L) crosses in crossbreeding HF with local breed at Asella dairy farm (Kiwuwa et al., 1983). Gebeyhu Goshu (1999) also reported longer calving interval for grade dairy HF cows and Boran crosses at cheffa dairy farm, Ethiopia. The relatively longer age at first calving for F_3 (1/2 HF× ½ L) and calving interval for F_2 (½ HF×½ L) crosses can be ascribed to unfavourable parental breakdown of epistatic combinations which have been built up in the parental populations (Syrstad, 1989).

Jersey crosses: The breed group F_2 (½ J× ½ L) Jersey crosses had significantly (p <0.05) longer age at first calving (by 5.82 months) and longer calving interval (69.07 days) but had lower breeding efficiency (5%) than the F_1 (½ J× ½ L) crosses. The F_3 (½ J× ½ L) crosses produced the first calf significantly earlier (by 12.21 months) and had significantly shorter calving interval (57.06 days) than F_2 (½ J× ½ L). The F_3 (½ J× ½ L) had also better breeding efficiency by 8% than F_1 (½ J× ½ L) and by 13% than F_2 (½ J× ½ L). Similar longer calving interval was reported for F_2 crosses than F_1 in crossbred of local with exotic at Haringhata, India (Bala and nagarcenkar, 1981). Parmar et al., (1980) also reported longer calving interval for F_2 than F_1 in crossbreeding between Hariana and Jersey at Haringhata, India. The longer calving interval of inter se mated of at 75% $(3/4J×1/4L)^2$ breed group compared to their parent might be related to recombination losses (epistatic effect).

Three breed crosses: The three way crosses (5/8J×2/8HF×1/8L) had significantly (*P*<0.05) longer age at first calving than (5/8HF×2/8J×1/8L). The difference in age at first calving between (1/4HF×1/4J×1/2L) and (5/8J×2/8HF×1/8 L) was not significant. The difference in calving interval among three way crosses was not significant. Breeding efficiency was significantly (*P*<0.05) higher for (5/8HF×2/8J×1/8L) while the difference in Breeding efficiency between (5/8J×2/8HF×1/8L) and (1/4HF×1/4J ×1/2L) was not significant.

The difference in age at first calving between F_1 (½ HF× ½ L) and F_1 (½ J× ½ L) crosses was not significant, while the breed group produced by inter se mating at 50% F_3 (½ J× ½ L) and 75% (3/4J×1/4L) of Jersey inheritance had significantly (*P*<0.05) shorter age at first calving than the breed group produced by inter se mating of HF at similar level. In similar way the 62.5% Jersey (5/8J×3/8L) inheritance had significantly (P<0.05) shorter age at first calving than the 62.5% HF (5/8HF×1/8L) inheritance but the 75% (3/4J×1/4L) Jersey inheritance had significantly longer age at first calving than the 75% HF crosses (3/4HF×1/4L). Calving interval was shorter for Jersey crosses compared to HF crosses and in most cases breeding efficiency was also higher for Jersey crosses than HF crosses indicating the superiority of Jersey crosses over HF crosses in terms of adaptation in harsh tropical environment. Similar shorter calving interval was reported for Jersey crosses compared to HF crosses in crossbreeding of Jersey and HF with local at Asella dairy herd, Ethiopia (Kiwuwa et al., 1983).

Crossbreeding parameters

Estimates of additive and heterosis effects for individual and maternal traits are presented in Table 3. The individual breed additive and individual heterosis effect were significant (P<0.05) on age at first calving while individual additive, individual heterosis, maternal heterosis and maternal recombination effects were significant (P<0.05) for calving interval. The individual breed additive effect was estimated at -7.9 months for age at first calving and 104.77 days for calving interval. Individual heterosis effect was estimated at -11.34 months for age at first calving and -72.38 days for calving interval. The significant and large individual additive genetic effects 104.77 days obtained in this study on calving interval is lower than the 213 days reported on crossbreeding HF with Arsi breed at Asella station Ethiopia (Million Tadesse, 1997). The significant and negative estimate of 72.38 days heterosis effect on calving interval in this study is similar with negative heterosis effect of 77 days of calving interval on crossbreeding HF with Arsi breed at Asella station (Million Tadesse, 1997). Syrstad (1984) reported negative heterosis effects (-30.3 days) for calving interval on crossbreeds of *Bos taurus* × *Bos indicus* in the tropics. Mandalena (1981) reported heterosis effect of positive 37 days at dry season and 129 days (22%) in rainy season on calving intervals between Holstein × Gir crosses. The lower heterosis effect obtained in this study compared to most of literature reports might be related to difference in environments in which the animals were kept. The significant individual heterosis on age at first calving and calving interval in this study between local and exotic genes is in accordance with the theory of heterosis which predicts that the wider the genetic distance or the greater the phenotypic differences between parental breeds, the greater the heterosis expressed.

Maternal heterosis effect was estimated to be positive 2.65 months for age at first calving and negative 62.66 days for calving interval. The negative value obtained for maternal heterosis on calving interval may imply that recombination loss is involved. Hirooka & Bhutyan (1995) obtained similar negative and significant estimate of maternal heterosis on crossbreeding of local × Friesian cross at Bangladesh, while Ahlborn-Breier & Hohenbhoken (1991) did not find any significant maternal heterosis between Bos Taurus and Bos indicus crosses. The individual and maternal recombination effect was not significant on age at first calving, while maternal recombination effect was significant (*P*<0.01) for calving interval and estimated to be negative 168.25 days.

Table 3. Estimated Genetic parameters and standard error for age at first calving and calving interval

Genetic parameter	AFC (months)		CI (days)	
	Estimate	S.e	Estimate	S.e
Additive breed effect	-7.9**	3.4	104.77**	82
Individual heterosis effect	-11.34**	2.4	-72.38**	42
Maternal additive effect	NA		-51.89**	81
Maternal heterosis effect	2.65NS	2.6	-62.66**	31
Individual recombination effect	-2.17NS	6.7	260.63NS	101
Maternal recombination effect	-2.68NS	4	-168.25**	47

*** *P*<0.0001; ** *P*<0.05; NS = not significant

Interaction effect

Results on interaction of both additive and heterosis effect with herd are presented in Table 4. The difference between pure Bos Taurus and Bos indicus breed (breed additive effect) were estimated to 115.83± 84 days at Asella herd,

111.54± 91 days at Debre Zeit herd and 86.93±97 days at Holetta herd. Interaction of heterosis with herd was significant (*P*<0.05) and estimated to be negative 132 days at Asella herd, -43 days at Debre Zeit herd and -41 days at Holetta herd. The Average performance of a group of animals is determined by the genetic capacity and by the environmental conditions in which the animals are kept. The genetic and environmental components interact when genetic differences between animals are larger in one environment than in another. Both, additive and heterosis effects can vary with environmental level. Rich and Bell (1980) demonstrate experimentally in Drosophila that the percentage of heterosis can be more than twice as much in a nutritionally poor environment than under good nutrition. This large and significant difference in breed additive and heterosis effect across herd in this study is attributed to the environmental differences (differences in feeding, breeding and climate) in which the animals are kept.

Table 4. Interaction effects of additive and heterosis by herd on calving interval

Interaction	Asella	Debre Zeit	Holetta
Additive by herd	115.83±84a	111.54±91ba	86.93c±97c
Heterosis by herd	-132±55a	-43±49b	-41b±50cb

Means within a column followed by different superscripts are significantly different

Conclusions

The shorter age at first calving, calving interval and better breeding efficiency of F1 than F_2 of both HF and Jersey crosses with local breed indicate the superiority of F_1 over other crosses. The pure HF breed and grade animals had longer age at first calving, calving interval and lower breeding efficiency indicating problems with adaptability in tropical environment. In most cases the Jersey crosses had shorter age at first calving and calving interval and had better breeding efficiency than the Holstein Friesian crosses indicating the suitability of Jersey crosses in tropical environment than HF crosses. The Individual heterosis effect was more important compared to individual breed additive effect and this vary with environmental and management level as indicated by significant difference in breed additive and heterosis effect across herd. Based on breeding efficiency which combine both age at first calving and calving interval and significant and large heterosis effect the optimum breed combination is about equal proportion of exotic and local inheritance, however to maintain heterosis advantage obtained in F_1 generation back crossing F_1 female with pure exotic bull to produce 75% or alternatively mating F_1 female with 75% exotic inheritance bull to produce 62.5% exotic inheritance is the best strategy. In general, breeding decisions aiming to increase herd productivity will be determined not only by lactation milk yield but also by reproductive performance of animals and the environment at which the animal kept.

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