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REGULAR ARTICLES

Genetic analyses of early-expressed reproduction traits of Boran and their crosses with Holstein Friesian and Jersey in Central Highlands of Ethiopia

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Abstract The study was conducted to assess early-expressed reproductive traits of Boran cattle and their crosses with Jersey and Holstein Friesian (HF). The traits studied were age at first services (AFS), number of services for first conception, age at first calving (AFC), first dry period (FDP), first calving interval (FCI), and first service period (FSP). Genetic group and period of birth/calving had a significant ($p<0.05$) effect on reproductive traits. The Boran cattle were inferior to HF or Jersey crosses. First crosses (F_1) for Jersey and Boran (50 % Jersey: 50 % Boran) showed a significantly ($p<0.05$) younger AFS (by 7.25 months) and AFC (by 10.75 months), had shorter FCI (by 63.27 days), FDP (by 61.13 days), and FSP (by 60.3 days), and needed less (by 0.35) numbers of services per first conception as compared to the Boran cattle. The F_1 for Jersey and Boran (50 % Jersey: 50 % Boran) crosses showed better performance than the F_1 for HF and Boran (50 % HF: 50 % Boran). Heritability values for AFS and AFC were the highest and were estimated at 0.51±0.10 and 0.49± 0.13, respectively, and lowest heritability was recorded for FDP (0.02±020) and FSP (0.10±0.29). The genetic correlation was highest (0.10±0.20) between AFS and AFC and was lowest (−0.01±0.66) between FCI and FSP. The breed additive for Jersey was only significant ($p<0.01$) for AFS and AFC. The crossing of HF with Boran cattle has desirably reduced 9.16±2.88 months in AFS; the corresponding reduction in AFS was 3.49±3.59 months by crossing with Jersey. The performance comparisons and genetic and crossbreeding parameters indicated that crossbreeding of Boran with HF or Jersey can improve reproductive performance.

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Introduction

Efficient reproductive performance in a dairy herd is a key indicator in ensuring profitability. The number of calves dropped in a herd per cow has an implication on herd replacement and genetic improvement. Production, marketable milk, and profit margin from the dairy sector are dependent on reproductive performance. Cows which calve early needed few services per conception, and possessing shorter calving intervals is preferred. Differences in reproductive performances are largely because of environmental effects although small, between-, and within-breed genetic differences also contribute to the variation (Demeke et al. 2004). The comparison of reproductive performance traits expressed at an early age is important to make decisions with respect to culling in a herd.

The knowledge of early-expressed reproductive traits facilitates prediction of future performance of an individual cow as well as a herd. Feeding, housing, and veterinary services of cows which are unproductive have an implication on the profitability of the dairy enterprise. Local cows such as Boran are alleged for poor production and reproductive performance (Demeke et al. 2004; Haile et al. 2009; Kefena et al. 2011). To improve reproductive performance, purebred European dairy cattle (mainly Friesian) and crosses of Friesian and Jersey with indigenous breeds are commonly used in the highlands of Ethiopia. Because of the lack of clearly defined breeding policy, many farmers often keep mixed purebred and a variety of crossbred cows for their perceived good milk production, reproduction, and adaptability to physical and socioeconomic environments (Demeke et al. 2004; Kefena et al. 2011). The studies conducted to compare crosses and indigenous cattle and estimates of genetic parameters for early-expressed reproductive performance traits are scanty in Ethiopia, and the few studies available have been focused on lifetime reproductive performance. This study is aimed to compare the performance of the different genotypes, assess the non-genetic factors, and estimate genetic parameters for early-expressed reproductive traits.

Materials and methods

Source of information

Data were obtained from Holeta Agricultural Research Center, managed by the Ethiopian Institute of Agricultural Research (EIAR) in one farm from 1980 to 2006 (Table 1). Cattle were the progeny of 691 dams and 112 sires. The number of sires used from the different genotypes involved in the crossbreeding program were 21 Boran (Bo), 20 Jersey (J), 42 Holstein Friesian (HF), 16 HF×Bo, and 13 J×Bo.

Description of the Holeta Agricultural Research Center

Holeta Agricultural Research Center is located 35 km west of Addis Ababa, Ethiopia, at 38.5°E longitude and 9.8°S latitude, and has an elevation of 2,400 m above sea level. The average annual rainfall is about 1,200 mm, most of it occurring between July and October. The dry season is from November to February, followed by the light shower season between March and June. The average monthly temperature is 17 °C with a minimum of 10 °C and a maximum of 26 °C.

Animals and management

Feeding of cattle comprised free grazing and concentrate supplementation. The animals were grazed on natural pasture for about 8 h during the day time. At night, all animals were housed and offered hay prepared from natural pasture. All animals had free access to clean water. All calves were weighed at birth and allowed to suckle their dams for the first 24 h to obtain colostrums, after which they were moved to individual calf pens for bucket feeding until 3 months. Each calf was fed a fixed total of 260 kg of whole milk up to 3 months of age. All calves were offered milk replacer at 90 days and kept indoors up to 6 months. Except for lactating cows which were supplemented with approximately 3–4 kg of concentrate at milking, no other animals received concentrate supplements. During indoor rearing, all calves were fed ad lib on hay and supplemented with approximately 1 kg of concentrate composed of 30 % wheat bran, 32 % wheat middling, 37 % noug seedcake (*Guzeta absynica*) and 1 % salt, per animal per day. All animals up to 6 months of age were grazed in a group on natural pastures for about 8 h a day and supplemented with hay at night. After 6 months of age, males and females were reared separately. Loose housing system was used to maintain the cows which provided adequate exercises. The animals were provided veterinary aid and prophylactic and sanitary measures as routine practices.

Classification of major effects

The fixed effects fitted in the model were genotype (seven classes: Boran, HF × Bo, HF × HFBo, HFBo × HFBo, J × Bo, JBo × JBo, J × JBo), calving/birth period of 3 years interval (nine classes: 1980–1982, 1983–1985, 1986–1988, 1989–1991, 1992–1994, 1995–1997, 1998–2000, 2001–2003, 2004–2006). A preliminary analysis was made to ascertain the effect of year. However, there was no meaningful variation observed over the years. As a result, years were grouped into periods consistent with trends in management of the herds that have increased a sample size for each period. Calving seasons were grouped into three classes, based on the pattern of annual rainfall distribution in the area (November to February, dry period; March to June, light showers; July to October, main rainy season).

Statistical analysis

Least squares analysis

To overcome the problem of non-orthogonality due to unequal subclasses, least squares analysis (SAS 2002) was employed. The pre-calving (age at first service (AFS), age at first calving (AFC), and number of services at first conception (NSFCON)) and post-calving (first calving interval (FCI), first service period (FSP), first dry period (FDP)) traits were analyzed for genetic group, season, and period of birth. Two-way interaction effects were fitted, and the effect which showed significant effect ($p<0.05$) was retained in the model. However, the interaction effects were not presented in this paper. Selected contrast was performed within each fixed effect to test for a significant difference between means of least squares using the Tukey–Kumar method.

Heritability, genetic and phenotypic correlations

Covariance components and genetic and phenotypic parameters (heritability, genetic, and phenotypic correlations) were estimated by an animal model using the derivative-free restricted maximum likelihood computer package of Meyer (1998). The (co)variance components and heritability were estimated using a multivariate animal model which fitted

Table 1 Number of heifers used in the analyses

Traits	Genetic groups			Total
	Friesian crosses	Jersey crosses	Boran	
AFS	478	255	89	822
AFC	513	236	112	861
NSFCON	685	301	89	1075
FCI	283	265	58	606
FDP	296	286	60	642
FSP	285	264	60	609

AFS age at first service, *AFC* age at first calving, *NSFCON* number of services at first conception *FCI* first calving interval, *FDP* first dry period, *FSP* first service period

direct additive effects (a) and random effects, and the model was explained as follows:

$$\mathbf{Y} = \mathbf{Xb} + \mathbf{Z_a a_a} + \mathbf{e}$$

where $\mathbf{Y}$ is the vector of records, $\mathbf{b}$ is a vector of an overall mean and fixed effects with incidence matrix $\mathbf{X}$, $\mathbf{a_a}$ is the vector of random additive direct genetic effect with incidence matrices $\mathbf{Z_a}$, and $\mathbf{e}$ is a vector of random errors. The genetic and phenotypic correlations were estimated using bivariate analyses. Heritability was obtained as $h^2{}_a = \delta^2{}_a/\delta^2{}_p$ (direct heritability), where $\delta^2{}_p$ is the phenotypic variance, which is the sum of all variance components in the model. Multiple regression analyses of SAS (SAS 2002) were used to estimate crossbreeding parameters. For regression analysis, coefficients of expected breed content and heterozygosity in the cow were fitted as covariate to obtain estimates of the individual breed additive for HF or Jersey (G_iHF, G_iJ), individual heterosis for HF or Jersey crossed with Boran (H_iHFBo, H_iJBo), and maternal heterosis (H_mHFBo, H_mJBo) effects using similar procedures as suggested by Kahi et al. (1995) and Haile et al. (2009).

Results and discussion

Effect of genetic and non-genetic factors on reproductive performance

The genetic group exerted a significant ($p<0.01$) effect. Crossing of Boran cattle with Jersey or HF had improved reproduction traits (Table 2). First crosses (F_1) values (50 % Jersey: 50 % Boran) were significantly ($p<0.05$) younger at AFS (by 7.25 months), and AFC (by 10.75 months), had shorter FCI (by 63.27 days), FDP (by 61.13 days), and FSP (by 60.3 days), and needed less (by 0.67) numbers of services per first conception as compared to the Boran cattle. The superiority of F_1 (50 % Jersey: 50 % Boran) or F_1 (50 % HF: 50 % Boran) to Boran was in agreement with those of earlier works (Kiwuwa et al. 1983; Negussie et al. 1998; Negussie et al. 1999; Demeke et al. 2004). The F_1 (50 % Jersey: 50 % Boran) crosses were superior to F_1 (50 % HF: 50 % Boran) for pre-calving traits. The superiority of Jersey × Boran crosses to HF × Boran possibly indicated that Jersey inheritance is suitable under a low input system. The comparison between the inter se mating (both in Jersey × Boran and HF × Boran) with 75 % of (both Jersey and HF) crosses did not show significant ($p>0.05$) differences in most of the reproduction traits. The comparison between the inter se mating (HFBo × HFBo or JBo × JBo) and first crosses of HF × Bo or J × Bo revealed that first crosses were superior to the inter se crosses. The superiority of the first crosses over the inter se crosses might be ascribed to a combination of additive and heterotic effect reflected in the first crosses and the reduction in heterotic effect in inter se mating (Cunningham and Syrstad 1987; Demeke et al. 2004). There was also a variation in AFS, AFC, and NSFCON in crossbred heifers between the current study and those reported, which may be a reflection of the differences in heifer rearing practices over the years (Demeke et al. 2004; Haile et al. 2009). The present study gives an indication of the improvement of early-expressed reproduction traits through crossbreeding and reproduction management. However, Kefena et al. (2006) showed a longer AFC, days open and calving interval in Jersey × Boran or HF × Boran crosses as compared to the Boran cattle by considering all parities.

The influence of season on NSFCON was significant ($p<0.05$) and was non-significant on the rest of the reproductive traits (Table 2). This is in agreement with a number of works that reported a non-significant effect of season (Negussie et al. 1998; Negussie et al. 1999; Haile et al. 2009). However, these results were not in agreement with studies which reported a significant influence of season (Haile-Mariam et al. 1993). The present study showed that heifers conceived in the heavy rain required fewer (1.63±0.05) numbers of services for first conception than heifers conceived in light rains (1.77) and dry season (1.79) (Table 2). The effect of season on NSFCON was in agreement with a number of works (Swensson et al. 1981; Haile-Mariam et al. 1993). A possible explanation could be the increased availability of green herbage during the wet season which improved the fertility of females, resulting in less numbers of services per conception. A number of workers have reported the association between season and number of services per conception in favor of the wet season (Haile-Mariam et al. 1993; Demeke et al. 2004; Haile et al. 2009)

The effect of period of birth/calving was significant ($p<0.001$; Table 2) but did not show a clear-cut trend. However, there was a tendency of improvement at later periods. The animals born from 1998 to 2000 had the lowest AFC (35.67±

Table 2 Genetic group, season, and period means of least squares and standard errors of reproduction traits for Boran and HF or Jersey crosses

Effects	Reproductive performance					
	AFS (months)	AFC (months)	NSFCON	FCI (days)	FDP (days)	FSP (days)
Overall	29.30±0.21	37.99±0.30	1.73±0.03	400.45±16.14	136.96±12.48	143.77±12.51
N	822	861	1075	606	642	609
CV (%)	18.30	20.34	47.21	17.81	23.71	29.53
Genetic group	**	**	**	*	*	*
Bo	33.63±0.58 d (89)	42.89±0.73 d (112)	2.06±0.09 ef (89)	471.74±10.59 d (58)	185.11±8.16 d (60)	191.38±8.18 d (60)
HF×Bo	26.22±0.41 b (159)	34.66±0.56 b (178)	1.85±0.05 df (238)	400.66±6.67 a (101)	131.66±5.18 ab (105)	138.90±5.19 b (101)
J×Bo	24.38±0.55 a (88)	32.14±0.64 a (82)	1.39+0.12 a (104)	408.47±7.17 ab (93)	123.98±5.40 a (101)	131.35±5.41 a (92)
HFBo×HFBo	30.33±0.44 c (165)	38.07±0.68 c (170)	1.65±0.06 ac (229)	444.57±8.89 c (95)	144.88±6.83 bc (97)	151.02±6.85 bc (97)
JBo×JBo	28.54±0.49 b (89)	39.03±0.66 c (79)	1.59±0.06 ab (99)	433.27±9.21 c (89)	149.90±6.75 c (98)	155.97±6.77 c (88)
HF×HFBo	28.04±0.55 b (154)	39.21±0.69 c (165)	1.86±0.08 de (218)	435.53±10.36 c (87)	137.23±8.07 ac (94)	143.48±8.09 ac (87)
J×JBo	31.91±0.74 cd (78)	39.94±0.99 c (75)	1.71+0.09 bcd (98)	416.42±11.52 bc (83)	147.01±8.96 c (87)	153.24±8.98 c (84)
Season	NS	NS	*	NS	NS	NS
Light rain	29.14±0.32 (280)	37.99±0.43 (289)	1.77±0.05 b (353)	429.46±5.68 (201)	143.85±4.40 (215)	150.29±4.41 (201)
Heavy rain	29.16±0.35 (265)	38.32±0.46 (284)	1.63±0.05 a (351)	431.82±6.12 (196)	147.31±4.63 (205)	153.77±4.64 (197)
Dry season	29.58±0.33 (277)	37.68±0.43 (288)	1.79±0.04 b (371)	429.01±5.49 (209)	145.88±4.23 (222)	152.52±4.24 (211)
Period	**	**	**	*	**	**
1980–1982	27.75±0.48 ac (101)	39.98±0.63 cdef (110)	1.85±0.08 bde (125)	457.26±7.99 f. (78)	154.48±6.18 bcd (82)	160.74±6.20 bc (74)
1983–1985	29.29±0.66 bcdef (89)	38.05±0.83 bc (89)	2.03±0.12 ef (103)	434.79±10.09 bcde (68)	158.90±7.86 cd (75)	165.17±7.88bc(69)
1986–1988	27.56±0.58 a (91)	38.31±0.79 bd (92)	1.71±0.09 d (120)	448.47±8.46 df (74)	155.74±7.41 bcd (60)	162.01±7.43 bc (68)
1989–1991	28.50±0.5 6ae (92)	38.44±0.75 be (98)	1.89±0.09 cdf (121)	423.33±9.14 ae (72)	145.40±7.04 ad (76)	151.68±7.06 ac (71)
1992–1994	27.61±0.68 ab (81)	36.99±0.75 ab (99)	1.60±0.08 a (125)	448.22±10.31 deg (66)	159.56±8.03 d (67)	165.81±8.05 bc (68)
1995–1997	28.06±0.63 ad (89)	37.74±0.84 b (88)	1.57±0.09 a (123)	404.89±9.41 a (70)	132.22±7.38 a (71)	136.25±7.09 a (69)
1998–2000	30.84±0.55 f. (93)	35.67±0.74 a (101)	1.70±0.08 ac (126)	422.06±10.42 ad (63)	129.02±7.07 a (74)	146.89±9.25 a (62)
2001–2003	31.66±0.50 gh (97)	37.56±0.79 b (97)	1.62±0.05 a (131)	413.51±11.78 ab (54)	137.41±9.23 ab (64)	146.89±9.25 ab (63)
2004–2006	32.41±0.66 h (89)	39.18±0.93 bf (87)	1.61±0.12 ab (101)	417.97±10.37 ac (61)	138.39±8.01 ac (63)	142.65±8.03 a (65)

Least squares means with similar letters in the same column indicate non-significance. Figures in parenthesis in front of the least squares means and standard errors are the number of records

AFS age at first service, *AFC* age at first calving, *NSFCON* number of services at first conception, *FCI* first calving interval, *FDP* first dry period, *FSP* first service period, *Bo* Boran, *HF* Friesian, *J* Jersey, *HF× Bo* or *J× Bo* first crosses, *HFBo× HFBO* or *JBO× JBO* inter se mating, *HFBO× HF or JBO× J* 75 % exotic: 25 % Boran, *NS* non-significant

$^{*}p<0.05$; $^{**}p<0.01$

0.74 months) and animals born from 1995 to 1997 required less (1.57±0.09) numbers of services for first conception. The animals born from 1980 to 1982 had the highest AFC (39.98± 0.63 months), and animals born from 1983 to 1985 required more (2.03±0.12) numbers of services for first conception. The heifers calved from 1980 to 1982 showed the longest FCI (457.26±7.99 days), whereas those calved from 1992 to 1994 had the shortest FCI (159.56±8.03 days). A number of works have shown a significant effect of period/year of birth/calving on reproduction traits (Kiwuwa et al. 1983; Haile-Mariam et al. 1993; Negussie et al. 1998; Demeke et al. 2004; Kefena et al. 2006; Million et al. 2006; Haile et al. 2009). The effect of period on reproduction traits may be due to the variability of heifer management practices including inconsistency of age at first breeding and scarcity of feed over the periods. This calls for the need to standardize heifer rearing and management practices for a better reproduction performance.

Genetic parameters for reproduction trait

Heritability parameters

Estimates for variance components and heritability (h^2) for reproduction traits are presented in Table 3. The heritability values for AFS and AFC were highest and estimated at 0.51± 0.10 and 0.49±0.13, respectively, and lower heritability values were recorded for FDP (0.02±0.2) and FSP (0.10± 0.29). The pre-calving traits had shown higher heritability value than post calving traits.

The estimated heritability values were in close agreement with the estimates of Demeke et al. (2004) who reported a heritability of 0.44 for AFS and Haile et al. (2009) who reported heritability estimates of 0.6 and 0.7, for AFS and AFC, respectively, in Ethiopian Boran and exotic crosses. The heritability estimates are higher than the reports of Alemseged

Table 3 Estimates of variance components and direct heritability (h^2_a±se) for reproduction traits

Estimates	Reproductive performance					
	AFS	AFC	NSFCON	FCI	FDP	FSP
V_a	13.46	29.81	0.07	1,218.90	89.65	1,167.60
V_e	12.66	30.92	0.58	4,212.60	3,668.70	2,676.80
V_p	26.12	60.73	0.65	5,431.50	3,758.40	3,844.50
h_a^2	0.51±0.10	0.49±0.13	0.10±0.08	0.22±0.17	0.02±0.20	0.30±0.39

AFS age at first service, *AFC* age at first calving, *NSFCON* number of services at first conception, *FCI* first calving interval, *FDP* first dry period, *FSP* first service period, V_a additive genetic variance, V_e residual variance, V_p phenotypic variance

(2002, Development of selection criteria of Fogera cattle and their Friesian crosses in Ethiopia, unpublished) who reported heritability values of 0.04 and 0.13 for AFS and AFC, respectively, in the Fogera breed in Ethiopia. The high heritability value recorded for the early reproductive traits suggested that mass selection and reproductive management could be effective for the improvement of the reproductive traits. The Ethiopian studies were conducted based on lifetime reproductive traits. There is a limited report for early-expressed reproductive traits in Ethiopia. The standard errors for heritability were relatively higher, which may be attributed to the small sample size of the population. It has been reported that standard errors of heritability are higher in the tropics as compared to the temperate breeds (Lobo et al. 2000; Roman et al. 2000). The heritability estimates for reproduction traits revealed that AFS and AFC had shown higher heritability as compared to FCI, FDP, and FSP. This indicates that improvement of AFS and AFC could be planned by selection and better reproductive management, where traits such as FCI, FDP, and FSP could be improved through better reproduction management.

Genetic and phenotypic correlations

Genetic and phenotypic correlations are presented in Table 4. The genetic and phenotypic correlations for most of the reproduction traits were found to be non-significant (p>0.05) and small in magnitude. The non-significant association between the reproduction traits might be ascribed to high sampling variance shown by high standard errors due to limited numbers of observations.

Genetic correlation was highest (0.10±0.20) between AFS and AFC and lowest (−0.01±0.66) between FCI and FSP. Phenotypic correlation was highest (0.12±0.53) between AFS and AFC and lowest (0.01±0.28) between AFS and FSP. The present study is in agreement with earlier findings (Demeke et al. 2004; Haile et al. 2009). The highest genetic correlation between AFS and AFC as compared to other reproduction traits is an indication that there is a room for considering these two traits to improve the herd by selection and management. For other reproduction traits, the result was either low or negative, which could indicate that selection for one trait may not significantly affect the other traits.

Table 4 Genetic and phenotypic correlations (±se) of reproduction traits for HF×Boran, Jersey×Boran, and Boran cattle

Reproductive performance	Reproductive performance					
	AFS	AFC	NSFCON	FCI	FDP	FSP
AFS	–	0.10±0.20**	0.07±0.33	0.01±0.32	0.02±0.94	0.01±0.30
AFC	0.12±0.21**	–	0.05±0.36	0.02±0.35	0.01±0.02	0.01±0.34
NSFCON	0.06±0.22	0.02±0.26	–	0.03±0.58	0.02±0.66	0.02±0.57
FCI	0.01±0.28	0.08±0.36	0.06±0.03	–	0.01±0.74	−0.01±0.66
FDP	0.01±0.18	0.08±0.64	0.02±0.09	0.03±0.92	–	0.01±0.34
FSP	0.02±0.09	0.05±0.002**	0.09±0.53	0.04±0.67	0.02±0.72	–

Genetic (above diagonal) and phenotypic (below diagonal) correlations

AFS age at first service, *AFC* age at first calving, *NSFCON* number of services at first conception, *FCI* first calving interval, *FDP* first dry period, *FSP* first service period, *NS* non-significant

*p<0.05; **p<0.01

Table 5 Estimates of breed additive, individual heterosis, and maternal heterosis for reproduction traits

Genetic effects	Reproductive performance					
	AFS (months)	AFC (months)	NSFCON	FCI (days)	FDP (days)	FSP (days)
GiHF	−9.16±2.88**	−4.56±3.90**	0.84±0.43*	−31.78±51.39NS	−8.93±39.73NS	−28.39±39.81
HiHFBo	−2.83+1.63	−10.51±2.25***	−0.62±0.26**	−62.85±28.28**	−41.35±22.09*	−40.76±22.07*
HmHFBo	−2.69±1.10*	−1.85±1.58NS	−0.51±0.16***	14.89±0.07NS	−8.04±15.45NS	−8.72±15.48
GiJ	−3.49±3.59***	−3.62±2.79**	−0.80±0.57NS	−36.60±54.61NS	−17.37±41.37NS	−17.98±41.46
HiJBo	−3.99±1.97**	−6.56±2.59**	0.05±0.32NS	−51.85±29.89*	−71.21±22.65**	−70.22±22.70*
HmJBo	−4.83±1.32***	0.61±1.75NS	−0.08±0.19NS	0.25±20.94NS	−13.39±15.61NS	−14.34±5.64

AFS age at first service, *AFC* age at first calving, *NSFCON* number of services at first conception, *FCI* first calving interval, *FDP* first dry period, *FSP* first service period, *GiHF* breed additive for Friesian, *HiHFBo* individual heterosis for HF×Boran, *HmHFBo* maternal heterosis for HF×Boran, *GiJ* breed additive for Jersey, *HiJBo* individual heterosis for Jersey×Boran, *HmJBo* maternal heterosis Jersey×Boran, *NS* non-significant

*$p<0.05$; **$p<0.01$; *** $p<0.001$

Crossbreeding parameters

Breed additive was significant ($p<0.05$) for AFS, AFC, and NSFCON for HF (Table 5). The breed additive for Jersey was significant ($p<0.01$) for AFS and AFC. The crossing of HF with Boran cattle has desirably reduced 9.16±2.88 months in AFS; whereas the corresponding reduction in AFS was 3.49±3.59 months by crossing Jersey and Boran cattle. The crossing of HF with Boran cattle has reduced 4.56±3.90 months in AFC, whereas a corresponding reduction in AFC was 3.62±4.79 months by crossing Jersey and Boran cattle due to additive genetic contribution. Several reports have shown that when *Bos taurus* dairy breeds are crossed with tropical indigenous breeds, the crossbreds exhibit a desirable reduction in age at first calving as result of the additive genetic contributions or heterosis or both (Cunningham and Syrstad 1987; Sharma and Pirchner 1991; Thorpe et al. 1993; Rege et al. 1994; Rege 1998; Demeke et al. 2004; Haile et al. 2009).

Individual heterotic (HiHFBo and HiJBo) estimates, expressed relative to the mid-parent values, were −2.83±1.67 and −3.99±1.97 months for AFS, −10.51±2.25 and −6.56±2.59 months for AFC, −62.85±28.52 and −51.85±29.89 days for FCI, −41.35±22.02 and −71.21±22.65 days for FDP, and −40.76±22.07 and −70.22±22.70 days for FSP, for HF, and Jersey crosses, respectively. Individual heterosis was negative and significant ($p<0.05$) for all reproduction traits. Maternal heterosis was significant ($p<0.05$) for AFS and NSFCON and for HF × Boran crosses, and AFS was significant ($p<0.05$) for Jersey × Boran. The significant heterosis values, particularly for AFC and CI, are consistent with reports in the literature (Sharma and Pirchner 1991; Thorpe et al. 1993; Rege 1998; Kahi et al. 2000). The current desirable heterotic estimates for AFC and CI are comparable with the average heterosis estimated for AFC (4.2 months) and CI (42 days) as reported in crossbreeding studies between *B. taurus* and *Bos indicus* crosses (Rege (1998). In contrast to this, no heterosis effect in crossing *B. taurus* dairy breeds with *B. indicus* cattle for number of service per conception (Teodoro et al. 1984) and for days open and number of services per conception (Rege et al. 1994). The breed additive and heterotic effect observed in the present study warrants the introduction of crossbreeding to improve early-expressed reproductive traits. A number of reports have shown that when *B. taurus* dairy breeds are crossed with tropical indigenous breeds, the crossbreds exhibit a reduction in age at first services and age at first calving as a result of the additive genetic contributions of dairy breeds, heterosis, or both (Cunningham and Syrstad 1987; Sharma and Pirchner 1991; Thorpe et al. 1993; Rege et al.1994; Rege 1998).

Conclusion

Crossbreds (HF × Boran or Jersey × Boran) excelled over indigenous Boran cattle. This demonstrates that crossbreeding could be judiciously applied under defined crossbreeding programs to improve reproductive efficiency. Jersey crosses were superior to HF crosses for reproduction traits. The comparison among the genetic groups showed that the F_1 of HF or Jersey excelled from other crosses of HF or Jersey. The performance of reproductive traits was affected by non-genetic factors and urges to take necessary measures to standardize the management. The heritability estimates for the pre-calving traits (AFS and AFC) were in the range of medium to high, and genetic improvement of those traits could be achieved through selection. The traits with low heritability could be improved by improving reproduction management and crossbreeding. The superiority of direct and maternal additive effects of Holstein or Jersey breeds over Boran for most of reproductive traits indicates that Holstein/Jersey could be used as an effective breed and improves in the dairy industry in Ethiopia.

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