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Genetic and non-genetic factors affecting first parity growth, reproductive and lactation traits in Barbari goats under semi-intensive management in semi-arid region of India

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ABSTRACT

Barbari is most preferred goat breed of commercial farmers in India and information on its first parity growth, reproduction and production traits are valuable for making present and future genetic progress of flock. Data for present study pertains to 2,554 kids, progeny of 227 sires and 1645 dam born during 2001 to 2019 at Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh. The least squares means of body weight of kids at birth, 3, 6, 9 and 12 months of age were 1.69±0.02, 7.48±0.13, 11.45±0.21, 16.08±0.28 and 20.21±0.33 kg, respectively. Period, sex, type of birth, and weight of dam at kidding were significant sources of non-genetic variation affecting body weights. The least squares mean of weight at first conception, weight at first kidding, age at first conception, age at first kidding and first gestation period were 18.04±0.07 kg, 21.79±0.09 kg, 381.65±2.51 days, 523.23±2.52 days and 143.33±0.21 days, respectively. Period of birth was major source of variation though these traits were also significantly affected by season and type of birth. The least squares means of first lactation 90-days milk yield, 140-days milk yield, total Lactation period milk yield, first lactation Length, milk yield per day of first lactation length and milk yield per day of first kidding interval were 50.22±0.41 litre, 69.94±1.05 litre, 57.32±0.53 litre, 123.01±0.53 days, 48.91±0.35 litre and 19.39±0.22 litres, respectively. Period, season, type of kidding, age and weight of dam at kidding were significant sources of non-genetic variation affecting above lactation traits. The h^2 for growth and production traits were moderate whereas low to moderate for reproductive traits except weight at first conception and kidding which have moderate h^2 estimates. The genetic and phenotypic correlations among the growth traits at different ages were moderate to high (0.3 to 0.8), however decrease with distant ages. Very high genetic and phenotypic correlation estimates were obtained among lactation traits suggesting that judicious selection of animals' for any lactation traits would yield consistent genetic improvement in the other milk production traits in the flock. The economic traits which were significantly influenced by non-genetic factors with high magnitude need attention for strategic management interventions such as planned breeding of females to avoid kidding in adverse weather conditions, better attention in suckling of milk for kids born with low birth weight, hygiene of shed, adequate supplementation of concentrate ration to those kids which have less pre-weaning growth regardless of type of birth, better nutrition level to maiden goats before and after mating and extension of weaning age for triplets by 10–15 days to obtain higher post weaning weight gains, optimization of breeding weight at first mating and strategic supplementary concentrate feeding as per milk yield.

Keywords: Barbari, Body weight, Goat, Genetic parameters, Milk yield, Parity, Post-weaning, Pre-weaning, Prolificacy, Productivity litter size

Goat has been traditionally playing a pivotal role in sustaining livelihood and nutritional security of resource poor people and providing supplementary income to small and marginal farmers (Singh *et al.* 2013). Importance of goat and its contribution have been becoming bigger in integral livestock farming not only in India but also in Asia and Africa primarily due to less risk, quick return, extended breeding season, round the year market, less input, ability to perform under wide range of feed and exceptional ability to tolerate extreme heat, humid and cold stresses. Driven by rapid increase in demand of goat products, many prosperous and educated persons are choosing this profession as their major source of income. High population growth rate (10.14%) during 2012–2019 in spite of >56% annual slaughter rate (DADH 2019) revealed its significance in agrarian economy. Barbari breed of goat is not only important genetic resources of India but also occupies a significant place in SAARC countries (India, Pakistan, Sri Lanka, Nepal, Bhutan, Maldives, Myanmar and Afghanistan). It is a dual purpose (meat and milk),

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medium sized goat breed, widely known for prolificacy-fecundity, reproductive efficiency, milk yield, lactation period, faster weight gain (body weight), delicious meat, relatively higher survival as compared other breeds of region and adaptability over wide range of agro-climatic conditions and feeds (Singh *et al*. 2020). Barbari goat is native of Agra-Aligarh division of Uttar Pradesh however its breeding tract has extended almost all states due to its multi-climate adaptability and consistent performance under intensive and semi-intensive feeding (Singh *et al*. 2021). Research information's are lacking on different aspects of first parity economic traits in spite of very valuable goat breed of Asia.

Higher growth rate and body weight in goat farming is not only essential for profit (right marketable age and carcass quality) but also for higher production and reproduction efficiency, better survivability and for faster genetic improvement. The reproductive traits in goats are of huge importance and determine overall productivity and profitability besides genetic progress per unit of time and replacement rate. Thus, the aim of present study was to estimate effects of genetic and non-genetic factors affecting first parity growth, reproduction and production performance to obtain faster genetic improvement by implementing necessary genetic and management interventions. Estimation of genetic parameters for growth reproductive and lactating traits is also necessary to develop efficient genetic improvement programme in goat.

MATERIALS AND METHODS

A nucleus flock of Barbari goats with 300 adult females along with about 450 followers and 25–30 bucks, maintained under All India Coordinated Research Project on Goat Improvement at Central Institute for Research on Goats, Makhdoom, Mathura since the year 1993 was used to know the performance and estimate genetic parameters.

The herd is maintained in semiarid climate with an average annual rainfall of 375–400 mm which is erratic in nature and scattered during the months of June to September. The soil of institute farm is sandy with poor quality natural pasture and bush as the main vegetation type. The pastures are mainly *Cenchrus ciliaris* and *C. setigerus* along with native annual and perennial flora. The temperature varies from 1.0°C to 24.3°C during winter and 27.5°C to 48.9°C during summer. The goats are kept separately according to age and sex. Goats are maintained on grazing with supplementary feeding like concentrate, dry and green fodders are provided according to age and sex. Goats were sent for grazing for 5–6 hour daily. The preventive health care measures were taken regularly such as vaccination for pestis-de-petitis (PPR), Foot and Mouth disease (FMD), enterotoxaemia (ET), goat pox (GP) and hemorrhagic septicemia (HS). Targeted deworming for the control of gastrointestinal nematodes was carried out during the pre-monsoon (May to June) and in the post-monsoon season (September to October). Lime treatment performed 2 to 3 time per month and white washing of sheds is done annually. The breeding is carried out seasonally (controlled) from 20th April to 30th June in summer and 20th September to 30th November in autumn seasons. Kidding happened from 15th September to November (autumn) and February to March (spring). Does were exposed to the bucks twice at each estrus. Kids were stall-fed up to 2 month of age and subsequently sent for grazing. Kids were weaned at 3 months of age and thereafter, housed separately according to sex.

Data recorded are body weighs at different ages since birth and subsequently at monthly interval, milk yield recorded twice, i.e. morning and evening at weekly interval, age and body weight at service, age and weight at kidding. Males and females are selected on the basis of selection index prepared on performance records. Males are selected on the basis of 9 months body weight and 90 days dam's milk yield. Females are selected on the basis of body weight at 9 month, type of kidding, age at first kidding and first lactation milk yield. Test day milk yield was measured on first and seventh day of week in the morning and evening which was multiplied by 7 to calculate weekly yield and finally 90-days, 140-days and total lactation milk yield estimated. The growth traits studied were body weight of kids at birth, 3, 6, 9 and 12 months of age, average daily weight gain from birth to 3 month, 3 to 6 month, 6 to 12 month and 3 to 12 months of age and litter weight at birth (LW-B), 3 months (LW-3M), 6 month (LW-6M), 9 month (LW-9M) and at 12 months (LW-12M) of age. The first lactation traits included in the study were weight at first conception (WFC), weight at first kidding (WFK), age at first conception (AFC), age at first kidding (AFK), first service period (FSP), first kidding interval (FKI), litter size, 90-days milk yield (90-d MY), 140 days milk yield (140-d MY), total lactation milk yield (TMY), lactation length (LL), milk yield per day of first lactation length (MY/FLL) and milk yield per day of first kidding Interval (MY/FKI). Incidences of prolificacy over the year were also recorded.

Data used in the present study pertains to 2,554 progeny of 227 sires and 1645 dam born during the year 2001 to 2019 at ICAR-Central Institute for Research on Goats, Makhdoom, Mathura. The whole year was divided into 2 birth/kidding seasons based on climatic conditions as spring (Season-1, February–March) and autumn as Season-2 (September–November). Whole years were divided into four periods comprising each of 5 years according to year of birth, i.e. period-1 from 2001 to 2005, period-2 from 2006 to 2010, period-3 from 2011 to 2015 and period-4 from 2016 to 2019. The environmental effects studied were period of birth/ kidding, season of birth/ kidding, type of birth, age and body weight at kidding. Data were analyzed using least-squares and maximum likelihood programs (Harvey 1990). Genetic parameters were estimated using a mixed model incorporating sire as random effect and period and season of birth, sex, type of birth/kidding, weight of dam at kidding and age of dam at kidding as fixed effect. Following statistical model was used to analyze the data for body weight and litter weight at different ages.

$$Y_{ijklmnop} = \mu + S_i + P_j + S_k + R_l + T_m + U_n + V_o + e_{ijklmnop}$$

where $Y_{ijklmnop}$, Body weight of p^{th} kid of i^{th} sire, j^{th} period of birth, K^{th} season of birth of l^{th} sex, m^{th} type of birth, n^{th} body weight of dam at kidding (n1–n4) and o^{th} age at first kidding (o1–o4); μ, population mean and $e_{ijklmno}$ is residual random error associated with $Y_{ijklmnop}$.

Model used in reproduction traits analysis was

$$Y_{ijkl} = \mu + S_i + P_j + S_k + T_l + e_{ijkl}$$

where Y_{ijkl} is the observation of i^{th} sire, j^{th} period of birth, k^{th} season of birth, l^{th} birth type; μ, population of mean; S_i, fixed effect of i^{th} sire, P_j, fixed effect of j^{th} period of birth; S_k, fixed effect of k^{th} season of birth; T_l, fixed effect of l^{th} birth type and e_{ijkl} is the random error associated with Y_{ijkl}.

Model used for lactation traits analysis was

$$Y_{ijkl} = \mu + S_i + P_j + S_k + T_l + e_{ijkl}$$

where Y_{ijkl} is the observation of i^{th} sire, j^{th} period of kidding, k^{th} Season of Kidding, l^{th} birth type; μ, population of mean; S_i, fixed effect of i^{th} sire; P_j, fixed effect of j^{th} period of kidding; S_k, fixed effect of k^{th} season of kidding; T_l, fixed effect of l^{th} birth type and e_{ijkl} is the random error associated with Y_{ijkl}.

RESULTS AND DISCUSSION

Effect of period of birth: The least squares means of body weight in Barbari kids belonging to first parity at birth, 3, 6, 9 and 12 months of ages were 1.69±0.02, 7.48±0.13, 11.44±0.21, 16.08±0.28 and 20.21±0.33 kg, respectively (Table 1). The corresponding litter weights were 3.08±0.05, 14.05±0.27, 21.55±0.44, 29.40±0.59 and 36.82±0.72 kg, respectively. The body weight and litter weight at birth from primiparous goat were slightly declined in period 2 however again showed increasing trend in period 3 and 4. Fluctuation in body weight at birth over the periods was mainly attributed to variation in weight at first kidding, age at first kidding, multiple birth rates and use of sets of different sires over the periods along with other climatic factors. Body weight and litter size at birth were very important economic traits which not only affects weight gain at later ages but also survival rate and fertility in female (Singh *et al.* 2008). Almost similar trend in body weight was observed with the advancement of age with respect to period of birth. The average body weight at 3, 6, 9 and 12 months of ages was

Table 1. First parity body weight (kg) in Barbari goats at different ages during 2001–2019

Factor	Body weight at different age				
	Birth	3M	6M	9M	12M
Overall mean	1.69±0.02 (2550)	7.48±0.13 (2179)	11.44±0.21 (1965)	16.08±0.28 (1670)	20.21±0.33 (1429)
Period (*year*)	**	**	**	**	**
1 (2001–05)	1.72±0.02^a (664)	7.40±0.15^a (530)	11.81±0.24^a (467)	17.38±0.32^a (431)	21.30±0.37 ^{a} (385)
2 (2006–10)	1.65±0.02^b (776)	7.19±0.15^b (651)	10.77±0.23^b (587)	14.96±0.31^b (450)	19.15±0.37^b (343)
3 (2011–15)	1.64±0.02^b (626)	7.43±0.14^b (589)	11.09±0.22^{ab} (541)	15.16±0.30^b (496)	19.03±0.35^b (452)
4 (2016–19)	1.67±0.03^a (494)	7.91±0.16^a (409)	12.10±0.24^a (370)	17.13±0.33^a (293)	21.36±0.39^a (249)
Season of birth	NS	NS	NS	NS	NS
Season 1	1.70±0.02 (1217)	7.61±0.14 (999)	11.48±0.22 (896)	15.52±0.30 (766)	20.18±0.35 (617)
Season 2	1.64±0.02 (1333)	7.35±0.14 (1180)	11.40±0.22 (1069)	16.65±0.29 (904)	20.24±0.34 (812)
Type of birth	**	**	**	**	**
Single	1.89±0.01^a (1454)	8.20±0.05^a (1275)	12.15±0.08^a (1153)	16.65±0.10 ^{a} (988)	20.71±0.12^a (855)
Twin	1.66±0.01^b (1072)	7.05±0.06^b (888)	11.23±0.09^b (797)	15.68±0.12^b (669)	19.73±0.15^b (562)
Triplet	1.45±0.06^c (24)	7.20±0.40^b (16)	10.93±0.62^c (15)	15.91±0.83^b (13)	20.20±0.97^a (12)
Sex	**	**	**	**	**
Male	1.75±0.01^a (1271)	7.80±0.14^a (1082)	12.13±0.22^a (965)	17.34±0.30^a (797)	21.79±0.35^a (676)
Female	1.66±0.01^b (1072)	7.17±0.14^b (1097)	10.75±0.22^b (1000)	14.83±0.29^b (873)	18.63±0.34^b (753)
WDFK (*kg*)	**	**	**	**	**
WFK-1 (<18.0)	1.62±0.03^a (386)	7.10±0.16^a (344)	10.72±0.24^a (315)	15.34±0.32^a (277)	19.38±0.38^a (246)
WFK-2 (18.1–20.0)	1.66±0.03^b (457)	7.50±0.16^b (404)	11.67±0.24^b (368)	16.29±0.33^b (327)	20.32±0.39^b (265)
WFK-3 (20.1–22)	1.69±0.02^{cb} (637)	7.62±0.15^b (545)	11.55±0.23^b (494)	16.23±0.31^b (416)	20.47±0.36^b (364)
WFK-4 (>22)	1.71±0.02^c (1070)	7.71±0.14^b (886)	11.83±0.22^b (788)	16.47±0.30^b (650)	20.68±0.36^b (554)
ADFK (*days*)	NS	NS	NS	NS	NS
AFK-1 (<450)	1.69±0.02 (618)	7.54±0.15 (531)	11.51±0.24 (478)	16.14±0.32 (424)	19.98±0.37 (369)
AFK-2 (451–500)	1.67±0.03 (415)	7.46±0.16 (361)	11.61±0.24 (337)	16.08±0.33 (285)	20.54±0.39 (240)
AFK-3 (501–550)	1.67±0.02 (691)	7.52±0.15 (613)	11.36±0.23 (551)	16.08±0.30 (480)	20.35±0.36 (407)
AFK-4 (>551)	1.64±0.02 (826)	7.41±0.15 (674)	11.28±0.23 (599)	16.04±0.31 (481)	19.97±0.37 (413)

Different subscript indicate (a, b, ...) significant difference at **(P<0.01) and *Significant at (P<0.05). WDFK, weight of dam at first kidding; ADFK, Age of dam at first kidding; NS, non-significant.

Table 2. Average daily weight gains (g/d) in Barbari kids at different ages during 2001–2019

Factor	ADG				
	No. OBS.	Birth-3M	3M-6M	6M-12M	3M-12M
Overall mean	1420	67.84±0.44	47.25±0.49	46.16±0.38	46.54±0.30
Period (year)		*	**	**	*
1 (2001–05)	375	65.56±0.85[a]	52.22±0.94[a]	50.69±0.73[a]	51.24±0.56[a]
2 (2006–10)	337	67.44±0.88[b]	41.46±0.98[b]	42.23±0.76[b]	41.96±0.59[b]
3 (2011–15)	450	67.72±0.76[b]	45.29±0.84[b]	41.74±0.65[b]	42.95±0.51[b]
4 (2016–19)	258	70.63±1.00[c]	50.05±1.11[a]	50.07±0.86[a]	50.03±0.67[a]
Season of birth					
1	600	68.72±0.66[a]	47.42±0.73	45.82±0.57	46.37±0.44
2	820	66.96±0.58[b]	47.09±0.65	46.50±0.50	46.72±0.39
Type of birth					
Single	829	72.07±0.57[a]	46.93±0.64	46.36±0.49	46.57±0.38
Twin	591	63.60±0.67[b]	47.57±0.74	45.96±0.57	46.51±0.44
Sex					
Male	680	70.91±0.63[a]	51.25±0.70[a]	50.93±0.54[a]	51.05±0.42[a]
Female	740	64.76±0.60[b]	43.26±0.67[b]	41.39±0.52[b]	42.04±0.40[b]

Different subscript indicate (a, b, ...) significant difference at **(P<0.01) and *significant at (P<0.05). ADG, Average daily weight gain.

significantly lower in period-2 and P-3 as compared to P-1 and P-4 (Table 1). It was also reflected by significantly lower body weight gain during different growth ages in period 2 and 3 (Table 2). However, significantly higher growth performances with respect to body weight at different ages were obtained in period 4, which might be due to improvement in mother milk yield and their lactation efficiency (as maximum dams >97% attained first 90 days lactation unlike other periods where about 74 to 77% goat could attain 90 days milk yield beside overall improvement in breeding practices and farm management, i.e. farm annual mortality reduced from >7% (2000–2012) to <3% (2013–2020). This was also well reflected by substantially and significantly high pre-weaning and post-weaning weight gain in period 4 in spite of high prolificacy rate (Table 2). Similar post weaning body weights in Barbari kids under farmers flock was reported by Singh and Rai (2006). However, higher means (27 to 56%) than present body weight of Barbari kids at different ages were observed at 6, 9 and 12 months of age under intensive feeding (Singh *et al.* 2020) and also with multiplier flocks of Barbari goat (Success Story, Annual Report ICAR-CIRG 2019) indicating much more potential for growth in the animals of this breed. The body weight of Barbari kids from primiparous doe were comparable with Surti, Malabari, Sangamneri, Mehsana, Marwari and Osmanabadi breeds (Deokar *et al*. 2007, Verma *et al.* 2009, Sabapara *et al*. 2010, Patel and Pandey 2013, Annual PC Report-2019 AICRP on Goat Improvement).

Effect of season of birth: Effect of season of birth was non-significant on body weight at different ages (Table 1). This agrees with the findings of Singh *et al.* (2009), Rai *et al.* (2004). However, litter weight gain was significantly affected by season of birth and kids born in spring season revealed significantly higher weight gain than those born in autumn. Though, superiority associated with season of birth become non-significant with the advancement of age from 3 month of age onwards. Maternal permanent environmental effects might also important source of variation of birth weight and weaning weight as it influences the uterine capacity of the does for growth of the fetus and the effect of multiple births. These results were in agreement with those reported by Singh *et al.* (1984), Singh *et al.* (2009), Gowane *et al.* (2011), Rout *et al.* (2018) and Ofori and Hagan (2020) in different goat breeds.

Effect of type of birth: Single born kids were significantly heavier than those born as multiple and maintained their superiority for body weight up to 12 month however, magnitude of difference in body weight between single and multiple declines with the advancement of age (Table 1). Decreased birth weight with the increase in litter size attributed to intra uterine nutrition, i.e. foetuses number increase in multiple and number of caruncles attached to each foetus decreases. Thus, reduction in feed supply to foetus leads to reduction in birth weight of kids. Space competition among multiple kids might also be attributed to less birth weight of multiple born kids. Single born kids also have greater access of suckling milk as compared to their counterpart which may impact pre-weaning and post-weaning weight up to 6 month. Therefore, concentrate supplementation should be increased to those kids whose pre-weaning growth is less primarily when milk yield of their dam is low regardless of litter size. Present results were in agreement of those reported by Singh *et al.* (1984), Todaro *et al*. (2006), Singh *et al*. (2009), Rout *et al.* (2018) and Ofori and Hagon (2020) in different goat breed.

Effect of sex: Males were (P<0.01) recorded heavier than their counterpart's right from birth to 12 months of ages

(Table 1). Higher birth weight and growth rate in male kids at later ages attributed to vigorous behaviour of male in suckling on account of differential hormone influence resulted in greater access of milk up to weaning, whose impact last at later ages also. Present results were in agreement of those reported by Sanchez *et al*. (1994) in Granadina graded goats, Singh and Rai (2006) in Barbari in farmers flock, Singh *et al.* (2008) in Jamunapari, Patel and Pandey (2013) in Mehsana goat, Ofori and Hagan (2020) in West African dwarf goat.

Effect of body weight at first kidding: Maiden doe with higher body weight at kidding produced kids with more birth weight and a linear association was observed between maiden doe weights at kidding and birth weight of their kids. The kid's birth weight over different doe's weight group was though small but significant and continued at later ages also, i.e. body weight up to 12 months of ages (Table 1). Similar trend was also observed in litter weight at different ages; moreover litter body weight right from birth to 12 months of age was significantly higher of those kids which were produced by maiden does with more than 22 kg weight at kidding. Body weight of females after 18 kg however, did not adversely affect post-weaning body weight of kids (Table 1). The higher birth weight of kids by heavier maiden doe might be due to better uterine environment for embryo development and good colostrum and milk production after kidding. These observations suggest for additional supplementary feeding right from conception of maiden goats till kidding. Present results were in agreement of those reported by Sanchez *et al*. (1994), Al-Shaikh and Mogawer (2001) and Singh *et al.* (2009) in different goat breeds.

Effect of age at first kidding: The effect of AFK was non-significant on birth weight of kids and body weight at later ages (Table 1), and in agreement of Shorepy *et al*. (2002) who did not find effect of doe's age on kid's body weight and growth rate in Emirati goat. Higher weight of doe with less age might be attributed to more number of singles which was evident by higher litter birth weight by those females which have highest body weight at kidding. However, Singh *et al*. (1984) and Sanchez *et al*. (1994) reported higher birth weight with the increase in age of dam and might be explained in reference to increase in parity or age and partly by an increase in body weight. An increase in AFK in period 3 and 4 was might be attributed to higher litter size during periods 3 and 4 (1.33 and 1.38) as against period 1 and 2 which have litter size as 1.23 and 1.26. These results suggest that an optimum age for first conception might be 9 months in Barbari females and simultaneously efforts should be made to breed maiden goats within 12 months of age. Efforts should be made to attain > 18 kg body weight at kidding to obtain higher weight per doe kidding and multiple births in a given period of time. Adequate nutrition is very important before and after mating to obtain early replacement, faster genetic gain and more pre-weaning and post-weaning growth of kids.

Reproductive traits performances: The overall least squares mean of first parity reproductive traits, i.e. WFC, WFK, AFC, AFK and FGP were 18.04±0.07 kg, 21.79±0.09 kg, 381.65±2.51 days, 523.23±2.52 days and 143.33±0.21 days respectively and all these traits were significantly affected by period of birth (Table 4).

Effect of period of birth: The WFC ranged from 16.12±0.15 (P-3) to 19.97±0.13 kg (P-4) and similar trend was obtained for age at first kidding, i.e. 20.85±0.19 kg (P-2 and P-3) to 23.41±0.17 kg (P-4). The variation in first conception weight was mainly attributed to management (nutrition quality and quantity) conditions, post weaning health and body score conditions, climatic conditions particularly pre monsoon rain shower as it act as catalysts and synchronize to bring large number of females in oestrous, type of birth as multiple born females took more age to attains first conception due to their less body weight as compared to single born. Present observations were in agreement of other medium sized goat breeds such as Surti (Sabapara *et al*. 2010) and Sangamneri (Deokar *et al*. 2007). On the contrary, Singh and Rai (2006) in Barbari goats reported lower body weight at first kidding in field conditions which might be due to uncontrolled breeding on account of mixed grazing with male. The weight and age at first kidding are dependent on genotype, environment and their interaction and predominately influenced by quality and quantity of nutrition and micro-climate. Breeding at this farm has been restricted only in both major breeding seasons, i.e. summer (15^{th} April to 30^{th} June) and autumn (15^{th} September to 30^{th} November) as high pre-weaned kid's mortality (15–25%) occurred in those kids who were born in peak summer or winter and in rainy season (Singh *et al*. 2008). Lactation performance (milk yield and lactation length) of such goats which were kidded in off breeding season also decreases (15–35%) considerably (AICRP Annual Report, Barbari 2020) which might be attributed to poor lactation adaptability of these goats in hot-humid conditions. The age at first conception varied from 354.21±4.21 (P-1) to 407.48±4.93 days (P-4) and almost similar trend was obtained for age at first kidding, which was varied from 495.26±4.22 kg (P-01) to 550.38±4.95 days (period-4) (Table 4). These results indicate an increasing trend in first conception and kidding over the period in both these traits. Higher AFS and AFK from present estimates was reported in other medium size Surti (Sabapara *et al.* 2010); Mehsana (Patel and Pandey 2013) and in Barbari goats (kharkar *et al.* 2014). Barbari females though attained puberty at 5 months of age (144±4.29 days) however, as per Institute breeding policy these goats were allowed for breeding with minimum 16 kg body weight and at 9 months of age for higher kid's survival, growth rate in kids, higher litter size and milk yield. The litter sizes over the period were 1.23, 1.26, 1.33 and 1.38 with an overall average of 1.29. Proper implementation of breeding practices from period-3 onward might lead to an increase in age at first kidding besides increase in litter size and much lower pre-weaned kid's mortality in period 3 and 4 as compared to period 1 and 2

(Table 3). Decrease in AFK beyond a certain level (physical and physiological maturity) nullifies the net gain by decreased kid's survival and lactation performance. The gestation period in Barbari goats was 143.33±0.21 days which varied from 141.09 (period-2) to 145.80 (period-4). Singh and Roy (2003) and Patel and Pandey (2013) in Jamunapari and Mehsana goats however, reported slightly more FGP. No consistent trend over the period was observed in case of first gestation period, might be influenced by litter size, litter weight, physical and climatic parameters occurred during the course of kidding.

Effect of season of birth and kidding: Effect of season of births on different reproductive traits was significant only in weight at first conception (Table 4) moreover, effect was small in magnitude and primarily influenced by prevailing climatic conditions. The females born in season 2 (autumns) were marginally heavier than those born in spring (Table 4) and attributed to better climatic conditions in their early life. Presents results were in agreement of those reported by Singh *et al*. (2009) in Jamunapari goats.

Effect of type of birth: Effect of type of birth was significant on age at first service and kidding (Table 4). Multiple born females took more age in getting mature thus for conception as compared to single born females. It may be due to their better pre-weaning growth on account of better birth weight and milk through suckling. The effect of type of birth was large in magnitude i.e > 50 days. Present result thus, suggests that multiple born females should be given better feeding to obtain their faster growth and early conception age. Presents results were in agreement of those reported by Singh *et al*. (2009) in Jamunapari goats.

Performances of lactation traits: Overall least squares means of first lactation 90-days milk yield, 140-days milk yield, total lactation milk yield, first lactation length, milk yield per day of first lactation length and milk yield per day of first kidding interval were 50.22±0.41 litre, 69.94±1.05 litre, 57.32±0.53 litre, 123.01±0.53 days, 48.91±0.35 litre and 19.39±0.22 litres, respectively (Table 5).

Effect of period of kidding: Milk yield performances of different first lactation traits by and large showed increasing trend over the period except period-02 (2006–2010) which was attributed mainly to environmental reasons as many goats became exhausted (became dry) before 90 days even a sharp decline in milk yield in about 23% goats were observed after 5–7 week of kidding which might be attributed to inadequate feed-fodder availability and delayed kidding (with respect to season) which account > 18% of total kidding's in period 2. Goats kidded in April–May or in rainy season (July–August) and in peak winter season, i.e. December-January were yielded lesser milk and stand with much lesser lactation length (82 vs 123 days). Onset of rain was resulted in sharp and heavy decline in milk yield and lactation length probably due to poor physiological adaptability of these goats for rain and hot-humid climatic conditions. Singh *et al.* (2009) also reported similar findings in Jamunapari goats. It is also evident from Table 5 that about 22% and 92% goats could not attain lactation length up to 90 and 140 days during period 2. However, later on in period 4 there was significant and substantial improvement in lactation performance in 90-DMY, 140-DMY, TMY, LL, MY/FLL and MY/FKI amounting 14.82, 13.67, 28.99,

Table 3. Pre-weaning kids mortality over the periods of birth

Period (year)	Kids born	Kids died
1 (2001–2005)	2,561	366 (14.3%)
2 (2006–2010)	2,325	214 (9.2%)
3 (2011–2015)	2,093	56 (2.7%)
4 (2016–2019)	1,512	36 (2.4%)
Total	8,491	672 (7.9%)

Table 4. Factors affecting first parity reproductive traits in Barbari goats

Factor	Reproductive performance				
	WFC (kg)	WFK (kg)	FGP (d)	AFC (d)	AFK (d)
Overall mean	18.04±0.07 (2051)	21.79±0.09 (2051)	143.33±0.21 (2051)	381.65±2.51 (2051)	523.23±2.52(2051)
Period	**	**	**	**	**
1 (2001–05)	18.47^{a}±0.11 (596)	22.08^{a}±0.14 (596)	142.95^{a}±0.35 (596)	354.21^{a}±4.21 (596)	495.26^{a}±4.22 (596)
2 (2006–10)	17.69^{b}±0.10 (703)	20.85^{b}±0.13 (703)	140.99^{b}±0.33 (703)	375.96^{b}±3.94 (703)	514.83^{b}±3.96 (703)
3 (2011–15)	16.12^{c}±0.15 (338)	20.85^{b}±0.19 (338)	143.59^{a}±0.45 (338)	388.94^{cb}±5.46 (338)	532.45^{cb}±5.48 (338)
4 (2015–19)	19.97^{d}±0.13 (414)	23.41^{c}±0.17 (414)	145.80^{c}±0.41 (414)	407.48^{cd}±4.93 (414)	550.38^{cd}±4.95 (414)
Season of birth	**	NS	NS	NS	NS
1 (Spring)	17.37^{a}±0.08 (1155)	21.70±0.10 (1155)	143.02±0.26 (1155)	386.04±3.09 (1155)	527.32±3.10 (1155)
2 (Autumn)	18.71^{b}±0.10 (896)	21.88±0.12 (896)	143.65±0.30 (896)	377.25±3.64 (896)	519.14±3.65 (896)
Type of birth	NS	NS	NS	**	**
1 (Single)	17.29±0.07 (1472)	21.13±0.09 (1472)	142.67±0.22 (1472)	353.79^{a}±2.66 (1472)	495.16^{a}±2.67 (1472)
2 (Multiple)	18.78±0.11 (579)	22.45±0.14 (579)	143.99±0.34 (579)	409.50^{b}±4.16 (579)	551.30^{b}±4.18 (579)

Different subscript indicate (a, b,..) significant difference at **(P<0.01) and *significant at (P<0.05). Weight at first conception (WFC), Weight at first kidding (WFK), Age at first conception (AFC), Age at first kidding (AFK), First gestation period (FGP); NS, non-significant.

12.08, 22.17 and 20.05% improvement over period (P-3). Improved lactation performance in P-3 and P-4 attributed mainly to changes in selection process, i.e. those bucks were given opportunity in breeding whose daughters lactation performance were >85.0 litre in 90 days, and simultaneously improvement in flock management (optimization of age and weight at first service, controlled breeding with respect to season). Lactation efficiency and persistence was also high during period 4 as 96 and 84% kidded goat's attained 90 days and 140 days lactation length in period 4 which was 79 and 08% in period 2. Effect of weight at first service and at first kidding; and age at first conception and age first kidding was significant, though magnitude of effect was small (8–20%) in period 4 as compared to other periods (P-1, P-2 and P-3) which might also had played beneficial effect on lactation performance in this flock (Table 5). Present results were in agreement of those reported in Jamunapari by Singh *et al.* (2009).

Effect of season of kidding: Kidding season was significant (P>0.01) in all lactation trat (Table 5). Goats kidded in spring season yielded 7.57, 7.67, 15.34 and 7.37% higher 90-DMY, 140-DMY, TMY and FLL than those which kidded in autumn season. It might be attributed to congenial climatic conditions supported by adequate fodder availability as last quarter of spring kidder falls in April–May–June and summer is the most suitable season for goat's health and milk production point of view. Varied milk yield performance over the seasons was attributed to mainly variation in climatic conditions, feed and fodder availability etc. Yadav *et al.* (2004) and Singh *et al.* (2009) also reported significant effect of season of kidding on milk performance traits in Kattchi and Jamunapari goats.

Effect of type of kidding: Analysis of variance revealed non-significant effect of type of kidding on milk production traits in these goats (Table 5). Singh *et al.* (2009) also reported non-significant effect of type of birth on lactation traits in Jamunapari goats.

Effect of weight at first kidding: Weight at first kidding has significantly affected all the lactating trait (Table 5). Almost linear association was observed in between body weight at kidding and milk yield. Similar results were also reported by Singh *et al.* (2009). Females with more than 22 kg body weight showed 20.08%, 25.36%, 24.88% and 3.92% higher performance in 90-DMY, 140-DMY, TMY and FLL as compared to those goats which had lesser body weight (<18 kg) at kidding (Table 5). Both, dietary concentrate level and and forages may also had affected level of milk production. These results indicate that body weight of primiparous Barbari females should be more than 22 kg at first kidding to obtain higher lactation performances.

Genetic parameters: The estimates of genetic parameter for different growth traits are illustrated in Table 6. The h^2 estimates for body weights at different stages of growth were moderate, indicating the existence of sufficient additive genetic variance and further scope of genetic improvement through effective selection. Similar h^2 estimates body weights were reported by Singh *et al.* (2009), Zhang *et al.* (2009), Rashidi *et al.* (2011), Rout *et al.* (2018) and Gautam *et al.* (2019) in different goat breeds. The genetic and phenotypic correlations between body weights at different stage of growth were positive and moderate to high in magnitude. Values of phenotypic correlation are higher than that of genetic correlation without antagonism between traits, indicating the linear relationship among them. Genetic as well as phenotypic correlation of birth weight was higher to pre-weaning weight as compared to post weaning weights, might be influenced by maternal effects. High and positive genetic correlation between the 6th and 9th month body weight indicates the scope for selection of kids at earlier age in this breed. Heritability estimates of reproductive traits in these goats were low to moderate (0.385±0.081, 0.470±0.086, 0.153±0.066, 0.128±0.065 and 0.118±0.064 for WFC, WFK, AFC, AFK and FGP). Higher h^2 for weight at first conception and kidding might be attributed as they are partially growth traits and indicating that selection has some role in their genetic improvement. Whereas low h^2 of age at first conception and kidding indicates that appropriate management interventions have greater role in their improvement. Therefore, identification of efficient reproducer based on their relative performance might allow scope to improve the flock productivity. The h^2 estimates of for 90 d-MY, 140 d-MY and FLMY were 0.243±0.066, 0.228±0.065, 0.239±0.065, respectively indicates that judicious selection of animals may bring sustainable genetic improvement in this flock. These estimates are in agreement of those reported by Singh *et al.* (2009). The estimates of genetic and phenotypic correlations among lactation traits were (>0.9) high indicating that selection on the basis of 90 days milk yield may bring equally effective improvement in other lactation traits.

Results of the present study suggest that growth, reproduction and milk production traits are significantly influenced by non-genetic factors and need to be adjusted before evaluating the performance of animals. Strategic management interventions such as breeding of females should be planned in such a manner that kidding of goat should have occurred in climatically conducive seasons (autumn and spring). Multiple born kids especially with low birth weight should be given better attention in suckling of milk and hygiene of shed. Supplementation of concentrate ration should be increased of those kids who have less pre-weaning growth regardless of type of births. Kids of those does which could not sustain lactation beyond 60 or 70 days shall be allowed for suckling of contemporary doe with good milk yield, better nutrition level to maiden goats before and after mating. Kids of 3–6 months of age has more scope to harvest higher daily weight gain thus preventive measures should be timely taken to avoid endo or ecto-parasitic infestation in kids. Weaning age for triplets may be extended for 10–15 days to obtain higher post weaning weight gains to achieve higher productivity. Optimization of breeding weight at first mating, kidding in

Table 5. Factors affecting first lactation milk production and production efficiency traits in Barbari Goats

Factor	Lactation performance of Barbari goats					
	90-d MY (l)	140-d MY (l)	TMY (l)	FLL (d)	MY/FLL (l)	MY/FKI (l)
Overall Mean	50.22±0.41 (1570)	69.94±1.05 (612)	57.32±0.53 (1734)	123.01±0.53 (1622)	48.91±0.35 (1620)	19.39±0.22 (1474)
Period	**	**	**	**	**	**
1 (2001–05)	50.01^{a}±0.87 (321)	63.86^{a}±2.42 (67)	58.49^{a}±1.14 (336)	118.22^{a}±1.13 (317)	49.76^{a}±0.71 (317)	20.31^{a}±0.42 (332)
2 (2006–10)	45.55^{b}±0.72 (422)	66.41^{a}±2.71 (44)	45.47^{b}±0.90 (536)	107.24^{b}±0.89 (468)	44.85^{b}±0.57 (468)	17.61^{b}±0.31 (504)
3 (2011–15)	48.35^{b}±0.68 (445)	68.84^{a}±1.49 (162)	56.27^{a}±0.94 (460)	126.16^{a}±0.88 (451)	45.65^{b}±0.60 (451)	18.35^{b}±0.36 (436)
4 (2016–19)	55.52^{c}±0.79 (382)	78.25^{b}±1.04 (339)	72.58^{c}±1.05 (402)	141.41^{c}±1.02 (384)	55.77^{c}±0.75 (384)	22.03^{c}±0.53 (202)
Season of kidding	**	**	**	**	NS	NS
1 (Spring)	52.03^{a}±0.54 (807)	72.30^{a}±1.18 (368)	62.47^{a}±0.72 (864)	127.38^{a}±0.69 (820)	49.23±0.46 (811)	19.67±0.29 (723)
2 (Autumn)	48.37^{b}±0.58 (763)	67.15^{b}±1.42 (244)	54.16^{b}±0.74 (870)	118.64^{b}±0.73 (800)	48.56±0.48 (809)	19.11±0.30 (751)
Type of birth	NS	NS	NS	NS	NS	NS
1 (Single)	50.38±0.44 (1117)	69.15±1.14 (399)	58.91±0.58 (1231)	122.98±0.57 (1153)	49.16±0.36 (1153)	19.43±0.24 (1063)
2 (Multiple)	49.88±0.67 (452)	70.72±1.14 (213)	57.62±0.88 (503)	123.04±0.86 (467)	48.63±0.58 (467)	19.36±0.37 (411)
Weight of DFK (kg)	**	**	**	*	NS	NS
WFK-1 (<18.0)	44.72^{a}±0.89 (277)	60.67^{a}±2.13 (76)	51.87^{a}±1.13 (328)	121.88^{a}±1.13 (290)	49.03±0.76 (324)	19.55±0.47 (303)
WFK-2 (18.1–20.0)	46.78^{a}±0.80 (345)	65.46^{a}±1.86 (107)	54.68^{a}±1.04 (382)	121.63^{a}±0.92 (361)	48.31±0.64 (375)	19.22±0.44 (345)
WFK-3 (20.1–22)	51.09^{b}±0.72 (399)	70.65^{b}±1.60 (164)	59.58^{b}±0.94 (436)	121.95^{a}±0.91 (416)	49.38±0.59 (415)	18.87±0.40 (378)
WFK-4 (>22)	54.04^{b}±0.64 (549)	76.06^{b}±1.42 (265)	64.78^{c}±0.84 (588)	126.66^{b}±0.82 (553)	49.87±0.63 (506)	20.17±0.37 (448)
Age of DFK (Days)	*	*	*	**	NS	NS
AFK-1 (<450)	47.89^{a}±0.72 (471)	67.94^{a}±2.14 (79)	54.27^{a}±0.93 (542)	117.93 ^{a}±0.92 (496)	49.51±0.63 (540)	19.85±0.39 (518)
AFK-2 (451–500)	48.72^{a}±0.89 (267)	64.41^{a}±1.92 (120)	56.4 ^{ab}±1.16 (294)	124.07^{b}±1.14 (276)	47.63±0.76 (283)	19.09±0.49 (253)
AFK-3 (501–550)	51.39^{b}±0.71 (463)	67.95^{a}±1.62 (247)	59.53^{b}±0.93 (497)	124.73^{b}±0.91 (467)	48.97±0.63 (352)	19.23±0.40 (390)
AFK-4 (>551)	51.95^{b}±0.78 (369)	72.05^{b}±1.76 (166)	62.63^{b}±1.06 (401)	125.61^{b}±1.03 (383)	50.03±0.74 (345)	19.20±0.46 (313)

Different subscript indicate (a, b, ...) significant difference at **(P<0.01) and *significant at (P<0.05); 90-days milk yield (90-d MY); 140 days milk yield (140-d MY); total yield in lactation (TMY), First lactation Length (FLL); Milk yield per day of first lactation length (MY/FLL) and Milk yield per day of first kidding interval (MY/FKI); NS, non-significant.

Table 6. Heritability, genetic and phenotypic correlation among growth traits in Barbari goats

Trait(s)	Birth weight	3 Month	6 Month	9 Month	12 Month
Birth weight	0.121±0.027	0.425	0.321	0.290	0.273
3 month	0.590±0.103	0.179±0.031	0.691	0.570	0.495
6 month	0.348±0.121	0.891±0.048	0.223±0.030	0.794	0.663
9 month	0.315±0.136	0.686±0.078	0.858±0.038	0.154±0.029	0.826
12 month	0.368±0.123	0.615±0.082	0.694±0.062	0.908±0.029	0.210±0.033

Heritability (Diagonal), Genetic correlation (below diagonal) and phenotypic correlation (above diagonal).

favourable seasons and strategic supplementary concentrate feeding as per milk yield of doe are other important management interventions. The estimates of h^2 for different growth and lactation traits were moderate and positive indicating further scope for genetic improvement through selection. The genetic and phenotypic correlations between body weights at different stage of growth were positive and high suggests that male for breeding may be select at 6 months of age instead of present practice at 9 month of age. Very high estimates of genetic and phenotypic correlation among lactation traits suggest that selection of sires on 90 days milk yield is equally effective to improve other lactation traits in the flock.

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