International Journal of Agriculture, Environment and Biotechnology
Citation: *IJAEB*: **17**(04): 679-685, December 2024
DOI: 10.30954/0974-1712.04.2024.5

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

RESEARCH PAPER

Effect of Season and Birth Weight on Reproductive Performance of Sahiwal Heifers in an Organized Herd

R.K. Meena[1], Indrasen Chauhan[2*], Santosh Kumar[3] and Ajesh Kumar[4]

[1]College of Agriculture (Bharatpur), Sri Karan Narendra Agriculture University, Jobner, Rajasthan, India
[2]ICAR-Indian Veterinary Research Institute, Mukteshwar Campus, Nainital, Uttarakhand, India
[3]Livestock Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, India
[4]College of Agriculture, Nagaur, Rajasthan, India

*Corresponding author: indrachauhan55@gmail.com (**ORCID ID:** 0000-0002-7727-9252)

Paper No. 1185 **Received:** 16-09-2024 **Revised:** 02-11-2024 **Accepted:** 24-11-2024

ABSTRACT

Heifers are the future cows of the herd. Moreover, the heifers are considered as the most important animals in cattle herd, as they are replacement animals. The investment on the heifers is considered as the investment in the future. Sahiwal is one of the superior milch breeds of India, and the breed is well known for its remarkable milk production, heat tolerance, disease resistance and low maintenance cost. Slow growth, delayed puberty and late attainment of sexual maturity in zebu heifers have been major constraints in maximizing their production efficiency. With an overall objective of improving reproductive efficiency of Sahiwal heifers, the present investigation was carried out. The data spanning ten years (January, 1996 – December, 2005) of the Sahiwal herd maintained at NDRI, Karnal were analysed for reproductive performance. The least squares analysis was used to assess the effects of the season of birth and birth weight on the reproductive traits, namely age at first service, age at first conception, age at first calving and numbers of services per conception. The mean age at first service, first conception, first calving and number of services per conception were 780.26 ± 7.35, 833.90 ± 9.71, 1107.39 ± 8.91 days and 1.88 ± 0.07 respectively. The effect of season of birth was significant on age at first service, age at first conception and age at first calving. The birth weight had significant effect on number of services per conception.

HIGHLIGHTS

- The effect of season of birth was significant on age at first service, age at first conception and age at first calving.
- The birth weight had significant effect on number of services per conception.
- The season of birth and birth weight should be taken into consideration during the selection of the Sahiwal heifers for the reproductive traits.

Keywords: Birth weight, Reproductive performance, Sahiwal heifers, Season

Raising heifers is generally a neglected component of dairy farm operations; however, heifers are considered the future cows of the herd. Sahiwal is one of the superior milch breeds of India. This breed is well known for its remarkable milk production, heat tolerance, disease resistance and low maintenance cost, although the contribution is only 3.2% out of the remaining 25.1% of total Indigenous cattle (Anonymous, 2013). Slow growth, delayed puberty and late attainment of sexual maturity in Sahiwal heifers have been major constraints in maximizing their reproduction and production efficiency. So, the Sahiwal heifer is considered a high investment endeavour and requires considerable expenditures including feed, housing and veterinary expenses.

How to cite this article: Meena, R.K., Chauhan, I., Kumar, S. and Kumar, A. (2024). Effect of Season and Birth Weight on Reproductive Performance of Sahiwal Heifers in an Organized Herd. *Int. J. Ag. Env. Biotech.*, **17**(04): 679-685.

Source of Support: None; **Conflict of Interest:** None

These expenses constitute 15 to 20% of the total expenses related to milk production (Heinrichs, 1993). A basic approach for reducing this cost is to reduce the age at first calving. The urgent need is to realize that cows' productive and reproductive performance profoundly depends on the care and management given at the heifer stage. Contributing to the profitability of dairy production, reproductive traits are recognized as the most economically important traits (Lobago *et al.* 2007). Among other reproductive traits, age at first service, age at first calving (AFC) and number of services per conception are the common reproductive traits of dairy cow influencing performance of breeding animals (Beneberu, 2023). Apart from the genetic factors, several other factors such as nutrition, management and environment affect the age at maturity, conception and first calving. The late maturity results in tremendous losses due to a lower productive life. It is essential to shorten AFC and therefore heifers with proper growth rate at an earlier age should be bred (Ferrari *et al.* 2024). In the countries such as United States and United Kingdom, an average daily cost of rearing a heifer to calving has been reported (Boulton *et al.* 2017; Tranel, 2019). Fodor *et al.* 2020 have reported that heifers with lower age at conception were more likely to persist in the herd until calving. De Vries and Marcondes, 2020 have reviewed the factors affecting productive lifespan of dairy cows, which included age at first calving. Anonymous, 2020 reported the effect of artificial insemination on reproductive status of cows in dairy herd improvement programs. Roche *et al.* 2015 have studied effect of heifer size at the time of first calving in pasture-based systems. Steele *et al.* 2020 and anonymous, 2022 studied as to how age at first calving can be utilized to maximize productivity in dairy cows. From the survey of the literature, it can be concluded that the mean average AFC differs by country (Sadeghi-Sefidmazgi *et al.* 2012; Krpálková *et al.* 2014; Wathes *et al.* 2014; Elahi Torshizi *et al.* 2016; Chester-Jones *et al.* 2017; Storli *et al.* 2017; Eastham *et al.* 2018). Many studies have reported the correlations of at first calving with other traits (Do *et al.* 2013; Cooke *et al.* 2013; Zavadilová and *Štípková*, 2013; Mohd Nor *et al.* 2013; Adamczyk *et al.* 2016; Hutchison *et al.* 2017; Heise *et al.* 2018; Brzáková *et al.* 2019; Sawa *et al.* 2019). Various authors have studied the reproductive traits and the non-genetic factors affecting these traits in Sahiwal and crossbred cows (Mudgal and Ray, 1965; Rafique *et al.* 2000a; Singh and Dubey, 2005; Rehman *et al.* 2008; Hadge *et al.* 2009; Kathiravan, 2009; Kumar and Gandhi, 2011; Manoj *et al.* 2012; Raja and Gandhi, 2015; Narwaria *et al.* 2015; Singh *et al.* 2017). The present investigation was undertaken to study the effects of season of birth and birth weight on reproductive performance with an overall objective of improving reproductive efficiency of Sahiwal heifers.

MATERIALS AND METHODS

The study was conducted at the National Dairy Research Institute Farm, Karnal, Haryana (132001) India. Geographically, NDRI livestock farm is situated at an altitude of 250 meters above the mean sea level in Indo-Gangetic alluvial plains at 29°42'N latitude and 72°02'E longitude under the subtropical climate with a maximum temperature of 45°C during the summer months and whereas the minimum value falls to near the freezing point (0°C) during winter months. The experimental site received average annual rainfall ranging from 760 to 960 mm distributed mostly July–August month. The relative humidity varies from 41 to 85%. Thus, the Sahiwal cows are exposed to a wide range of extreme climatic conditions typically sub-tropical in nature. The calves were weaned at birth and were kept on colostrum for the first five days and then whole milk was provided for up to 30 days. Calves of both sexes were reared together and after 6 months of age, male and female calves were reared separately. They were fed according to body weight as per nutritional standards. Heifers above 6 months were given 1.5 kg concentrate per day per animal. The nutritional requirements were met through a balanced ration of concentrates, mineral mixture along with farm-grown good quality green fodder and other roughage ad libitum. Silage and hay have also been used during lean periods. During later age feeding schedules/standards were laid down according to the age group and body weight along with considering the requirement for growth, maintenance and production and heifers were housed under a loose housing system. The data spread over a period of 10 years (January, 1996-December, 2005) for the present study related to reproduction traits of Sahiwal heifers were collected from body weight registers, AI register, AI laboratory and history sheets of Sahiwal cattle

herd maintained at the record section of Dairy Cattle Breeding, Division, National Dairy Research Institute, Karnal. The data on non-genetic factors affecting reproductive parameters as age at sexual maturity, age at first conception, number of services per conception and age at first calving were then classified into different season of birth (Summer: March to June, Rainy: July to October and Winter: November to February) and birth weight categories.

Traits and variables used for study

The reproductive traits, namely age at first service, age at first conception, age at first calving and numbers of services per conception were considered in the study. The variables were the season of birth and birth weight of Sahiwal heifers.

Data analysis

To study the effect of season of birth and birth weight on reproductive traits of Sahiwal heifers, the following model was used:

$$Y_{ijk} = \mu + S_i + BW_j + e_{ijk}$$

Where,

Y_{ijk} = Dependent variable

μ = Overall population mean

S_i = Fixed effect of i^{th} season (i = 1, 2, 3)

BW_j = Fixed effect of j^{th} class of body weight (j = 1, 2, 3, 4)

e_{ijk}= Random effect of error with mean 0 and variance σ^2_e.

R package '*emmeans*', version 1.5.5–1 (Lenth, 2021) was used to perform the least squares analysis in *R* programming environment, version 4.0.2 (R Core Team, 2020).

RESULTS AND DISCUSSION

For studying reproductive performance of Sahiwal heifers, the traits analyzed were age at first service, age at first conception, age at first calving and number of services per conception. The variables were season of birth and birth weight.

Age at first service

The overall least squares mean for age at first service was found to be 780.26 ± 7.35 days (about 26 months) (Table 1), which is the age at sexual maturity. In the present study, it was observed that the females born during the summer season attained the first service at the lowest age (764.97 ± 10.37 days) than those born during the winter season (809.22 ± 10.65 days) (Table 1). The effect of birth weight on the age at first service was found to be non-significant (Table 1). The calves born with a birth weight of 17–19 kg had the lowest age at first service (767.61 ± 12.91 days). While calves with birth weight <17 kg had the highest age at first service (791.29 ± 18.12 days) in Sahiwal heifers. The age at first service reported in this study was lower than the values reported in earlier studies (Ali and Farooque, 1989; Singh *et al.* 2011; Ratwan *et al.* 2020; Baruah *et al.* 2022) in Sahiwal heifers and Gahlot *et al.* (2001) in Tharparkar heifers. However, it is higher than the value obtained by Bhosrekar (1976) in Sahiwal heifers and Prasanna *et al.* (2023) in HF × Sahiwal heifers. The effect of the season of birth was found to be highly significant (P<0.01) on age at first service. The present findings are in agreement with those reported by Singh *et al.* 2011 who observed a significant effect of season of birth on age at first fertile service in Sahiwal heifers. On the contrary, Gahlot *et al.* (2001) reported a non-significant effect of season of birth on age at first service in Tharparkar cattle. In the present study, it was observed that the females born during the summer season attained the first service at the lowest age than those born during the winter season. These findings are in agreement with that of Srivastava and Kadu (1992), who also reported that females born in the summer season reached puberty at an earlier age than those born in the rainy and winter seasons. The variation in age at first service could be due to climatic factors and the availability of nutrients from green fodder during different seasons.

Age at first conception

The overall least squares mean for age at first conception was found to be 833.90 ± 9.71 days (Table 1). Season of birth significantly (P<0.05) influenced the age at first conception in Sahiwal heifers (Table 1). Heifers born in the summer season are conceived at an earlier age (811.49 ± 13.74 days) than those born in rainy (830.05 ± 17.04 days) and winter seasons (860.17 ± 2.93 days). The heifers

Table 1: Effects of season of birth and birth weights on the reproductive performance of Sahiwal heifers

	Age at first Service (days)	Age at first conception (days)	Age at first calving (days)	Number of services/ conception
Overall Mean	780.26±7.35 (314)	833.90±9.71 (308)	1107.39±8.91 (296)	1.88±0.07 (314)
Season of birth	**	*	*	NS
Summer	764.97±10.37 (122)	811.49±13.74a (119)	1083.98±12.59 (117)	1.78±0.10 (122)
Rainy	765.99±12.98 (72)	830.05±17.04ab (71)	1108.72±15.87 (67)	1.99±0.14 (72)
Winter	809.82±10.65 (120)	860.17±2.93b (118)	1129.49±12.98 (112)	1.87±0.11 (120)
Birth Weight	NS	NS	NS	*
< 17 Kg	791.29±18.12 (35)	836.66±24.24 (33)	1091.81±22.42 (32)	1.71±0.19 (35)
17–19 Kg	767.61±12.91 (71)	804.99±16.91 (70)	1090.57±15.52 (69)	1.77±0.14 (71)
20–22 Kg	788.32±9.28 (154)	840.95±12.23 (152)	1116.78±11.40 (141)	1.75±0.97 (154)
> 22 Kg	773.82 ± 14.54 (54)	853.02±19.10 (53)	1130.40±17.27 (54)	2.29±0.15 (54)

*Number of observations are shown in the parentheses;** Significant at P<0.01, * Significant at P<0.05, NS Non-significant.*

born in the summer season had the lowest age at first conception; this may be due to favourable climatic conditions and availability of *ad lib* green fodder during subsequent rainy and winter seasons, which enabled the heifers to grow at a faster rate during early life. The calves with birth weight >22 kg had the highest (853.02 ± 19.10 days) age at first conception. While calves with a birth weight of 17–19 kg had the lowest (804.99 ± 16.91 days) age at first conception in Sahiwal heifers. However, the effect of birth weight on the age at first conception was statistically found to be non-significant (Table 1). Least squares mean for age at first conception reported in the present study was closer to the estimates earlier reported (Mudgal and Ray, 1965) in Sahiwal heifers. It was lower than those reported by Ali and Farooque (1989), Kushwaha *et al.* (2002) for Sahiwal heifers and Ulmek and Patel (1993) in Gir cattle. However, it is higher than the value obtained by Bhosrekar (1976) in Sahiwal heifers. Sattar *et al.* (2005) reported non-significant effect of season of birth on age at first conception in Holstein cattle in Pakistan. Similarly, non–significant effect of season of birth on age at first conception was also reported in Sahiwal heifers (Sethi *et al.* 2001), Holstein-Friesian x Sahiwal heifers (Rafique *et al.* 2000a). Gir heifers (Barwe *et al.* 1995) and Malvi heifers (Kushwaha *et al.* 2001). Usman *et al.* (2014) have reported highly significant effect (P<0.01) of season of birth on age at first conception in Holstein cattle.

Age at first calving

The overall least squares mean for age at first calving was found to be 1107.39 ± 8.91 days (Table 1). Season of birth on age at first calving were found to be significant (p<0.05). Heifers born during the summer season had the lowest age at first calving (1083.98 days), while those born during the winter season had the highest (1129.49 days) age at first calving in Sahiwal heifer. The significant effect of the season of birth on age at first calving may be attributed to the variability in the availability of different feed and fodder and environmental fluctuations in different seasons of the year. The effect of birth weight on the age at first calving was found to be non-significant (Table 1). The calves with higher birth weight >22 kg had the highest (1130.40 ± 17.27 days) age at first calving. While, calves with a birth weight of 17–19 kg had the lowest (1090.57 ± 15.52 days) age at first calving in Sahiwal heifers, indicating better growth during subsequent periods in those heifers. Singh *et al.* (2017) reported the least squares mean for age first caving in Sahiwal cows to be to be 1251.77 ± 22.15 days, which is higher than that in the present study. Narwaria *et al.* 2015 reported marginally higher overall least squares mean for age at first caving in Sahiwal cattle than the present study (1136.14 ± 10.48 days). Baruah *et al.* (2022) and Kathiravan (2009) have reported higher estimates of age first caving in Sahiwal cattle. Mudgal and Ray (1965) and Hadge *et al.* (2009) reported on significant effect (P<0.05) of season on age at first calving of Sahiwal heifers, which was similar to the present study. However, Vinothraj *et al.* 2016 reported a non-significant effect of season of birth on age at first calving in Jersey Red Sindhi crossbred cows. Contrary to the findings in this

study, Singh and Dubey (2005), Manoj *et al.* (2012) and Raja and Gandhi, (2015) have reported non–significant effect of season of birth on age at first calving in Sahiwal cows. Singh *et al.* (2017) reported non–significant effect of season of birth on age at first calving in Sahiwal cows. Similar to the findings in the present study, Narwaria *et al.* (2015), Kumar and Gandhi, (2011) and Rehman *et al.* (2008) have reported observed a significant effect of season of birth on at first calving in Sahiwal cows.

Number of services/ conception

The overall least squares mean for the number of services per conception was found to be 1.88 ± 0.07 (Table 1) which is significantly (P<0.5) affected by birth weight. The heifers born with birth weight <17 kg took the lowest (1.71 ± 0.19) services to get conceived. While calves with birth weight >22 kg had the highest (2.29 ± 0.15) number of services per conception in Sahiwal heifers. The season had a non-significant effect on the number of services per conception in Sahiwal heifers. However, higher values (2.1–2.7) than the present estimate reported by Rafique *et al.* (2000b) in crossbred heifers, Vinothraj *et al.* (2016) in Jersey × Red Sindhi crossbred cows and Kumar and Bhat (1979) in Hariana heifers.

CONCLUSION

Based on the results of the present study, it is summarized that the effect of season of birth was significant on age at first service, age at first conception and age at first calving. The birth weight had significant effect on number of services per conception. Therefore, it is concluded that the season of birth and birth weight should be taken into consideration during the selection of the Sahiwal heifers for the reproductive traits considered in this study.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, NDRI and Head, Animal Genetics & Breeding Division for providing the necessary facilities for the study.

REFERENCES

Adamczyk, K., Makulska, J., Jagusiak, W. and Węglarz, A. 2016. Associations between strain, herd size, age at first calving, culling reason and lifetime performance characteristics in Holstein-Friesian cows. *Animal*, **11**(2): 327–334.

Ali, C.S. and Farooque, M.A. 1989. Puberty of Sahiwal heifers. *Pakistan Veterinary Journal*, **9**(4): 170–172.

Anonymous, 2013. Estimated livestock population Breed wise based on breed survey. Department of Animal Husbandry, Dairying & Fisheries (Animal Husbandry Statistics Division), Ministry Of Agriculture & Farmers Welfare, Government of India, Krishi Bhawan, New Delhi. Available from https://dahd.nic.in/sites/default/filess/Breeding%20Survey%20Book%20-%20Corrected.pdf. Accessed on July 07, 2024.

Anonymous, 2020. Reproductive Status of Cows in Dairy Herd Improvement Programs and Bred Using Artificial Insemination. Available from https://queries.uscdcb.com/publish/dhi/current/reproall.html. Accessed on 24th July, 2024.

Anonymous, 2022. Age at first calving in dairy cows: which months are optimum to maximise productivity? Available from https://www.veterinary-practice.com/article/age-at-first-calving. Accessed on 23rd July, 2024.

Baruah, U., Kaushik, P., Kalita, D., Akhtar, F. and Kalita, K.B. 2022. An Evaluation of the Reproductive Performance of Sahiwal Heifers in the High Humid Climatic Condition of Assam. *Asian Journal of Dairy and Food Research*, **41**(1): 43-46.

Beneberu, N. 2023. Genetic and Non-Genetic Parameters for Reproductive Traits of Dairy Cattle in Ethiopia: A Review. *Journal of Biology, Agriculture and Healthcare*, **13**(5): 1–10.

Bhosrekar, M. 1976. Age at first insemination and conception of three different breeds of Indian milch cattle and various strains of Zebu × Taurus cattle. *Tropical Animal Health and Production*, **8**(2): 83–84.

Boulton, A.C., Rushton, J. and Wathes, D.C. 2017. An empirical analysis of the cost of rearing dairy heifers from birth to first calving and the time taken to repay these costs. *Animal*, **11**(8): 1372–1380.

Brzáková, M., Zavadilová, L., Pribyl, J., Pešek, P., Kašná, E. and Kranjčevičová, A. 2019. Estimation of genetic parameters for female fertility traits in the Czech Holstein population. *Czech Journal of Animal Science*, **64**(5): 199–206.

Chester-Jones, H., Heins, B.J., Ziegler, D., Schimek, D., Schuling, S., Ziegler, B., de Ondarza, B., Sniffen, C.J. and Broadwater, N. 2017. Relationships between early-life growth, intake, and birth season with first-lactation performance of Holstein dairy cows. *Journal of Dairy Science*, **100**(5): 3697–3704.

Cooke, J.S., Cheng, Z., Bourne, N.E. and Wathes, D.C. 2013. Association between growth rates, age at first calving and subsequent fertility, milk production and survival in Holstein-Friesian heifers. *Open J. of Animal Science*, **3**: 1–12.

De Vries, A. and Marcondes, M.I. 2020. Review: Overview of factors affecting productive lifespan of dairy cows. *Animal*, **14**(S1): 155–164.

Do, C., Wasana, N., Cho, K., Choi, Y., Choi, T., Park, B. and Lee, D. 2013. The effect of age at first calving and calving interval on productive life and lifetime profit in Korean Holsteins. *Asian-Australasian Journal of Animal Science*, **26**(11): 1511–1517.

Eastham, N.T., Coates, A., Cripps, P., Richardson, H., Smith, R. and Oikonomou, G. 2018. Associations between age at first calving and subsequent lactation performance in UK Holstein and Holstein-Friesian dairy cows. *PLoS One*, **13**: e0197764.

Elahi Torshizi, M., Mashhadi, M.H. and Farhangfar, H. 2016. Effects of season and age at first calving on genetic and phenotypic characteristics of lactation curve parameters in Holstein cows. *Journal of Animal Science and Technology*, **58**(6): 112–118.

Ferrari, V., Galluzzo, F., van Kaam, J.B.C.H.M., Penasa, M., Marusi, M., Finocchiaro, R., Visentin, G. and Cassandro, M. 2024. Genetic and genomic evaluation of age at first calving in Italian Holsteins. *Journal of Dairy Science*, **107**(5): 3104–3113.

Fodor, I., Lang, Z. and Ózsvári, L. 2020. Relationship of dairy heifer reproduction with survival to first calving, milk yield and culling risk in the first lactation. *Asian-Australasian Journal of Animal Science*, **33**(8): 1360–1368.

Gahlot, G.C., Pant, K.P., Kachwala, R.N. and Barhat, N.K. 2001. Effect of genetic and non-genetic factors on reproductive maturity of Tharparkar cows. *Indian Veterinary Journal*, **78**(6): 505–508.

Hadge, M.R., Kuralkar, S.V., Ali, S.Z. and Kharkar, K.P., 2009. Performance of Sahiwal and its jersey crosses for reproductive traits in different lactations. *Indian Journal of Animal Research*, **43**(1): 75-76.

Heinrichs, A.J. 1993. Raising dairy replacements to meet the needs of the 21st century. *Journal of Dairy Science*, **76**(10): 3179–3187.

Heise, J., Stock, K.F., Reinhardt, F., Ha, N.T. and Simianer, H. 2018. Phenotypic and genetic relationships between age at first calving, its component traits, and survival of heifers up to second calving. *Journal of Dairy Science*, **101**(1): 425–432.

Hutchison, J.L., VanRaden, P.M., Null, D.J., Cole, J.B. and Bickhart, D.M. 2017. Genomic evaluation of age at first calving. *Journal of Dairy Science*, **100**(8): 6853–6861.

Krpálková, L., Cabrera, V.E., Kvapilik, J., Burdych, J. and Crump, P., 2014. Associations between age at first calving, rearing average daily weight gain, herd milk yield and dairy herd production, reproduction, and profitability. *Journal of Dairy Science*, **97**(10): 6573–6582.

Kumar, A. and Gandhi, R.S. 2011. Evaluation of pooled lactation production and reproduction traits in Sahiwal cattle. *Indian Journal of Animal Sciences*, **81**(6): 600–604.

Kumar, S. and Bhat, P.N. 1979. Reproductive performance of Hariana cattle. *Indian Journal of Animal Science*, **49**: 1001–1008.

Kushwaha, S., Khan, F.H., Singh, A. and Qureshi, M.I. 2002. Economic traits in Sahiwal cattle. *Indian Veterinary Medical Journal*, **26**(9): 193–196.

Kushwaha, S., Qureshi, M.I. and Nanawati, S. 2001. Factors affecting age at first fertile service in Malvi heifers. *Indian Veterinary Medical Journal*, **25**: 19–20.

Lenth, R.V. 2021. Emmeans: estimated marginal means, aka least-squares means. R package version 1.5.5-1. https://CRAN.R-project.org/package=emmeans.

Lobago, F., Bekana, M., Gustafsson, H. and Kindahl, H. 2007. Longitudinal observation on reproductive and lactation performances of smallholder crossbred dairy cattle in Fitche, Oromia region, Central Ethiopia. *Tropical Animal Health and Production*, **39**(6): 395–403.

Manoj, M., Gandhi, R.S., Raja, T.V., Singh, A. and Sachdeva, G.K. 2012. Effect of non-genetic factors on first lactation production and reproduction performance in Sahiwal cattle. *Indian Journal of Dairy Science*, **65**(3): 264–265.

Mohd Nor, N., Steeneveld, W., van Werven, T., Mourits, M.C.M. and Hogeveen, H. 2013. First-calving age and first-lactation milk production on Dutch dairy farms. *Journal Dairy Science*, **96**(2): 981–992.

Mudgal, V.D. and Ray, S.N. 1965. Growth studies on Indian breeds of cattle. II: Studies on the growth of Sahiwal cattle. *Indian Journal of Dairy Science*, **18**: 65–71.

Narwaria, U.S., Mehla, R.K., Verma, K.K., Shiv Prasad, Gupta, A.K., Lathwal, S.S. and Verma, A.K. 2015. Non-genetic factors affecting economic traits in Sahiwal cattle at organized farm. *Indian Journal of Dairy Science*, **68**(4): 379–383.

Prasanna, J.S., Rao, S.T.V., Prakash, M.G., Rathod, S., Kalyani, P. and Sharma, R. 2023. Production and Reproduction Performance of Sahiwal and HF × Sahiwal Cows. *Indian Journal of Animal Research*, **57**(6): 698-701.

Rafique, M., Chaudhry, M.Z. and Amer, M.A. 2000b. Reproductive performance of interse Holstein-Friesian × Sahiwal crossbred. *Pakistan Veterinary Journal*, **20**(3): 109-112.

Rafique, M., Chohan, K.R. and Chaudhry, Q.Z. 2000a. Factors affecting age at maturity and age at first conception in Holstein-Friesian × Sahiwal crossbreds. *Pakistan Veterinary Journal*, **20**(1): 40-42.

Raja, T.V. and Gandhi, R.S. 2015. Factors influencing productive and reproductive performance of Sahiwal cattle maintained at organized farm conditions. *Indian Journal of Animal Sciences*, **85**(6): 628–633.

Ratwan, P., Chakravarty, A.K. and Kumar, M. 2020. Lactation wise performance of Sahiwal cattle at an organized herd of northern India. *Indian Journal of Animal Sciences*, **90**(8): 1179–1185.

R Core Team, 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.R-project.org/. Accessed on July 07, 2024.

Rehman, Z.U., Khan, M.S., Bhatti, S.A., Iqbal, J. and Iqbal, A. 2008. Factors affecting first lactation performance of Sahiwal cattle in Pakistan. *Arch Tierz Dummerstorf*, **51**(4): 305–317.

Roche, J.R., Dennis, N.A., MacDonald, K.A., Phyn, C.V.C., Amer, P.R., White, R.R. and Drackley, J.K. 2015. Growth targets and rearing strategies for replacement heifers

in pasture-based systems: A review. *Animal Production Science*, **55**(7): 902–915.

Sadeghi-Sefidmazgi, A., Moradi-Shahrbabak, M., Nejati-Javaremi, A., Miraei-Ashtiani, S.R. and Amer, P.R. 2012. Breeding objectives for Holstein dairy cattle in Iran. *Journal of Dairy Science*, **95**(6): 3406–3418.

Sattar, A., Mirza, R.H., Niazi, A.A.K. and Latif, M. 2005. Productive and Reproductive performance of Holstein Friesian cows in Pakistan. *Pakistan Veterinary Journal*, **25**: 75–81.

Sawa, A., Siatka, K. and Krężel-Czopek, S. 2019. Effect of age at first calving on first lactation milk yield, lifetime milk production, and longevity of cows. *Annals of Animal Science*, **19**(1): 189–200.

Singh, C.V. and Dubey, P.P. 2005. Estimates of genetic and phenotypic paramenters considering first lactation and life time performance traits in Sahiwal and Crossbred cattle. Indian *Journal of Animal Sciences*, **75**(11): 1289–1294.

Singh, J., Singh, V.K., Yadav A.K. and Jha, A.K. 2017. Effect of genetic and non-genetic factors on age at first calving in Sahiwal cattle. *Indian Journal Animal Research*, **51**(4): 635–639.

Singh, U., Kumar, A., Kumar, S. and Beniwal, B.K. 2011. Evaluation of Sahiwal cattle for lifetime traits in an organized herd. *Indian Journal of Animal Sciences*, **81**(7): 708–710.

Steele, M. 2020. Age at first calving in dairy cows: Which months do you aim for to maximize productivity? *Veterinary Evidence*, **5**: 11–16.

Storli, K.S., Klemetsdal, G., Volden, H. and Salte, R. 2017. The relationship between Norwegian Red heifer growth and their first-lactation test-day milk yield: a field study. *Journal of Dairy Science*, **100**(9): 7602–7612.

Tranel, L. 2019. Heifer Raising Costs in 2019. Available from https://www.extension.iastate.edu/dairyteam/content/iowa-dairy-budgets. Accessed on 23rd July, 2024.

Usman, T., Suhail, S.M., Zhang, X., Guo, G., Ullah, I., Sadique U. and Wang, Y. 2014. Effects of non-genetic factors on age at first conception and calving interval in Holstein cattle under subtropical conditions. *Indian Journal of Animal Sciences*, **84**(1): 45–49.

Vinothraj, S., Subramaniyan, A., Venkataramanan, R., Joseph, C. and Sivaselvam, S.N. 2016. Genetic evaluation of reproduction performance of Jersey × Red Sindhi crossbred cows. *Vet. World*, **9**(9): 1012–1017.

Wathes, D.C., Pollot, G.E., Johnson, K.F., Richardson, H. and Cooke, J.S. 2014. Heifer fertility and carry over consequences for life time production in dairy and beef cattle. *Animal*, **8**(S1): 91–104.

Zavadilová, L. and Štípková, M. 2013. Effect of age at first calving on longevity and fertility traits for Holstein cattle. *Czech Journal of Animal Science*, **58**(2): 47–57.