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Estimation of Crossbreeding Parameters for Milk Production and Reproduction Traits in Holstein Friesian and Ethiopian Boran Crosses

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Abstract: Data on the Ethiopian Boran and their crosses with Holstein Friesian cows collected over a period of 23 years (1990 to 2012) at Holeta Agricultural Research Center (HARC) were used to determine the contributions of individual breed additive, heterotic and recombination effects for milk production and reproduction traits of Ethiopian Boran cattle with different levels of Holstein Friesian inheritance. Multiple regression analysis was used to estimate the contribution of individual breed additive, heterosis and recombination effects. The results of the study clearly revealed that heterosis effect was significant for daily milk yield, lactation length, total lactation milk yield, calving interval, days open and age at first calving and the corresponding estimate values were 2.78±0.32lt, 43.05±14.38 days, 899.02±132.68lt, -70.14±27.88days, -64.03±27.81days and -354.47±129.63, respectively. Breed additive effect showed significant in daily milk yield (5.18±0.62lt), lactation length (85.95±27.75 days) and total lactation milk yield (2040.19±256.01lt). Recombination loss also showed significant effect on total lactation milk yield (-586.44±162.02lt). Thus, crossbreeding can improve Ethiopian Boran cattle through additive genetic effects particularly heterotic effects. Hence, it can be concluded that crossbreeding should be designed for optimum breed additive and heterotic contribution.

Key words: Breed Additive · Crossbreeding · Heterosis · Milk · Production Reproduction · Trait

INTRODUCTION

The economy of Ethiopia, like most of the countries in sub-Saharan Africa, is highly based on agriculture. Livestock production is an integral part of the Ethiopian agricultural system and Ethiopia believed to have the leading livestock population in Africa. Based on survey results at regional and zonal levels for sedentary rural areas except the non-sedentary population of three zones of Afar and six zones of Somali region the total cattle population for the country is estimated to be about 53.99 million [1].

On the other hand 98.95 percent of the total cattle in the country are local breeds. The remaining are hybrid and exotic breeds that accounted for about 0.94 percent and 0.11 percent, respectively. Livestock accounts for 15-17% of national GDP and 35-49% of agricultural GDP. It directly contributes to the livelihoods of more than 70% of Ethiopians [2].

The average lactation period per cow is estimated to be about six months and average milk yield per cow per day is about 1.32 liters in the sedentary areas of the country [1]. Whilst the national per capita consumption of milk and milk products is about 20 liters per person per year. This is extremely low from the recommended amount of the world health organization (WHO), which is 180 liters. This is even lower than the per capita consumption of other countries in the region (Kenya=120 liters/capita, Uganda=53 liters/capita, Tanzania=42 liters per capita and Rwanda=38 liters per capita) [3].

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This indicates the existence of a wide gap between demands of the growing population of Ethiopia and the available local supply. In order to meet the demand of the growing population of Ethiopia, milk production has to be improved through introducing genetic improvement and management intervention options.

Crossbreeding of local breeds with European dairy breeds has been widely used as a tool to improve milk production potential in tropical cattle [4]. As part of the same effort, crossbreeding has long been in process as practical solution in Ethiopia for decades to bring about the desired genetic change quickly to combine the high productivity of exotic and better adaptability of indigenous breeds to existing climate condition, disease, low quality feed and poor management in the crossbreeds.

Ethiopian Institute of Agricultural Research has conducted long term dairy cattle crossbreeding experiments in few research centers of the country. Holeta Agricultural Research Center is one of the main centers that have been playing great role in improvement of dairy cattle since 1966. In this research center, Boran/indigenous cattle have mainly been crossed with Holstein-Friesian with the aim of combining productivity and adaptability in the crossbreds. This long term crossbreeding effort resulted in the development of various genetic groups which could be vital to analyze the data and suggest possible intervention for improving the breeding program.

Even though few studies have been done on dairy herd of Holeta Agricultural Research Center that assessed cross breeding effects on production and reproduction traits, there is a need to include recent data for timely recommendations. In this study, F_2 particularly F_3 genetic groups have been also included which were not studied by other researchers. It is therefore, imperative that crossbreeding effects should be estimated on the basis of recent data and hence, timely crossbreeding and genetic parameters are estimated for evaluation of breeding programs due to changing environments and ongoing selection. Moreover, there is no strategy to maintain the improvement in milk production obtained after 50% crosses. Thus, study of the recent development in crossbreeding efforts by estimating crossbreeding parameters including the main genetic and phenotypic parameters is very important.

MATERIALS AND METHODS

Description of the Study Area: This study was conducted at Holeta Agricultural Research Center (HARC) of the Ethiopian Institute of Agricultural Research (EIAR) that is located 35 km west of Addis Ababa (38.5°E longitude and 9.8°N latitude) in the high lands of Ethiopia at an elevation of 2400 m above sea level. The minimum and maximum daily temperature of the area is ranging from 5 to 10°C and 18.7 to 24.0°C, respectively. The periods of heavy rainfall may occur during rainy season and the area receives an average rainfall of 1200mm.There are three main seasons in the year; long rainy season from June to September, dry season lasts from October to February followed by short rainy season having light rain from March to May. The principal soil type is vertisol.

Study Animals and Management: Regular conditions of feeding and management practices were adopted for all animals during the entire experimental periods. All animals will be identified using plastic ear tags. There is no biased management option based on the genetic groups or level of milk production [5]. The animals were grazed on natural pasture for about 8 hours during daytime. At night all animals were kept in their barn and supplemented with natural pasture hay. Individual pen was given for each animal. The barn was cleaned every day. Both scientific hand milking and machine milking was used to milk the cows. In addition vaccination against Rinderpest, Foot and Mouth disease, Anthrax, Pasteurolsis, Blackleg and Contagious Bovine Pleuropneumonia (CBPP) were given to the farm animals. They are also drenched and sprayed for internal and external parasites at regular intervals. Specific treatments are given whenever any disease occurs. Artificial insemination with semen produced from locally recruited bulls or imported semen from National Artificial Insemination Centre (NAIC) has been used for breeding. Pregnant animals and calves were also managed well.

Data Collection: Data on reproductive traits (Calving interval (day), Days open (day), Age at first calving (day) and milk production traits (Daily milk yield (liter), total lactation milk yield (liter) and lactation length (day) were collected from 1990 -2012 at Holeta Agricultural Research Center. Identification number of each cow, parity, breed group, sire of cow, dame of cow and disposal date were also recorded. All data were coded and recorded in excel sheet of 2003 for both productive and reproductive traits.

Statistical Analysis: Daily milk yield (liters), total lactation milk yield (liter), lactation length (days), calving interval (days), days open (days) and age at first calving (days) were analyzed using General Linear Model (GLM) procedure of [6]. A multiple regression model was used to estimate the contribution additive breed effects; heterosis and epistatic (recombination loss) effects. In this model the coefficients of expected breed content and heterozygosity in cows were used as co(variant) to obtain estimates of the individual additive and heterotic effects using similar procedure to those of Robison *et al*. [13], Hirooka and Bhutyan [8] and Kahi *et al.* [15]. Heterozygosity with respect to genes of two breeds was calculated as the expected proportion of genes from the sire and dam. For example, the expected heterozygosity with respect to local (L) and exotic (F), H^I_{FB} was calculated as $(G^s_B * G^d_F) + (G^s_F * G^d_B)$ where the superscript *s* and *d* denote that the genes come from the sire and dam, respectively. Similarly expected heterozygosity with respect to two breeds were calculated for the genotype of the dam of individual and were denoted H^M_{FB} as before [7]. For expected recombination between pairs of loci originating from F and B, R^I_{FB} calculated as $G^s_F(1- G^s_F) + G^d_F(1- G^d_F)$ [7]. Thus the model included effects for (G^I_F), (H^I_{BF}) and (R^I_{FB}) as well as the fixed effects described above except breed group. The breed groups and coefficients for expected effects of breed content and heterotic are shown in Table 1.

Model 1: Age at first calving were analyzed using the main basic model but without the effect of parity.

$$Y_{iklm} = \mu + G_i + Y_k + S_l + e_{iklm}$$

Model 2: The multiple regression approach developed by Robinson *et al*. [8] was used to estimate the contribution of breed additive genetic, heterosis and recombination effects to differences among breed groups with respect to average daily milk yield (liters), total lactation milk yield (liter) lactation length (days), calving interval (days) and days open (days) as follows:

$$Y_{jklm} = \mu + P_j + Y_k + S_l + G^I_F b_1 + H^I_{FB} b_2 + R^I_{FB} b_3 + e_{jkl}$$

Table 1: Proportion of additive, hetrosis and recombination effects used in prediction of performance of different genetic group

	Effects		
Genetic groups (sire X dam)	G^I	H^I	R^I
0%F [B X B]	0	0	0
25%F [B X (FB)]	0.25	0.5	0.25
37.5%F [BF X {(BF)B}]	0.375	0.5	0.4375
50%F_1 [F X B]	0.5	1.0	0
50%F_2 [FB X FB]	0.5	0.5	0.5
50%F_3 [FBFB X FBFB]	0.5	0.5	0.5
62.5%F [BFF X BF]	0.625	0.5	0.4375
75%F [F X (FB)]	0.75	0.5	0.25
87.5%F [F X {F(FB)}]	0.875	0.25	0.1875
93.75%HF [F X [F{F(FB)}]]	0.9375	0.125	0.109375

B: Boran; F: Holstein Friesian

where; Y_{ijkl}= daily milk yield (liters), total lactation milk yield (liter), lactation length (days), calving interval (days) or days open (days) of an individual animal with parity j, year groups k, in season l of genetic group i

- G^I_F = Individual additive genetic effect of Holstein Friesian breed (relative to Boran)
- H^I_{FB} = The expected individual heterosis in the crossbred cow, i.e. direct heterosis
- R^I_{FB} = The expected recombination effect in the individual cow, i.e. direct recombination loss
- b_1 = Individual breed coefficient of the trait (calculated as proportion of genes from Friesian)
- b_2 = Individual heterosis coefficients of the trait (calculated as proportion of heterozygous loci)
- b_3 = Individual recombination coefficient of the trait

μ, Pj, Y_k and S_l have been already defined in model one.

Model 3: for Age at first calving (days)

$$Y_{iklm} = \mu + Y_k + S_l + G^I b_1 + H^I b_2 + R^I b_3 + e_{kl}$$

RESULTS AND DISSCUSIONS

Crossbreeding Parameters: Results in Table 2 indicated that breed additive genetic effects were significant ($P < 0.01$) for daily milk yield, lactation length and total lactation milk yield. Individual heterosis effects were significant for daily milk yield, total lactation milk yield, lactation length, calving interval, days open and age at first calving. The individual recombination effect was significant for total lactation milk yield.

Additive Genetic Effects

Milk Production Traits: Breed additive genetic differences between Ethiopian Boran and Holstein Friesian were positively significant ($P < 0.01$) for daily milk yield, lactation length and total lactation milk yield. This indicates the presence of genetic differences between the two breeds. The additive differences between these breeds for average daily milk yield resulted in the production of 5.18±0.62 liter more milk by their crossbreed relative to local breed.

Similarly, 2040.19±256.13 liters of total lactation milk yield were attributed to the additive genetic differences in favor of Holstein Friesian. The same effect was expressed in lactation length where additional contribution of 85.95±27.75 days was found from Holstein Friesian. In general the results revealed that the genetic difference

Table 2: Estimates and standard errors of individual crossbreeding effects for Ethiopian Boran and Holstein Friesian

		Estimates ± Standard Error		
Traits	Boran means	Additive	Heterosis	Recombination
DMY (lit)	1.76	5.18±0.62**	2.78±0.32**	-0.61±0.40^{ns}
LL (days)	246.22	85.95±27.75**	43.05±14.38**	-25.47±17.56^{ns}
TLMY (lit)	447.73	2040.19±256.01**	899.02±132.68**	-586.44±162.02**
CI (days)	476.48	55.01±54.51^{ns}	-70.14±27.88*	-17.34±33.97^{ns}
DO (days)	200.24	40.51±54.37^{ns}	-64.03±27.81*	-8.51±33.88^{ns}
AFC (days)	1388.11	385.30±208.92 ^{ns}	-354.47±129.63**	-62.60 ±138.41 ^{ns}

**:P<0.01 *:p<0.05 lit: liters DMY: daily milk yield LL: lactation length TLMY: total lactation milk yield CI: calving interval DO: days open AFC: age at first calving

between Holstein Friesian and Ethiopian Boran breeds improved milk production traits in their crossbred cows in favor of the former over the later.

Earlier works in Ethiopia also reported that cross breeding had significant additive genetic effect on milk production traits. The findings of some past studies are in agreement with the results of the current study [9-12] indicated that the direct genetic effect of the Holstein-Friesian significantly influenced lactation milk yield, daily milk yield and lactation length. The crossbreeding effect of local Arsi and Holstein-Friesian resulted in significant additive genetic effect for daily milk yield per lactation length and daily milk yield per calving interval [10]. In the study on crossbreeding of Ethiopian Boran with Holstein Friesian and Jersey, Sendros Demeke et al. [11] found significant breed additive effect of Friesian and Jersey over Boran for lactation milk yield, daily milk yield, annualized milk yield and lactation length. Aynalem Haile [12] reported that the individual additive genetic difference for milk production traits were significant for milk traits. He also presented the estimates in favor of Holstein Friesian to be 108 days for lactation length which was longer by 22 days than the present work, 2055 kg for lactation milk yield and 5.9 kg for daily milk yield which was close to the present estimate.

Similar studies of crossbreeding effects in other tropical countries resulted in strong evidence that breed additive genetic differences significantly affected milk production traits. The data of Hirooka and Bhutyan [13] was in agreement with the present study that significant breed additive differences between Holstein Friesian and local breed for average daily milk yield. Mackinnon *et al.* [14] studied sources of genetic variation for milk production in a crossbred herd in the tropics and found that the genetic effect with the largest influence on production traits was additive breed effects. A work in Pakistan by Ahmad *et al.* [15] also found that additive breed effects for Friesian and Sahiwal crosses were larger than for Jersey and Sahiwal crosses in lactation milk yield and daily milk yield per lactation. Ghorbani and Salamatdoustnobar [16] worked on crossbreeding effects for milk production traits involving local breed and Holstein Friesian in Iran and found the direct additive‘s effect on milk yield and milk days traits were significant. Sharma and Princhner [17] reported 773 kg difference in lactation milk yield between Friesian and Sahiwal in India which was lower than the present study. Holsteins and Friesians are superior in their individual and maternal additively for milk yield traits [8, 18].

Based on the results obtained in this study, additive genetic effect was significant for milk traits and this indicated that the presence of genetic differences between Holstein Friesian and Ethiopian Boran for milk traits. Therefore milk production could be increased attribute to breed additive genetic effects in crossbreeding of Holstein Friesian with Ethiopian Boran. The non significant effect of maternal additive and heterosis effect in present study is expected because prenatal maternal effect is not expected at adult stage to affect milk yield of the progeny. After birth calves were kept separately from their mother and feed bucket milk. Similar results were reported by Million Tadesse and Tadelle Dessie [10] and Aynalem Haile [12].

Reproduction Traits: The additive breed effects between Ethiopian Boran and Holstein Friesian for calving interval, days open and age at first calving were non-significant (P>0.05). The corresponding estimate values of breed additive were 55.01±54.51, 40.51±54.37 and 385.30±208.92 respectively. This work is close to some comparable works in Ethiopia and other tropical countries [11, 12, 15, 18, 19]. SendrosDemeke *et al.* [11] reported non-significant additive genetic effects for calving interval. The crossbreeding effects between Ethiopian

Boran and Holstein Friesian were studied by Aynalem Haile [12] and he found non-significant additive effect for calving interval. On the other hand he found significant additive effect for age at first calving which was different from the present study. Martinez *et al*. [18] found that Holstein Friesian cows matured 6 months earlier than the Zebu cows and had a shorter calving interval of 37 days than the later one. Ahmad *et al*. [15] presented non-significance additive genetic differences between Sahiwal and Jersey crosses for calving interval and days open but Sahiwal and Friesian crosses were significant for days open in opposite of this work. Kahi *et al*. [19] reported significant additive effect for calving interval in crossbreeding involving Holstein Friesian and Sahiwal in Kenya which was in disagreement of this work. But this difference was small (-6 to -22 days).

The non-significant of breed additive effect on reproduction traits might be associated with no differences in reproduction traits between Holstein Friesian and Ethiopian Boran.

Non-Additive (Heterosis) Effects

Milk Production Traits: In this work individual heterosis effect was significant (P< 0.01) for daily milk yield, total lactation milk yield and lactation length (Table 2). The individual heterosis contribution were 65.04%, 30.21% and 66.08%% above the average of Ethiopian Boran and Holstein-Friesians for daily milk yield, lactation length and total lactation milk yield, respectively.

Sendros Demeke *et al.* [9] indicated that crossbreeding Holstein-Friesians with Borans resulted in desirable direct individual heterosis effect for lactation milk yield, daily milk yield and lactation length. The individual heterotic advantages of the crosses were 51%, 21% and 27% above the average of both Ethiopian Boran and Holstein Friesian for lactation milk yield, daily milk yield and lactation length, respectively. The results on heterosis effect in present study is in agreement with most studies: Sendros Demeke *et al*. [11] estimated individual heterosis effect 431 ± 83 kg (22%) for LMY, 0.7 ± 0.2 kg (11%) for DMY, 79 ± 8 days (29%) for LL and 360 ± 81 kg (21%) for AMY in crosses involving Friesian and Boran. Aynalem Haile [12] reported that crossbreeding of Friesian with the Ethiopian Boran resulted in desirable and significant individual heretosis effect for all milk production traits. Million Tadesse and Tadelle Dessie [10] recorded significant individual heterosis effect for daily milk yield per lactation length and daily milk yield per calving interval.

Ahmad *et al*. [15] presented heterosis effects that were significant for lactation milk yield and milk yield per calving interval traits of Sahiwal crosses with Friesian and Jersey. Ghorbani and Salamatdoustnobar [16] reported significant regression coefficients were estimated for the effect of individual heterosis on milk yield and milk-days traits. But the individual heterosis estimation on milk yield trait was negative. Mackinnon *et al*. [14] stated significant heterosis effects for lactation milk yield, average daily milk yield, milk yield per calving interval and milk yield per lactation length; heterosis effects of 1.04 kg/day on milk/LL and 1.22 kg/day of milk/CI reported on crossbreeding of *Bostaurus X Bosidicus.* However, Hirooka and Bhutyan., [13] reported a small and non-significant estimate of individual heterosis effects for average daily milk yield on crossbreeding between *Bostaurus* and *Bosindicus* cattle in the tropics which was different from this work.

Reproduction Traits: Negative and significant (p<0.05) estimates of direct heterosis effects for calving interval and days open and age at first calving interval were obtained in this study. The individual heterosis contributions of the crosses were 28.95% (-70.14 days), 65.55% (-64.03) and 40.42% (-354.47 days) shorter than the average of Ethiopian Boran and Holstein-Friesians for calving interval, days open and age at first calving respectively. Similar result was reported by others studies; Ahmad *et al*. [15] reported negative and significant estimates of direct heterosis effects for calving interval and days open. Significant heterosis effects for reproduction traits were also reported by Sharma and Princhner [17 in India and Kahi *et al*. [19] in Kenya. The crossing of Friesian and Jersey with Boran resulted in significant heterosis for calving interval, days open, number of service per conception and age at first calving [11]. On other hand, Aynalem Haile [7] found non-significant hetrosis effect for calving interval differently from this study but negative and significant effect for age at first calving.

Direct Recombination Effect

Milk Production Traits: The estimate of direct recombination loss (R^I) for daily milk yield and lactation length was negative and insignificant (p>0.05) where as the estimates of direct recombination loss for total lactation milk yield were negative and significant (p<0.01). This was associated with decline of heterosis dominance effect in F_2, F_3, 75%F and 62.5%F. Million Tadesse and

Table 3: Predict daily milk yield, lactation length, total lactation milk yield, calving interval, days open and age at first calving using genetic parameters from analysis (method 2)

	Milk production performance			Reproductive performance		
Genetic group	DMY	LL	TLMY	CI	DO	AFC
0%F	1.76	246.22	447.73	476.48	200.24	1388.11
25%F	4.29	282.65	1260.68	449.35	176.23	1291.55
37.5%F	4.83	274.51	1405.74	454.45	179.70	1327.98
50% F_1	7.13	332.25	2366.85	433.85	156.46	1226.29
50%F_2	5.43	298.00	1624.34	460.25	184.23	1372.23
50%F_3	5.43	298.00	1624.34	460.25	184.23	1372.23
62.5%F	6.11	310.32	1915.79	465.71	189.83	1424.30
75%F	6.87	325.84	2280.77	478.33	196.48	1484.20
87.5%F	6.87	348.94	2347.69	503.83	218.10	1624.89
93.75%F	6.89	329.40	2408.64	517.39	229.28	1698.17

F: F_1:first generation; F_2: second generation; F_3:third generation; Holstein Friesian; DMY: daily milk yield; LL: lactation length; TLMY: total lactation milk yield; CI: calving interval; DO: days open; AFC: age at first calving

TadelleDessie [21] revealed estimate of recombination loss for milk yield per lactation length and milk yield per calving interval was negative but insignificant. Moreover, Ahmad *et al*. [15] reported the effects of recombination was negative and significant in Friesian and Sahiwal crosses for lactation milk yield, milk yield per calving interval and days dry traits. SendrosDemeke *et al*. [11] indicated that there was a significant negative direct epistatic effect on lactation milk yield and daily milk yield due to the lowered performance observed on both the F_2's and backcrosses.

Reproduction Traits: As indicated in (Table 3) non-significance and negative direct epistatic effect was found for calving interval, days open and age at first calving. Ahmad *et al*. [15] found estimates of recombination loss for calving interval and days open were negative and significant in crossbreeding involving Friesian X Sahiwal and Jersey X Sahiwal. The findings of linear regression approach that are additive genetic difference, heterosis and recombination effects can be also used to predict performance of various breed combinations which are known or unknown in the original data [15] quoted by Hirooka and Bhutyan. Predicted daily milk yield, lactation length, total lactation milk yield, calving interval, days open and age at first calving computed as a function of coefficients in Table 3. According to the predicted results presented on Table 3, the highest daily milk yield and the lowest calving interval and days open were obtained in F_1 crossbred cows. Likewise, F_1 cows had the highest daily milk yield and the lowest calving interval, days open and attained early for age at first calving in observed least square means. In general excluding F_1 crossbred cows the prediction analysis showed that milk production performance relatively increased as fraction of Holstein Friesian gene increased in contrary the reproductive performance delayed. Thus, the poor reproductive performance of a cow resulted in low total life time milk production.

CONCLUSION

The crossbreeding parameter estimates clearly indicated the importance of additive effects on milk production and non-additive effect (hetrosis) on both milk production and reproduction traits. The estimated values of both observed and predicted showed that better performance in both milk production and reproduction traits were observed in F1 crosses. Animals with this level of Holstein Friesian inheritance calved earlier than the indigenous stock, produced more milk and had longer lactations and shorter calving intervals. Even though 75% Holstein Friesian genetic group was less delayed in age at first calving, it was comparable with F_1 in milk production performance. Hence, it can be concluded that crossbreeding should be designed for optimum breed additive and heterotic contribution.

REFERENCES

1. CSA (Central Statistical Agency), 2013. Agricultural Sample Survey 2012, Volume II report on livestock and livestock characteristics. Addis Ababa, Ethiopia.
2. Ethiopian Agricultural Transformation Agency (EATA), 2014. Livestock resources: Ethiopian Agricultural Transformation Agency. html.

3. Davis K. Jr., 2012. The cash cow of Africa (part I): Dairy. http:// www.africa.com/blog/dairy consumption -in-Africaa-part1./.
4. Van Raden P.M. and A.H. Sanders, 2003. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci., 86: 1036-1044.
5. Kefena Effa, Zewdie Wondatir, Tadelle Dessie and Aynalem Haile, 2012. Genetic and environmental trends in the long-term dairy cattle genetic improvement programmes in the central tropical highlands of Ethiopia. Journal of Cell and Animal Biology, 5(6): 96-104.
6. SAS (Statistical Analysis System), 2008. SAS for windows, Release 9.1. SAS Institute, Inc., Cary, NC, USA.
7. Akbas, Y., S. Brotherstone and W.G. Hill, 1993. Animal model estimation of non-additive genetic parameters in dairy cattle and their effect on heritability estimation and breeding value prediction. Journal of Animal Breeding and Genetics, 110: 105-113.
8. Robison, O.W., M.G. Kelly, B.T. McDaniel and R.E. McDowell, 1980. Genetic parameters of body size in purebred and crossbred dairy cattle. J. Dairy Sci., 63: 1887-1899.
9. SendrosDemeke, Neser F.W.C., S.J. Schoeman, G.J. Erasmus, J.B. Van Wyk and Alemu Gebrewolde, 2000. Crossbreeding Holstein-Friesian with Ethiopian Boran cattle in a tropical highland environment: preliminary estimates of additive and heterotic effects on milk production traits. S. Afr. J. Anim. Sci., 30 suppl 1:32. http://www.sasas.co.za/Sajas.html.
10. Million, Tadesse and Tadelle Dessie, 2004. Estimation of crossbreeding parameters for milk production traits of crosses between Holstein Friesian and local Arsi breed in the highlands of Ethiopia. Ethiopian J. Anim. Prod., 3(1): 25-35.
11. SendrosDemeke, F.W.C. Neser and S.J. Schoeman, 2004. Estimates of genetic parameters for Boran, Friesian and crosses of Friesian and Jersey with the Boran cattle in the tropical highlands of Ethiopia: reproduction traits. J. Anim. Breed. Genet., 121: 57-65.
12. Aynalem Haile, 2006. Genetic and Economic Analysis of Ethiopian Boran Cattle and their Crosses with Holstein Friesian in Central Ethiopia. A Ph.D. Thesis division of dairy cattle breeding National dairy research institute, Karnal-132001 (Haryana), India, pp: 65-146.
13. Hirooka, H. and A.K.F.H. Bhutyan, 1995. Additive and heterosis effect on milk yield and birth weight from crossbreeding experiments between Holstein Friesian and the local breed. American J. Anim. Sci., 8: 295-301.
14. Mackinnon, M.J., W. Thorpe and R.L. Barker, 1996. Sources of genetic variation for milk production in a crossbred herd in the tropics. Animal Sci., 62: 5-16.
15. Ahmad, M., J.H.J. Van Der Werf and K. Javed, 2001. Genotypic and phenotypic correlations for some economic traits in dairy cattle. Pakistan Vet. J., 21(2): 81-86.
16. Ghorbani, A. and R. Salamatdoustnobar, 2012. Estimation of non additive effects on milk production traits in Iranian Holstein crossbred population. Archiv Tierzucht, 55(6): 562-566.
17. Sharma, B.S. and F. Princhner, 1991. Heterosis in Friesian & Sahiwal crosses. J. Anim. Breed Genet., 108: 241.
18. Martinez, M.L., A.J. Lee and C.Y. Lin, 1988. Age and Zebu-Holstein additive and heterotic effects on lactation performance and reproduction in Brazil. J. Dairy Sci., 71: 800.
19. Kahi, A.K., M.J. Mackinnon, W. Thorpe, R.L. Baker and D. Njubi, 1995. Estimation of individual and maternal additive genetic and heterotic effects for preweaning traits of crosses of Ayrshire, Brown Swiss and Sahiwal cattle in the lowland tropics of Kenya. Livest. Prod. Sci., 44: 139-146.
20. Salamatdoustnobar, R., 2012. Estimation of non additive effects on milk production traits in Iranian Holstein crossbred population. Archiv Tierzucht, 55(6): 562-566.
21. Million, Tadesse and Tadelle Dessie, 2003. Milk production performance of Zebu, Holstein Friesian and their crosses in Ethiopia. Livest. Res. Rural Develop., 15(3): 31-40.