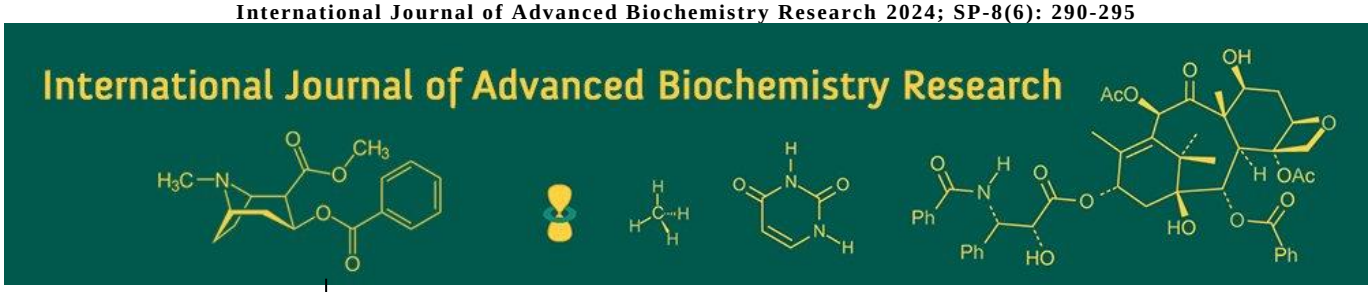

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Effect of various agro-climatic factors on production, reproduction and growth traits in Hardhenu cattle

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Abstract
This study was conducted to evaluate the effect of different agro-climatic factors on various production, reproduction and growth traits of Hardhenu cattle. Effects of period and season of birth, period and season of calving, and parity on different targeted traits were analysed in 440 Hardhenu cows held at the Cattle breeding farm, Department of Animal Genetics and Breeding, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana. The overall least-squares means of Total Milk Yield (TMY), 300 days milk yield (300D MY), lactation length (LL), dry period (DP), service period (SP), calving interval (CI), number of AI per conception (AI/conception), birth weight, body weight at one month, two month and three month were 3854.47±181.79 kg, 3691.13±205.02 kg, 299.89±10.86 days, 89.12±13.64 days, 385.00±16.00 days, 104.50±15.71 days, 1.57±0.22, 24.88±0.54 kg, 32.96±0.85 kg, 41.08±1.06 kg and 60.94±1.54 kg, respectively. Among different agro-climatic factors, the period of birth had significant (p<0.05) effect on birth weight, one month body weight and two month body weight. Similarly, calving period (p<0.01) and parity (p<0.05) had significant effect on TMY, 300D MY, LL and DP. It was observed that winter season was found to be suitable for lesser AI/conception. It was concluded that proper managerial practices need to be followed for overall improvement in the targeted traits in Hardhenu cattle.

Keywords: Agro-climatic factors, dry period, growth, hardhenu cattle, milk yield, reproduction

Introduction
Globally, the livestock industry is highly dynamic and evolving in developing countries in response to the ever-increasing demand for livestock products. Livestock is important in India in many ways, including wealth handling, generation of employment, insurance, recycling of waste and leftovers from crops and agriculture industries, improvement of soil structure and fertility, and pest control. Globally, the livestock sector is seen as an ideal approach for the issue of food insecurity (Braun, 2010) [45].

India has the world's largest cattle population, but its per animal average milk produced is very low in comparison to developed nations. There are 193.46 million (36.04%) cattle, with approximately 51.35 million (26.5%) crossbred cattle (20th Livestock Census 2019) [1]. The cattle population trend (2012-2019) shows a clear shift in dairy animal stock towards crossbreds, with their population increased by 26.90% (20th Livestock Census 2019) [1]. In comparison to many developed countries around the world, the India's milk productivity remains the lowest. Milk production in India was 209.96 million tonnes in 2020-21 and 221.06 million tonnes in 2021-22, representing a 5.29% annual increase. Out of total milk produced, 29.91% milk is contributed by crossbred cattle and average milk production of crossbred cows is about 8.32 kg/day (BAHS 2022-23). All India per capita availability of milk was around 444 grams/day, while 320 grams/ day worldwide (BAHS 2022-23).

Dairy animal productivity could be raised by crossbreeding low milk producing cows with high milk producing exotic cows. The purpose of this systematic breeding is to combine the high milk production and early maturity of exotic cattle breeds with the hardiness, disease resistance, and adaptability of indian cows (Ayad *et al*. 2022; Vinothraj *et al*. 2016) [5, 44]. Hardhenu is a crossbred (Bostaurus × Bosindicus) dairy cow developed by the Department of Animal Genetics and Breeding, LUVAS, Hisar, with 62.5% exotic lineage and Holstein predominance.

It is popular in northern India due to its high milk production capability as well as better adaptability to local climatic variations; additionally, it has a promising high tendency for further improvement on genetic basis (Dev *et al*. 2021) [16].

A number of different agro-climatic factors (period and season birth, period and season of calving, parity etc.) influence reproduction, production, and growth traits and thus directly obscure the expression of actual worth of a breed and animal (Dev *et al*. 2021, Yadav *et al*. 2020, Abera *et al*. 2012, Garrick *et al*. 2009, Prayaga and Henshall 2005, Demeke *et al*. 2003) [16, 47, 20, 2, 34, 15]. The present study was conducted to assess the importance and effect of different agro-climatic factors on production, reproduction and growth traits of Hardhenu cattle.

Materials and Methods

Data: Records on production, reproduction and growth traits of 440 Hardhenu cows kept at Department of Animal Genetics and Breeding, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana kept over a period of 10 years (2008-2018) were used. Animals with lactation lengths less than 100 days and milk produced less than 3 kg per day were excluded from the study.

Traits: Eleven different production, reproduction and growth traits up to third parity were examined in this study. Production traits taken under consideration were total milk yield (TMY), 300 days milk yield (300D MY), lactation length (LL), dry period (DP); reproduction traits as calving interval (CI), service period (SP), number of artificial insemination per conception (AI/Conception). However, birth weight, one month body weight, two month body weight and three month body weight were considered as growth traits.

Statistical analysis: The following least-squares method of the General linear model was used to discern the influence of effect of period and season of birth, period and season of calving and parity order on reproduction, production and growth traits in targeted population.

$$Y_{ijk} = \mu + P_i + Q_j + e_{ijk} \quad (1)$$

$$Y_{ijklmn} = \mu + P_i + Q_j + R_k + S_l + T_m + e_{ijklmn} \quad (2)$$

Where,

Y_{ijk} = Observed value of growth traits;

Y_{ijklmn} = observed value of reproduction and production traits;

μ = Overall mean;

P_i = Effect of i^{th} period of birth;

Q_j = Effect of j^{th} season of birth;

R_k = Effect of k^{th} period of calving;

S_l = Effect of l^{th} season of calving;

T_m = Effect of m^{th} parity;

e_{ijk} and e_{ijklmn} = random error associated with each observation assumed to be NID e $(0, \sigma^2)$.

Where, i = 1, 2; j = 1, 2, 3; k = (1, 2, 3 for 1st parity) and (1, 2 for 2nd and 3rd parity); l = 1, 2, 3; m = 1, 2, 3.

Model [1] analysed the growth traits *viz*. birth weight, one month, two month and three month body weight whereas Model [2] analysed production and reproduction traits *viz*. TMY, 300D MY, LL, DP, CI, SP, AI/Conception.

For this study, the data were classified according to period of birth, season of birth, period of calving and season of calving. Different agro-climatic factors were classified in various categories as two period of birth i.e. I (2008-2011) and II (2012- 2016); three season of birth: I -Winter (December to March), II- Summer (April to July), III - Rainy (August to November); three period of calving: - I (2011-2013), II (2014-2016), III (2017-2019); three season of Calving: I -Winter (December to March), II- Summer (April to July), III –Rainy (August to November) and three group in parities i.e. I (1st parity), II (2nd parity) and III (3rd parity).

Results and Discussion

The overall least–squares means for reproduction, production and growth traits, *viz*. TMY, 300D MY, LL, DP, CI, SP and AI/Conception, birth weight, body weight at one month, two month and three month were 3854.47±181.79 kg, 3691.13±205.02 kg, 299.89±10.86 days, 89.12±13.64 days, 385.00±16.00 days, 104.50±15.71 days, 1.57±0.22, 24.88±0.54 kg, 32.96±0.85 kg, 41.08±1.06 kg and 60.94±1.54 kg respectively in Hardhenu cattle (Table 1, 2 and 3).

Analysis revealed that there was no significant association of period of birth, season of birth and season of calving with TMY, 300D MY and LL (p>0.05) in Hardhenu cattle. However, animals born in period 2012-2016 and summer season were producing higher TMY, 300D MY and longer LL than period 2008-2011, winter and rainy season (Table 1). Cows calved in winter season were having higher mean values of TMY, 300D MY and LL than the cows calved in summer and rainy season. There was significant association (p<0.01) of period of calving with TMY, 300D MY and LL. Animals calved during period 2017-2019 were having significantly higher TMY (4222.22±178.93) kg, 300D MY (3938.31±201.80) kg and longer LL (311.57±10.68) days than period 2011-2013 - TMY (3262.27±245.33) kg, 300D MY (3223.94±276.68) kg and LL (305.26±14.65) days and period 2014-2016 - TMY (4078.92±189.90) kg, 300D MY (3911.14±214.16) kg and LL (309.84±11.34) days. Petrovic *et al.* (2009) [32] depicted significant effect of year and season of birth on all the lactation traits. On the other hand, Habib *et al.* (2010) [22] and Veraparsad *et al.* (2013) [47] depicted non-significant effect of year and season of birth on lactation traits. Animals calved during period 2017-2019 were having significantly 960 and 715 kg higher TMY, 300D MY respectively than period 2011-2013 and animals calved during period 2017-2019 were having significantly 144 and 27 kg higher TMY and 300D MY respectively than period 2014-2016 TMY and 300D MY. Similarly, significant effect of calving period was noticed in the literature on 300D MY (Thakur and Singh 2000 and 2001) [41, 42]. In contrast, Tewari *et al.* (1995) in Jersey × Sahiwal cows and Das *et al.* (2006) [12] in HF and Sahiwal cows observed no significant effect of period on various performance traits. The best performance of cows calved during the period 2014-2019 might be due to improvement of managemental practices over years, coupled with high number of high milk yield cows. Das *et al.* (2001) [13] and Thakur and Singh (2000 and 2005) [41, 42] also noticed the influence of season of calving on various production traits

of purebred and crossbred cows and winter calvers were recorded to have the highest means, while non-significant influence of season of calving was reported on TMY (Jadhav and Khan 1995) [25] and 300D MY (Das *et al.* 2006) [12]. There was significant (p<0.05) association found in TMY, 300D MY and LL of cows and different parities in Hardhenu cattle. On basis of Table 1, it was evident that animals in parity III were having higher TMY (4162.258±135.567) kg, 300D MY (3937.566±152.890) kg and longer LL (319.531±8.095) days than parity I TMY (3151.637±77.235) kg, 300D MY (2969.660±87.105) kg and LL (314.462±4.612) days and parity II TMY (3599.823±108.005) kg, 300D MY (3417.622±121.806) kg and LL(314.132±6.449) days. Animals in parity II were having 448 litre higher TMY and 300D MY as compared to animals of parity I and animals in parity III were having 563 and 520 litre higher TMY and 300D MY respectively as compared to animals of parity II. The studies carried out on LL by Kumar *et al.* (2014) [27] also reported similar findings. On contrary, Wondifraw *et al.* (2013) [46] and Singh *et al.* (2013) reported non-significant effect of parity on lactation length. Wondifraw *et al.* (2013) [46] and Japheth *et al.* (2015) [26] also depicted significant effect of parity on 300D MY in cattle.

Analysis revealed that, there was no significant association of period and season of birth and season of calving with DP (p>0.05) in Hardhenu cattle. However, animals born in period 2008-2011and summer season had shorter DP than period 2012-2016, winter and rainy season and animals calved in rainy season were having favourable mean values of DP than the animals calved in winter and summer season. Significant association (p<0.01) of period of calving with DP in Hardhenu cattle (Table 1) was observed. Animals calved in period 2011-2013 were having significantly shorter DP (78.54±18.41) days than period 2014-2016 and period 2017-2019 DP i.e. (95.198±14.248) days and (93.633±13.425) days respectively. There was significant (p<0.05) association found in DP of cows with different parities in Hardhenu cattle. It was evident that animals in parity III were having significantly shorter DP as compared to animals of parity I and II respectively. Similar to our findings, non-significant effect of year and season of birth on dry period by Habib *et al.* (2010) [22]. There was significant association (p<0.01) of period of calving with DP. Animals calved in period 2011-2013 were having significantly shorter DP than period 2014-2019. Season of calving had no significant effect on DP and those animals calved in rainy season were having favourable mean values of DP than the animals calved in winter and summer season. Similar to our findings, Bhutkar *et al.* (2014) [9], Dhawan *et al.* (2015) [17], Kumar (2015) [28] and Sawant *et al.* (2016) [38] reported non-significant effect of season of calving on DP. Whereas, numerous researchers have documented the considerable impact of calving season on DP in the literature (Chaudhari *et al.* 2013, and Raja and Gandhi, 2015) [11, 36]. According to Ahmed *et al.* (2007) [11, 36], parity has considerable effects on DP in crossbred cattle. On the other hand, Poudel *et al*. (2017) [33] found that parity had no significant impact in Murrah buffalo.

Analysis showed that neither the period and season of birth, nor the period and season of calving, were significantly associated with SP or CI (p>0.05) in Hardhenu cattle (Table 2). However, animals born during period 2008-2011and winter season were having shorter SP and CI than period 2012-2016, summer and rainy season in Hardhenu cattle. Animals calved in period 2011-2013 and rainy season were having shorter SP and CI than later period 2014-2019, winter and summer season. Similarly, the non-significant effect of calving period on SP and CI was reported by Saha *et al.* (2010) [37] in Karan-Fries cattle. Non-significant effect of season of calving on SP and CI was reported by Divya *et al.* (2014) [18] and Kumar (2015) [28] in crossbreed cattle and Basak *et al.* (2018) [6] in Deoni. Repungent to the above findings, a significant effect of calving period and calving season on SP and CI was reported by many scientists (Chaudhari *et al.* 2013 and Dash *et al.* 2016) [11,]. Here, there was non-significant association found in different parities of animals with their SP and CI in Hardhenu cattle. On perusal of Table 2, animals in third parity were having shorter SP and CI. There was no significant association found between different parities of animals with their SP and CI in Hardhenu cattle. However, the significant effect of parity on SP and CI was observed by Dash *et al.* (2016) [14] in crossbreed (Karan-Fries) and Basak *et al.* (2018) [6] in Deoni cattle.

It was observed that there was no significant association of period and season of birth with AI/conception (p>0.05) in Hardhenu cattle. However, animals born in period 2008-2011 and winter season were having lesser AI/conception than period 2012-2016, summer and rainy season and animals of 1st parity were having lesser AI/conception as compared to animals of later parities. There was significant association (p<0.01) of period and season of calving with AI/conception in Hardhenu cattle (Table 2). The mean value of AI/conception was found lesser for animals calved during the period 2011-2013 in comparison to the later period 2014-2019.Animals calved in period 2011-2013 were having significantly lesser AI/conception (1.11±0.30) than period 2014-2016 AI/conception (1.62±0.23) and period 2017-2019 AI/conception (1.99±0.22). Animals calved in winter season were having significantly (p<0.01) lesser AI/conception (1.38±0.24) than summer season (1.66±0.26) and rainy season (1.68±0.23). The mean value of AI/conception was found 0.5 and 0.8 lesser for animals calved during the period 2011-2013 in comparison to the later period 2014-2016 and period 2017-2019 respectively and animals calved in winter season were having significantly 0.28 and 0.3 lesser AI/conception than summer and rainy season respectively. Bolacali and Ozturk (2017) [10] revealed a significant influence of calving season in Simmental cows, which is consistent with the current findings. Lactation parity (Ozkan and Gunes, 2007) [30] have significant effect on the number of AI per conception, similar with the findings of our study. However, Ozkan and Gunes (2011) [31] found non-significant effect of calving year, lactation parity, and calving season on the number of AI per conception.

Analysis revealed that there was significant association of period of birth with birth weight, one and two month body weight (p<0.05) in Hardhenu cattle. Animals born in period 2008-2011 were having significantly higher birth weight (26.58±0.87) kg, one month weight (34.42±1.36) kg and two month weight (41.20±1.70) kg than period 2012-2016 birth weight (23.19±0.85) kg, one month weight (31.50±1.34) kg and two month weight (40.96±1.67) kg. However, there was no significant association of period of birth with three month body weight (p>0.05). Animals born in period 2012-2016 were gaining higher weight than period 2008-2011.

Animals born in period 2008-2011 were having significantly 3.39, 2.92 and 0.92 kg higher birth, one month and two month body weight respectively than period 2012-2016 birth, one month and two month body weight respectively. Animals born in period 2012-2016 were gaining higher three month bodyweight than period 2008-2011. Similarly, In numerous breeds of cattle, including Brahman cross (Duma and Tanari, 2008) [19], North-eastern Thai (Intaratham *et al*. 2008) [24], Bali (Supriyantono *et al*. 2011) [40], and Aceh cattle (Putra *et al*. 2014) [35], the growth traits of cattle has been improved. Climatic variation in the breeding and feeding area can lead to differences in feed availability between years, which can affect growth traits and there was no significant association of season of birth with birth weight, one month, two month and three month body weight in the targeted population (p>0.05). Calves born in winter season gain higher birth weight, one month and two month body weight than born in summer and rainy season. Similarly, according to various studies, the season had an insignificant effect on the birth weight of Bos-indicus cattle breeds including Fogera cattle (Addisu *et al*. 2010) [3] and Ongole grade (Hartati *et al*. 2015) [23]. Despite this, there have been reports of the season having a major effect on a number of breeds of cattle, including Bali (Gunawan and Jakaria, 2011) [21], Gudali, and Wakwa (Ndofor-Foleng *et al*. 2011) [29], and Sheko (Bayou *et al*. 2015) [8].

This study concluded that, among the agro-climatic factors, period of birth had significant (p<0.05) effect on Birth weight, one month body weight and two month body weight. Similarly, the period of calving had significant (p<0.01) effect on TMY, 300D MY, LL and DP taken into consideration and the period and calving season was found to have significant (p<0.05) effect on AI/conception. Parity had significant (p<0.05) effect on TMY, 300D MY, LL and DP.

Table 1: Effect of agro-climatic factors on production traits in Hardhenu Cattle

Effects	No. of animals(n)	TMY	300D MY	LL	DP
Overall mean	440	3854.47±181.79	3691.13±205.02	299.89±10.86	89.12±13.64
Period of birth					
2008-2011	280	3748.62±170.08	3627.45±191.82	295.82±10.16	89.00±12.76
2012-2016	160	3960.32±226.09	3754.81±254.98	303.96±13.50	89.25±16.96
Season of birth					
Winter	115	3660.67±200.41	3521.06±226.02	288.17±11.97	92.67±15.04
Summer	147	4002.54±188.48	3847.73±212.56	309.83±11.26	87.45±14.14
Rainy	178	3900.20±200.71	3704.60±226.35	301.67±11.99	87.48±15.06
Period of Calving **					
2011-2013	93	3262.27^{b}±245.33	3223.94^{b}±276.68	305.26^{b}±14.65	78.54^{b}±18.41
2014-2016	200	4078.92^{a}±189.90	3911.14^{a}±214.16	309.84^{a}±11.34	95.20^{a}±14.25
2017-2019	147	4222.22^{a}±178.93	3938.31^{a}±201.80	311.57^{a}±10.68	93.63^{a}±13.43
Season of calving					
Winter	156	3889.24±196.24	3779.22±221.32	295.52±11.72	100.36±14.72
Summer	88	3888.88±208.26	3757.15±234.88	312.76±12.44	90.35±15.63
Rainy	196	3788.29±187.49	3567.02±211.44	291.40±11.20	76.67±14.07
Parity *					
I	184	3151.64 ^{b}±77.24	2969.66 ^{b} ±87.11	314.46 ^{b}±4.61	116.94 ^{b} ±5.80
II	108	3599.82 ^{a} ±108.01	3417.62 ^{a}±121.81	314.13 ^{a} ±6.45	105.10 ^{a} ±8.10
III	74	4162.26^{a}±135.57	3937.57 ^{a} ±152.89	319.53 ^{a} ±8.10	97.21 ^{a} ±10.17

* Significant (p<0.05); ** Significant (p<0.01) Mean values with different superscripts differ significantly

Table 2: Effect of agro-climatic factors on reproduction traits in Hardhenu cattle

Effects	No. of animals(n)	SP	CI	AI/conception
Overall mean	440	104.50±15.71	385.00±16.00	1.57±0.22
Period of birth				
2008-2011	280	100.76±14.70	380.17±14.97	1.24±0.21
2012-2016	160	108.24±19.54	389.83±19.90	1.31±0.28
Season of birth				
Winter	115	93.91±17.32	373.67±17.64	1.46±0.25
Summer	147	114.31±16.29	396.20±16.59	1.52±0.23
Rainy	178	105.29±17.34	385.12±17.67	1.54±0.25
Period of Calving **				
2011-2013	93	99.08±21.20	377.37±21.60	1.11 ^{a}±0.30
2014-2016	200	112.46±16.41	393.03±16.72	1.62^{b}±0.23
2017-2019	147	101.97±15.46	384.59±15.75	1.99 ^{b}±0.22
Season of calving **				
Winter	156	109.84±16.96	391.19±17.28	1.38$^{a\pm}$0.24
Summer	88	118.90±18.00	399.29±18.33	1.66^{b}±0.26
Rainy	196	85.59±16.20	364.51±16.51	1.68^{b}±0.23
Parity				
I	184	146.44±6.67	426.65±6.80	1.59±0.10
II	108	134.08±9.33	415.88±9.51	1.80±0.13
III	74	131.79±11.72	412.60±11.93	1.97±0.17

* Significant (p<0.05); ** Significant (p<0.01) Mean values with different superscripts differ significantly

Table 3: Effect of agro-climatic factors on growth traits in Hardhenu cattle

Effects	No. of animals (n)	birth weight	1 month BW	2 month BW	3 month BW
Overall mean	470	24.88±0.54	32.96±0.85	41.08±1.06	60.94±1.54
Period of birth *					
2008-2011	240	26.58^{b}±0.87	34.42^{b}±1.36	41.20^{b}±1.7	60.64±2.46
2012-2016	230	23.19^{a}±0.85	31.50^{a}±1.34	40.96^{a}±1.67	61.25±2.42
Season of birth					
Winter	163	25.81±0.89	34.93±1.42	43.52±1.77	60.63±2.55
Summer	117	24.66±1.10	32.08±1.73	38.57±2.16	57.21±3.13
Rainy	190	24.17±1.04	31.87±1.64	41.15±2.05	64.99±2.96

* Significant (p<0.05); Mean values with different superscripts differ significantly,

Conclusion

In conclusion, this study highlights significant findings regarding the impact of various factors on reproduction, production, and growth traits in Hardhenu cattle. Specifically, the period of birth significantly influenced birth weight, one-month body weight, and two-month body weight. Moreover, the period of calving had a substantial effect on total milk yield (TMY), 300-day milk yield (300D MY), lactation length (LL), and dry period (DP). Additionally, both the period and calving season were found to significantly affect AI/conception rates. Furthermore, parity demonstrated significant effects on TMY, 300D MY, LL, and DP. These results underscore the complex interplay of temporal factors in shaping the performance metrics of Hardhenu cattle, contributing valuable insights for breeding and management practices in this breed.

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