

Estimation of Genetic Parameters for Birth Weight and Reproduction Traits of Pure Jersey Dairy Cattle at Adea Berga Research Station

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Abstract: This study was conducted to estimate genetic parameters for birth weight and reproduction traits of pure Jersey dairy cattle at Adea Berga Research Station. A total of 9310 pure Jersey dairy cattle performance records which were collected from 1986 to 2019 were used for the study. Genetic parameters and variance components were estimated by Average Information Restricted Maximum Likelihood (AIREML) algorithm using WOMBAT software fitting animal models. The estimated heritability values of reproductive traits were 0.48 ± 0.04 , 0.06 ± 0.03 , 0.21 ± 0.07 and 0.03 ± 0.02 for age at first calving (AFC), calving interval (CI), cow weight at calving (CW) and number of service pre-conception (NSC), respectively. Additive and maternal heritability of birth weight (BW) were 0.25 ± 0.08 and 0.1 ± 0.07 . Repeatability value for CI, NSC and CW were 0.12 ± 0.04 , 0.09 ± 0.02 and 0.28 ± 0.06 , respectively. The genetic correlations among reproductive traits varied from 0.10 to 0.92. The Phenotypic correlations among reproductive traits were varied from -0.02 to 0.50. The moderate heritability estimate observed for AFC and BW indicated that genetic improvement for these traits might be possible through selection. Therefore, from the result of this study, it can be concluded that, AFC and BW performances of pure Jersey cattle at Adea Berg research dairy farm were promising for further improvement through selection of parental lines to produce better calves of the next generation. However, the lower heritability estimates of CI and NSC indicated the need of good practical management of the herd in order to improve the reproductive performance.

Key words: Adea Berga • Birth Weight • Genetic Parameters • Pure Jersey Dairy Cattle • Reproductive performance

INTRODUCTION

As a result of low reproductive and production performance of indigenous cattle in Ethiopia, the genetic improvement of dairy cattle is mainly based on cross breeding and adoption of improved exotic breeds [1, 2]. Even though there is a worry about adaptation of pure exotic dairy cattle in the tropical environment (climate, feed and disease challenge), pure Jersey and Frisian dairy breeds raised by large scale state and private dairy farm in Ethiopia.

Research reports revealed that Jersey cows are characterized by small body size, hardy and adaptable, low maintenance requirement, high feed conversion

efficiency, high milk fat content and good reproductive performance and has been selected for tropical research and development program [3]. Thus, they could be a good alternative in Ethiopian highland environment to use as an additional option for intensive and large-scale dairy farms [1].

Both genetic and environmental factors affect economically important traits of animals. The genetic factors due to a random sample of genes received from the two parental gametes whereas the environmental factors include influences of climate, nutrition, health and management [4]. Genetic analysis of animal genetic resources most often aims at separating genetic and environmental effects [5]. The estimates of genetic

parameters are helpful in determining the method of selection to predict direct and associated response to selection, choosing a breeding system to be adopted for future improvement as well as in the estimation of genetic gains [6-8].

Periodical evaluation of growth and reproductive performance of the dairy cattle is very important for future improvement planning and management. Previous studies have been conducted to evaluate productive and reproductive performances of pure Jersey cattle in the central highland of Ethiopia [9], but there is limited information on growth performance and their genetic performances were not evaluated since 2005 and that cannot consider the current change due to selection, climatic change and breeding program followed and experience gained.

Having current performance on growth and reproduction performance of pure Jersey cows in Adea Berga Jersey dairy herd would help to suggest the future management and genetic improvement intervention for this herd.

MATERIALS AND METHODS

Study Area: The current research was conducted at Holetta Agricultural Research Center, Adea Berga Dairy Research Station which is found in West Shewa Zone of Oromia Regional State, Ethiopia. Adea Berga is situated in the central highlands of Ethiopia 35 km North West of Holetta and 70 km West of Addis Ababa at 38° 23' E longitude, 9° 16' N latitude and an altitude of 2500 meter above sea level. The annual temperature and rainfall ranges from 18°C to 24°C and 1000 to 1225 mm, respectively and characterized by cool sub-tropical climate with. Vegetation is mainly composed of perennial sedges and grasses. Pennisetum and Andropogon are the most common species dominating the pasture in the area [10].

Description of the Farm: Adea Berga dairy farm was established at in 1986 as one of government state farm. Four hundred pure Jersey pregnant heifers and 2 sires were importing from Denmark to use as foundation stock. The initial objective of the farm was commercial milk production and supply to Addis Ababa. Parallel to this the farm has been serving as a bull dam for the national animal genetic improvement institute (NAGII). Then the farm was transferred to Holeta agricultural research center for genetic improvement research since 2007.

Study Animal and Breeding Program: Data collected from pure Jersey calves, heifers and cows were used for this study. The herd management practices depend on sex, age and physiological status. Bucket feeding system was followed for calves, except the first 5 days that calves suckle colostrum. During the dry and short rainy season, all cows (except late pregnant) and heifer were allowed to graze natural pasture for about 4-6 hours a day. Then supplemental feeds (concentrate composed of wheat bran, wheat middling, noug cake and salt) and hay were provided up on return to barn. However, all animals were restricted from grazing and managed indoor during main rainy season except for 1-2 hours exercise. The farm has disease prevention and control practices. There was scheduled deworming against internal parasite and vaccination against Blakleg, Anthrax, Foot and mouth, pasteurellosis and Lumpy skin disease.

Pure line selection with controlled mating has been carried out in the farm. Mating was mostly based on artificial insemination and conducted throughout the year. Few male calves were recruited each year by national animal genetic improvement institute (NAGII) for national crossbreeding activities. Thus, most of the male calves were culled at early age. The main source of semen for this herd was NAGII. However, worldwide sire semen has been used since 2009 to further improve this herd.

Statistical Analysis: Genetic parameters (heritability, repeatability and genetic and phenotypic correlations) and variance components (genetic and environmental variance) of BW, AFC, CI, NSC and CW traits were estimated from Multivariate analysis by Average Information Restricted Maximum Likelihood (AIREML) method, using WOMBAT software [11] fitting animal models.

The log-likelihood ratio test was performed to determine significant random effects and consequently the most appropriate model for birth weight trait. A random effect was considered significant when its presence in the model caused a significant increase in the log likelihood value that is when $2(\log \text{ likelihoods value of model } y - \log \text{ likelihoods value of model } x)$ is greater than the critical value, model y was considered significant [12]. However, when the difference between the values of log-likelihood is not greater than a critical value of chi-square (χ^2), the simplest model was the best model. One degree of freedom and Chi-square distribution for $\alpha = 0.05$ was used as the critical test statistic (3.841) to compare model which includes one random effect with

two random effect. For AFC trait direct additive genetic effect (animal) was the only random effect fitted in the model (Model 1). However, for CI, CW and NSC traits a repeatability animal model was fitted (Model 2), where direct additive effects (animal) plus permanent environmental effect due to repeated records per cow were fitted as random effects. For BW trait both direct additive genetic effect and maternal additive genetic effect was fitted in the model as random effects (Model 3) While, year, season, parity, cow weight at calving and calf sex were all significant in the fixed effect analysis and fitted as a fixed effect in the analysis of genetic model. The models were presented as follows.

Model 1: $Y = Xb + Z_1a + e$

Model 2: $Y = Xb + Z_1a + Z_2c + e$

Model 3: $Y = Xb + Z_1a + Z_3m + e$

where, Y = vector of records; b = the vector of fixed effects; X = incidence matrix relating record with fixed effects a = vector of direct additive genetic effect; c = vector of permanent environmental effect, m = maternal additive genetic effect and Z_1, Z_2 and Z_3 = incidence matrix relating record with direct additive genetic effect, permanent environmental effect and maternal additive genetic effect respectively; e = vector of random residual errors.

The model was assumed as expected value of Y to be Xb . The vector random individual additive genetic effects, permanent environmental effects, maternal additive genetic effect and residual effects are assumed to be uncorrelated and have expected mean of zero and variances $\sigma_a^2, \sigma_c^2, \sigma_m^2$ and σ_e^2 , respectively.

RESULTS AND DISCUSSION

Estimation of Heritability for Birth Weight: Birth weight of calves and its early growth rate are determined not only by its own genetic potential but also by the maternal environment. The Dam's genotype affects the calf growth through a sample of half of her direct additive genes as well as through her genotype for maternal effects on calf weight.

Heritability and variance components for birth weight trait of Pure Jersey cattle breed at Adea Berga research dairy farm were estimated by using two animal models (1 and 3) presented in Table 1. From the likelihood ratio tests model, three was the "best" model which includes maternal additive genetic effects in addition to direct

additive genetic effect. The additive heritability estimate was reduced in the Model 3 as compared to Model 1, indicating that animal models which ignored maternal effects tend to overestimate additive heritability. This is may be due to improper partitioning of variance in the absence of maternal effect.

The estimated additive heritability value from the best model 0.251 ± 0.08 of BW was comparable with estimates of 0.25 ± 0.10 [13] for Fogera breed and 0.22 ± 0.01 [14] for Hanwoo cattle and higher than the estimates of 0.128 ± 0.242 [15] for Fogera and Holstein Frisian crossbred cattle, 0.14 ± 0.05 [16] for Sahiwal cattle and 0.15 ± 0.04 [17] for Holstein Frisian and Boran crossbred. However, lower than the heritability estimates of 0.49 ± 0.14 for Holstein, Jersey and reciprocal crosses [18], 0.38 for Jersey breed [19], 0.61 ± 0.04 for Horro and crosses of Holstein Frisian and Jersey cattle breeds [20], 0.32 ± 0.06 for Holstein Frisian cattle [21] and 0.32 ± 0.181 for different grades of dairy cattle [22].

The estimated maternal heritability of 0.10 ± 0.07 , for birth weight in the present study was comparable with maternal heritability estimates of 0.12 [14] and lower than 0.166 ± 0.02 [15] and 0.19 ± 0.03 [16]. However, it was higher than the values of $0.023, 0.07$ and 0.09 [17, 23, 24] respectively.

The moderate heritability estimate of birth weight from the best model in the present study revealed that genetic improvement of birth weight can be achieved through selection program.

Heritability Estimation for Reproductive Traits

Age at First Calving (AFC): Estimates for variance components and heritability (h^2) of AFC are presented in Table 2. The heritability estimate for AFC was 0.48 ± 0.04 which was comparable with heritability estimates of 0.48 ± 0.35 [25] for pure Jersey cattle in Pakistan, 0.53 ± 0.12 [8] and 0.47 ± 0.06 [26] For Holstein Friesian cattle in Ethiopia. However, higher results were reported 0.62 ± 0.09 [9] for Holstein, 0.61 ± 0.15 and 0.7 ± 0.16 [27, 28] for Boran and Holstein Frisian crosses in Ethiopia respectively. On the other hand our estimate was higher than 0.44 ± 0.05 [29], 0.16 ± 0.06 [9], 0.4 [30], 0.22 ± 0.11 [31], 0.3 ± 0.19 [32], 0.408 ± 0.13 [33] and 0.19 ± 0.16 [22]. In general heritability estimate on AFC in present study is within a range of literature reports. The high heritability estimate for AFC in present study indicated that this trait is governed more by additive genetic effect than environmental effect which reflects that genetic improvement of this trait is possible through genetic selection.

Table 1: Estimate of variance components and heritability ($h^2 \pm SE$) for birth weight (BW) from multivariate analysis

Model	σ^2_a	σ^2_e	σ^2_p	σ^2_m	$h^2_a \pm SE$	$h^2_m \pm SE$	Maxi. LogL
1	4.56	6.04	10.60		0.43 \pm 0.09		-27935.413
3	2.06	6.10	9.05	0.89	0.25 \pm 0.08	0.10 \pm 0.07	-27921.403

σ^2_a = additive genetic variance; σ^2_e = residual variance; σ^2_p = phenotypic variance; σ^2_m = maternal genetic variance; h^2_a = additive heritability; h^2_m = maternal heritability; SE = standard error.

Table 2: Variance components, heritability ($h^2 \pm SE$) and repeatability ($r \pm SE$) of reproductive traits from multivariate analysis

	AFC	CI	CW	NSC
σ^2_a	17381.2	976.758	350.186	0.09
σ^2_c		1974.35	466.123	0.232043
σ^2_e	18987.7	13160.5	827.188	2.38860
σ^2_p	36368.9	16335.5	1646.38	2.71
$h^2 \pm SE$	0.48 \pm 0.04	0.06 \pm 0.03	0.21 \pm 0.07	0.03 \pm 0.02
$r \pm SE$		0.12 \pm 0.04	0.28 \pm 0.06	0.09 \pm 0.02

σ^2_a = additive genetic variance; σ^2_c = permanent environmental variance; σ^2_e = residual variance; σ^2_p = phenotypic variance; h^2 = heritability; r = repeatability; CW = Cow weight at calving; SE = standard error.

Calving Interval (CI): Estimates for variance components and heritability (h^2) of CI are presented in the Table 2. Heritability estimate of 0.06 ± 0.03 CI in this study was comparable with estimates of 0.072 ± 0.098 [34] for the same breed and higher than heritability of 0.026 ± 0.004 reported [35] for pure Jersey cattle and 0.029 ± 0.009 [36] for Holstein Frisian cattle. But lower than heritability estimates of 0.10 ± 0.19 reported [25] for the same breed 0.222 ± 0.101 for Jersey and Red Sindhi crosses [31], 0.111 ± 0.04 [26] for Holstein Frisian cattle in Ethiopia, 0.16 ± 0.08 [37] for Jersey crossbred cows in India and 0.14 ± 0.211 [22] for different grades of dairy cattle reared under subtropical conditions in Pakistan were reported. Low heritability estimates for CI is indicative of the presence of less additive genetic variance and large environmental variance. Therefore, improvements in nutrition and reproductive management should lead to a considerable decrease in length of CI than focusing genetic selection alone.

Cow Weight at Calving (CW): Estimates for variance components and heritability (h^2) of CW are presented in Table 2. A heritability estimate of 0.21 ± 0.07 for CW in the present study was higher than the estimate of 0.10 ± 0.03 [38] for Boran, Frisian and crosses of Frisian and Jersey with the Boran cattle. However, lower than heritability estimates of 0.29 ± 0.04 and 0.33 ± 0.03 [39] for Brangus-Ibage cattle and Crook *et al.* [40] for South African Simmental cattle respectively. The medium heritability (h^2) estimate of CW may show the need of including CW in the selection criteria and providing better management during pregnancy as this trait influences BW, DO and CI traits.

Number of Services per Conception (NSC): Estimates for variance components and heritability (h^2) of NSC are presented in Table 2. The heritability estimate of NSC in the present study was low (0.03 ± 0.02). Similarly, Low heritability estimates for NSC were reported by various authors. For instance, 0.08 ± 0.02 for Boran, Frisian and crosses of Frisian and Jersey with the Boran cattle in Ethiopia was reported [29]. In addition, M^hamdi *et al.* [41] estimated 0.027 ± 0.034 for Holstein breed, [34] 0.093 ± 0.097 for Jersey cattle, while Vinothraj *et al.* [31] found 0.042 ± 0.003 for Jersey and Red Sindhi crosses and Kumari *et al.* [33] reported 0.08 ± 0.06 for cross-breed cows in India. The low heritability estimate for NSC in present study implied that this trait is governed more by environment than genetics and has limited scope for genetic improvement, but appropriate management practices are the major remedies to improve the trait in the herd.

Repeatability Estimation for Reproductive Traits

Calving Intervals (CI): The repeatability estimate (0.12 ± 0.04) for CI in the present study was comparable with the finding of [9] who estimated 0.12 ± 0.08 for pure Jersey breed in Ethiopia and higher than the estimates of 0.074 ± 0.116 [34] for pure Jersey cattle in Colombia. Inconsistent to the present result higher values of 0.14 ± 0.02 [27] for dairy cattle in Ethiopia, 0.133 ± 0.364 [42] for pure Jersey cattle in Malawi, 0.234 ± 0.06 [31] for Jersey and Red Sindhi crossbred cows in India and 0.23 ± 0.02 [26] for Holstein Frisian cattle in Ethiopia were reported. The low repeatability observed here might reveal that the association of subsequent CI is low and this trait is affected more by temporary or specific environmental factors than genetics.

Number of Services per Conception (NSC): The repeatability estimate of NSC 0.09 ± 0.03 in the present study was comparable with Zambrano and Echeverri [34] who reported 0.094 ± 0.105 for pure Jersey cattle and higher than the result of Vinothraj *et al.* [31] for Jersey and Red Sindhi crosses 0.001 ± 0.00 . A higher estimate compared to this study was indicated [36] for Holstein cattle 0.115 ± 0.03 . The low repeatability estimate for NSC could be due to low h^2 of the trait and higher influences of temporary environment (climate and husbandry) in a given period.

Cow Weight at Calving (CW): The repeatability estimates of 0.28 ± 0.03 CW in this study was lower than the estimates of 0.5 ± 0.03 [40] for Simmental cattle in South Africa and 0.34 ± 0.02 [38] for Boran, Frisian and crosses of Frisian and Jersey with the Boran cattle in the tropical highlands of Ethiopia. The moderate repeatability estimate observed in current study indicates that an animal evaluation and genetic improvement are possible using heritability value for this trait.

Genetic and Phenotypic Correlation

Genetic Correlation: The genetic correlations among reproductive traits in the present study were weak for most and highly positive for few and ranges from low 0.1 to high 0.92. The positive genetic correlation between reproductive traits indicates that improvement of one trait has positive impact on the other trait.

The joint analysis of CI and NSC in the present study indicates that the genetic association between these two traits was positive and high (0.92 ± 0.33). Consistent to our estimate 0.95 ± 0.45 for Holstein cattle but lower (0.541 ± 1.357) value for Jersey cattle were found [34]. This highly positive genetic correlation result also supported [43] of 0.81 and Rahbar *et al.* [36] 0.88 ± 0.15 for Holstein cattle. The highly positive association suggests that these two reproductive traits are genetically linked i.e., they are influence by the same genes. This is known as pleiotropic effect [44]. This means common genetic and physiological mechanisms controlling these traits. The positive association between these two traits indicated that simultaneous genetic improvement could be achieved while selecting any one of them, that is, animals with lower NSC should be selected to have less value for CI on genetic scale, which is very much desirable.

Genetic correlation of 0.56 ± 0.20 between CI and AFC in this study was comparable with 0.599 ± 0.487 and 0.52 ± 0.13 reported by Dhal *et al.* [45] for crossbred Jersey cattle and Lopez *et al.* [14] for Hanwoo cattle respectively and higher than Wondossen Ayalew *et al.* [26] and Brzakova *et al.* [46] who reported 0.16 ± 0.12 and 0.291 ± 0.0018 for Holstein cattle. However, in contrast to this result highly negative genetic association of -0.76 ± 0.03 and -0.99 were reported for Jersey cattle by Yosef Tadesse [9] and Orengé *et al.* [47] for Charolais and Hereford cattle respectively. On the other hand low negative genetic correlation of -0.13 for Brahman cattle was reported by Cavani *et al.* [48]. The variation of the present study from others literature might be due to breed, number of observation studied and software procedure used for analysis.

The present study has shown that negative, weak and moderately positive genetic correlations between birth weight and reproductive traits. The positive genetic correlation between BW and CI (0.19 ± 0.27) and between BW and NSC (0.25 ± 0.26) in this study was in line with the report of Rahbar *et al.* [36] of 0.32 for BW with CI and 0.16 for BW with NSC. Contrary to present study negative genetic correlation (-0.34) between BW and CI was reported [22].

Likewise, the genetic correlation between BW and AFC was positive 0.27 ± 0.17 . Similarly, positive genetic correlations of 0.13, 0.77, 0.15 ± 0.05 and 0.33 were reported by Lopez *et al.* [14], Orengé *et al.* [47], Almaz Bekele *et al.* [49] and Lopez-Paredes *et al.* [50]. In contrast to this result negative, genetic correlation (-0.07) was reported by Ali *et al.* [22].

The genetic correlation between cow weight at calving with BW, NSC and CI were 0.57 ± 0.2 , 0.36 ± 0.29 and 0.10 ± 0.03 respectively. Similar to this result positive genetic correlation 0.25 ± 0.15 was reported by Lacerda *et al.* [51] between CW with CI for Nelore cows. The Positive genetic correlation of cow weight at calving with birth weight and fertility traits (NSC and CI) in this study could suggest that cow weight at calving is important trait to achieve better calf birth weight, smaller number of service per conception and shorter calving interval.

Phenotypic Correlation: Phenotypic correlation among reproductive traits varied from -0.02 to 0.50 . A phenotypic correlation between AFC and CI was 0.02 ± 0.04 . Similarly, weak positive phenotypic correlation 0.11 ± 0.03 and 0.03 ± 0.01 were indicated by Lopez *et al.* [14] and Wondossen Ayalew *et al.* [26] respectively. However, lack of phenotypic correlation reported by Orengé *et al.* [47] while, weak negative phenotypic correlation of -0.005 ± 0.05 , -0.008 ± 0.003 and -0.10 ± 0.0 were reported by Dhal *et al.* [45], Wakchaure and Meena [52] and Chawala *et al.* [53] respectively.

Phenotypic correlation between CI and NSC was low 0.05 ± 0.03 . This low phenotypic correlation might be due to negative environmental correlation between these two traits. Similar to present study low phenotypic correlation of 0.047 ± 0.01 and 0.041 ± 0.04 were obtained by Zambrano and Echeverri [34] for Holstein and Jersey cattle respectively and 0.19 by Kefale Getahun *et al.* [54] for Holstein Frisian and Boran crosses. In contrary to present study, higher values of 0.68, 0.70 ± 0.002 and 0.83 ± 0.01 were reported by some other studies Rahbar *et al.* [36], González-Recio and Alenda [55], Ghiasi *et al.* [56].

Table 3: Genetic (above diagonal) and phenotypic (below diagonal) correlations of birth weight and reproductive traits using multi trait analysis

	CI	CW	NSC	AFC	BW
CI		0.10 ± 0.03	0.92 ± 0.33	0.56 ± 0.20	0.19 ± 0.27
CW	-0.02 ± 0.03		0.36 ± 0.29	0.12 ± 0.12	0.57 ± 0.2
NSC	0.05 ± 0.03	0.07 ± 0.02		0.32 ± 0.16	0.25 ± 0.26
AFC	0.02 ± 0.04	0.17 ± 0.04	0.50 ± 0.03		0.27 ± 0.17
BW	0.05 ± 0.05	0.06 ± 0.06	0.03 ± 0.04	0.04 ± 0.05	

CONCLUSION

This study confirms that heritability and repeatability estimates of reproductive traits except AFC were low (<10%). The heritability estimates for age at first calving and calf birth weight were high (0.48) and moderate (0.25) respectively. The study also showed that the genetic correlations among reproductive traits were weak for most and highly positive for few and ranges from low 0.1 to high 0.92.

The low heritability and repeatability estimates of reproductive traits of CI and NSC in this study indicates that the traits are affected mostly by environment than genetics and improvement through selection is render low magnitudes and long-term responses. Nevertheless, the economic importance of these traits should not be overlooked. Therefore, these reproductive qualities should be further improved through application of enhanced management techniques. The high and moderate heritability estimate of age at first calving and birth weight respectively suggested that improvement of these traits are possible through selection based on phenotypic performance of animals.

REFERENCES

- Direba Hunde, Gabor, M. Tadelles Dessie, Getnet Assefa, Million Tadesse and S. Johan, 2015. Milk yield and reproductive performance of pure Jersey dairy cattle in the Central Highlands of Ethiopia. *Journal of Livestock Research for Rural Development*, 27(130).
- Destaw Worku and Kefyalew Alemayehu, 2018. Evaluation of the reproductive performance of Holstein Frisian dairy cows in Alage ATVET College, Ethiopia. *International Journal of Livestock Production*, 9(6): 131-139.
- Njubi, D., J. E.O. Rege, W. Thorpe, E. Collins- Lusweti and R. Nyambaka, 1992. Genetic and environmental variation in reproductive and lactation performance of Jersey cattle in the coastal lowland semi-humid tropics. *Tropical Animal Health Production*, 24(4): 231-241.
- Bourdon, M.R., 1999. *Understanding animal breeding*. 2nd ed. Upper saddle River NJ07458, Colorado State University, pp: 538.
- Falconer, D.S. and T.F.C. Mackay, 1996. *Introduction to quantitative genetics*. 4th edition. Longman group, England.
- Wasike, C.B., 2006. Genetic evaluation of growth and reproductive performance of Kenya Boran Cattle. M.sc Thesis, Egerton University, Njoro, Kenya.
- Edward, M., I.C. Venancio and H. Tinyiko, 2013. Estimation of Genetic and Phenotypic Parameters for Production Traits and Somatic Cell Count for Jersey Dairy Cattle in Zimbabwe. *International Scholarly Research Notices (ISRN) Veterinary Science*, pp: 1-5.
- Gebeyehu Goshu, Harpa, S., P. Karl-Johan and L. Nils, 2014. Heritability and correlation among first lactation traits in Holstein Frisian cows at Holetta Bull Dam Station, Ethiopia. *Academic Journals*, 5(3): 47-53.
- Yosef Tadesse, 2006. Genetic and non-genetic analysis of fertility and production traits in Holetta and Adea Berga dairy herds in Ethiopia. M.Sc Thesis, Haramaya University, Haramaya, Ethiopia.
- Tamirat Siyoum, Aster Yohannes, Yosef Shiferaw, Zerihun Asefa and Melese Eshete, 2016. Major reproductive disorders on Jersey breed dairy cattle at Adea Berga dairy farm, West Shewa Zone, Oromia Region, Ethiopia. *Ethiopian Veterinary Journal*, 20(1): 91-103.
- Meyer, K., 2012. WOMBAT, A program for mixed model analyses by restricted maximum likelihood. User notes. Animal Genetics and Breeding unit, University of New England Armidale, Australia.
- Zelege Tesema, 2019. On-station and on-farm performance evaluation and genetic parameters estimation of Boer x Central Highland crossbred Goat in north Wollo zone, Ethiopia. M.Sc Thesis, Bahir Dar University, Bahir Dar, Ethiopia.
- Assemu Tesfa, 2015. Estimation of Genetic and Non Genetic Parameters for Growth and Reproductive Performance Traits of Fogera Cattle Breed. M.Sc, Thesis, Bahir Dar University, Bahir dar, Ethiopia.

14. Lopez, B.I., K.G. Santiago, K. Seo, T. Jeong, J.E. Park, H.H. Chai, W. Park and D. Lim, 2020. Genetic Parameters of birth weight and weaning weight and their relationship with gestation length and age at first calving in Hanwoo (*Bos Taurus coreanae*). *Animals*, 10(6): 1083.
15. Belay Zeleke, Kefelegn Kebede and Ajay Kumar Banerjee, 2016. Estimation of genetic parameters for reproductive traits of Fogera and Holstein Friesian crossbred cattle at Metekel Ranch, Amhara region, Ethiopia. *Online J. Anim. Feed Res.*, (6): 90-95.
16. Selvan, A.S., M.S. Tantia, A. Kumaresan, A. Kumar, D. Ravi Kumar, T. Karuthadurai and A. Upadhyay, 2018. Phenotypic and genetic parameters estimation for birth weight in Zebu and crossbred calves born under organized farm conditions in India. *International Journal of Livestock Research*, 8: 48-58.
17. Fikadu Wodajo, 2020. Phenotypic and genetic parameters estimation for growth traits of Holstein Friesian and Boran crossbred dairy cattle at Holetta Agricultural Research Center. M.Sc Thesis, Bahir Dar University, Bahir Dar, Ethiopia.
18. Olson, K.M., B.G. Casse, A.J. Allister and S.P. Washburn, 2009. Dystocia, stillbirth, gestation length and birth weight in Holstein, Jersey and reciprocal crosses from a planned experiment. *Journal of Dairy Science*, 92(12).
19. Akadag, F., S. Arslan, A. Caynak and B. Teke, 2011. The relationship of phenotype, genotype and some environmental factors with birth weight in Jersey calves. *African Journal of Biotechnology*, 10(37): 7308-7313.
20. Habtamu Abera, 2017. Genetics and environmental trends in growth performance of Horro (Zebu) and crosses of Holstein Friesian and Jersey cattle breed. *African Journal of Biotechnology*, 16(18): 1007-1015.
21. Sanad, S.S. and M.G. Gharib, 2017. Estimation of Genetic and Phenotypic Parameters for Growth Traits of Friesian Cattle Raised in Egypt. *Journal of Animal and Poultry Production*, 8(8): 253-259.
22. Ali, I., S. Muhammad Suhail and M. Shafiq, 2019. Heritability estimates and genetic correlations of various production and reproductive traits of different grades of dairy cattle reared under subtropical condition. *Reproduction in Domestic Animals*, 54(7): 1026-1033.
23. Habtamu Abera, Solomon, Abegaz and Yosphe Mekasha, 2011. Genetic parameter estimates of pre-weaning weight of Horro (Zebu) and their crosses with Holstein Friesian and Jersey cattle breeds in Ethiopia. *International Journal of Livestock Production*, 2(6): 84-91.
24. Molla Shumye, Kefelegn Kebede and Kefena Effa, 2018. Genetic Analysis of Early Growth of Crossbred Dairy Cattle in Central Ethiopia Using Random Regression Model. *Ethiopian Journal of Agricultural Sciences*, 28(3): 19-34.
25. Syed Muhammad, Ijaz Ahmed, Abdul Hafeez, Sohail Ahmed, Dawood Jan, Sarzamin, K. and Altaf-ur-rehman, 2010. Genetic study of some reproductive traits of Jersey cattle under subtropical conditions. *Sarhad Journal of Agriculture*, 26(1).
26. Wondossen Ayalew, Mohammed Aliy and Enyew Negussie, 2017. Estimation of genetic parameters of the productive and reproductive traits in Ethiopian Holstein using multi-trait models. *Asian-Australas Journal of Animal Science*, 30: 1550-1556.
27. 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.
28. Aynalem Haile, Joshi, B.K., Workneh Ayalew, Azage Tegegne and A. Singh, 2009b. Genetic evaluation of Ethiopian Borena cattle and their crosses with Holstein Friesian in central Ethiopia: Reproductive traits. *Journal of Agricultural Science*, 147: 81-89.
29. Sandrose Demeke, Nesor, F.W.C. and S.J. Schoeman, 2004b. 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. *Journal of Animal Breeding and Genetics*, 121: 57-65.
30. Kefena Effa, Zewdie Wondatir, Tadelle Dessie and Aynalem Haile, 2011. Genetic and Environmental trends in the long-term Dairy cattle genetic improvement programs in the Central Tropical Highlands of Ethiopia. *Journal of Cell and Animal Biology*, 5(6): 96-104.
31. Vinothraj, S., A. Subramaniyan, R. Venkataramanan, C. Joseph and S.N. Sivaselvam, 2016. Genetic evaluation of reproduction performance of Jersey× Red Sindhi crossbred cows. *Veterinary World*, 9(9): 1012-1017.

32. Anshuman, K., M.Ajoy, A.K. Gupta, R. Poonam and K. Narendra, 2017. Genetic evaluation of reproductive traits in Jersey crossbred heifers at an organized farm of eastern India. *Indian Journal of Animal Research*, 51(4): 619-624.
33. Kumari, S., R. Narang, P. Malhotra, N. Sharma and A. Mehrotra, 2019. Evaluation of reproductive performance of crossbred cattle maintained at an organized farm in Punjab. *The Pharma Innovation Journal*, 8(7): 159-162.
34. Zambrano, J.C. and E. Echeverri, 2014. Genetic and environmental variance and covariance parameters for some reproductive traits of Holstein and Jersey cattle in Antioquia (Colombia). *Journal of Revista Brasileira de Zootecnia (R. Bras. Zootec)*, 43(3): 132-13.
35. Haile-Mariam Mekonen, P.J. Bowman and J.E. Pryce, 2013. Genetic analyses of fertility and predictor traits in Holstein herds with low and high mean calving intervals and in Jersey herds. *Journal of Dairy Science*, 96(1).
36. Rahbar, R., M. Aminafshar, R. Abdullhappour and M. Chamani, 2016. Genetic analysis of fertility traits of Holstein dairy cattle in warm and temperate climate. *Acta Scientiarum. Animal Sciences*, 38(3): 333-340.
37. Kumar, A., A. Mandal, A.K. Gupta, M. Karunakaran, S.K. Das and T.K. Dutta, 2018. Genetic analysis of fertility traits in Jersey crossbred cows. *Indian Journal of Animal Research*, 52(8): 1113-1118.
38. Sandrose Demeke, F.W.C. Nesor and S.J. Schoeman, 2004. Estimates of genetic parameters for Boran, Frisian and crosses of Frisian and Jersey with the Boran cattle in the tropical highlands of Ethiopia: milk production traits and cow weight. *Journal of Animal Breeding and Genetics*, 121(3): 163-175.
39. Henkes, L.E., M.V. Benavides, J.F.C. Oliveira, J.C.F. Moraes and T.A. Weimer, 2004. Maternal inheritance on reproductive traits in Brangus-Ibagé cattle. *Ciencia Rural*, 34(4): 1163-1167.
40. Crook, B.J., F.W.C. Nesor and M.J. Bradfield, 2010. Genetic parameters for cow weight at calving and at calf weaning in South African Simmental cattle. *South African Journal of Animal Science*, 40(2).
41. M'hamdi, N., R. Aloulou, S.K. Brar, M. Bouallegue and B.M. Hamouda, 2010. Phenotypic and genetic parameters of reproductive traits in Tunisian Holstein cows. *Journal of Biotechnology in Animal Husbandry*, 26(5-6): 297-307.
42. Nandolo, W., 2015. The performance of Jersey cattle at Naming'omba Tea and Coffee Estate in Malawi. *Livestock Research for Rural Development*, 27(1).
43. Eghbalsaied, S., 2011. Estimation of genetic parameters for 13 female fertility indices in Holstein dairy cows. *Tropical animal health and production*, 43(4): 811-816.
44. Falconer, J.C. and F. MacKay, 2001. *Introduction quantitative genetics*. 4th edition. Editorial Acribia, Zaragoza, Spain, pp: 163.
45. Dhal, S.K., S. Mishra, S. Ray, L. Sahoo, G. Sahoo and S.K. Dash, 2016. Genetic Studies on Reproduction Traits in Crossbred Jersey Cattle in Western Odisha. *Exploratory Animal and Medical Research*, 6(1): 68-74.
46. Brzakova, M., L. Zavadilova, J. Priby, P. Pesek, E. Kasna and A. Kranjcevicova, 2019. Estimation of genetic parameters for female fertility traits in the Czech Holstein population. *Czech Journal of Animal Science*, 64(5): 199-206.
47. Orange, J.S.K., E.D. Ilatsia, I.S. Kosgey and A.K. Kahi, 2009. Genetic and phenotypic parameters and annual trends for growth and fertility traits of Charolais and Hereford beef cattle breeds in Kenya. *Tropical Animal Health and Production*, 41(5): 767-774.
48. Cavani, L., D.A. Garcia, L.O.D. Carreño, R.K. Ono, M.P. Pires, M.M. Farah, H.T. Ventura, D.D. Millen and R. Fonseca, 2015. Estimates of genetic parameters for reproductive traits in Brahman cattle breed. *Journal of Animal Science*, 93(7): 3287-3291.
49. Almaz Bekele, Zewdu Wuletaw, Aynalem Haile, Solomon Gizaw and Getinet Mekuriaw, 2016. Genetic parameter estimation of pre weaning growth traits of Fogera cattle at Metekel Ranch, Northwest Ethiopia. *International Journal of Scientific Research in Science and Technology*, 2(5): 15-21.
50. Lopez-Paredes, J., M.A. Pérez-Cabal, J.A. Jiménez-Montero and R. Alenda, 2018. Influence of age at first calving in a continuous calving season on productive, functional and economic performance in a Blonde d'Aquitaine beef population. *Journal of Animal Science*, 96(10): 4015-4027.
51. Lacerda, V.V., G.S. Campos, V.M. Roso, F.R.P. Souza, C.C. Brauner and A.A. Boligon, 2018. Effect of mature size and body condition of Nelore females on the reproductive performance. *Theriogenology*, 118: 27-33.

52. Wakchaure, R.S. and R. Meena, 2010. Factors Affecting, birth weight, age and weight at first calving in Sahiwal cattle. *Indian Journal of Animal Research*, 44(3): 173-177.
53. Chawala, A.R., G. Banos, D.M. Komwihangilo, A. Peters and M.G.G. Chagunda, 2017. Phenotypic and genetic parameters for selected production and reproduction traits of Mpwapwa cattle in low-input production systems. *South African Journal of Animal Science*, 47(3): 307-319.
54. Kefale Getahun, Direba Hunde, Million Tadesse and Yosef Tadesse, 2019. Reproductive performances of crossbred dairy cattle at Holetta Agricultural Research Center. *Livestock Research for Rural Development*, 31(9).
55. González-Recio, O. and R. Alenda, 2005. Genetic parameters for female fertility traits and a fertility index in Spanish dairy cattle. *Journal of Dairy Science*, 88: 3282-3289.
56. Ghiasi, H., A. Pakdel, A. Nejati-Javaremi, H. Meharabani-Yeganeh, M. Honarvar, O. González-Recio, M. J. Carabano and R. Alenda, 2011. Genetic variance components for female fertility in Iranian Holstein cows. *Livestock Science*, 139(3): 277-280.