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Non-genetic factors affecting pre-weaning growth and survival rate in Barbari kids under semi-intensive management system

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ABSTRACT

The effect of non-genetic factors on pre-weaning growth and survival performance in Barbari kids was assessed to maximize pre-weaning growth and survival rates. Performance records of 10,013 Barbari goats maintained at ICAR-Central Institute for Research on Goats, Makhdoom, Mathura, India, from 1995 to 2020 were analyzed for non-genetic factors. The effect of period and season of birth, type of births, sex of kids, parity of doe and dam's 90-days milk yield were significant on birth weight and pre-weaning growth. Kids born in spring and winter had higher birth weight than those born in summer, monsoon and autumn, and maintained their superiority up to weaning. Male and single-born kids at birth were heavier than their counterparts and maintained superiority up to weaning. Significant linear association was observed in body weight at birth, 3 months and average daily weight gains with the increase in doe's milk yield. Multiparous does produced kids with higher birth weight than primiparous does. Kidding in inclement seasons such as the peak of monsoon, summer and winter was associated with higher mortality. Autumn-born kids had the lowest pre-weaning mortality followed by the spring season. Higher mortality incidences were obtained in multiple-born kids, kids with low birth weight (<1.5 kg) and doe's with low milk yield. The results suggest that to obtain higher growth and survival of kids, breeding should be planned to obtain maximum kidding during the spring and autumn seasons. Adequate care should be given to kids born from does with lesser milk yield, triplet or less birth weight, and for first 15 days of birth.

Keywords: Average daily weight gain, Barbari goat, Non-genetic factors, Parity, Pre-weaning mortality, Season

The Barbari goat breed is one of the important genetic resources for India and occupies a significant place in SAARC countries. It is a dual-purpose, medium-sized goat breed, widely known for prolificacy, meat quality and adaptability over a wide range of agro-climatic and management conditions (Singh *et al.* 2020). Goat production is affected both by genetic and non-genetic (environmental) factors. Pre-weaning growth, weight gain and survival rate are economically very important traits in goats and help to determine the productivity, profitability, replacement and genetic improvement rate. Expressions of these traits are heavily affected by non-genetic factors (Singh *et al*. 2008, Chauhan *et al*. 2019). Thus, the performances of these traits could be improved by implementing a strategic package of management practices according to age, seasons, parity and doe's milk yield. Pre-weaning kids mortality in Indian flocks has been reported up to 17.78%, which lowers the genetic progress by limiting selection intensity and also result in huge economic loss to farmers (Singh *et al.* 2008, Chauhan *et al.* 2019). Therefore, important probable causes must be explored and addressed by developing management strategies. This is a comprehensive study on pre-weaning growth and survival performance of Barbari kids considering all important non-genetic factors. Barbari goats are very much in demand for commercial goat farming in North India and rapidly expanding their presence in North-West and Southern states. As more than 98% of goats in India are found in farmers' flocks, therefore, development of an appropriate breed-based package of management practices has become essential to improve farmers' knowledge, adoption of technologies and profitability. The performance of animals is influenced by both genetic and environmental factors. Assessment of non-genetic factors on early growth and survival traits of goats is essential to understand the nature, reasons and extent of these factors on performances. Therefore, the present study was planned to assess the effect of important non-genetic factors on body weight at birth, body weight at 3 months, pre-weaning average daily weight gain (ADG) and pre-weaning mortality of kids under semi-intensive management system. The information generated in the study will help to devise appropriate breeding measures to maximize the pre-weaning growth and survival of kids.

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MATERIALS AND METHODS

A Nucleus flock of Barbari goats of 300 adult females along with 450–500 followers (kids) and 25–30 bucks are maintained at the Central Institute for Research on Goat, Makhdoom since the year 1993, under the All India Coordinated Research Project (AICRP) on Goat Improvement, under a semi-intensive management system with health protective measures (Singh *et al.* 2021). Each kid born was assigned an identification number by ear tattooing and date of birth, sex, birth type, and live body weights were recorded. Kids were stall-fed up to 2 months of age and subsequently sent for 2 to 3 h grazing up to weaning and thereafter for 5 h a day. Kids were weaned at 3 months of age and thereafter, housed separately according to sex. The parameters recorded were kids body weight at birth and at 3 months of age, average daily weight gain from birth to 3 months, milk yield, dams age and weight at service and at kidding, and kids mortality rate were taken up for present study. Data for the present study on growth and survival traits pertain to 10,013 kids, the progeny of 370 bucks, and 2,570 does born during 1995 to 2020. The entire study duration was divided into five periods based on year of birth as Period 1 (1995 to 2000), Period 2 (2001 to 2005), Period 3 (2006 to 2010), Period 4 (2011 to 2015), and Period 5 (2016 to 2020). The whole year was divided into 5 birth seasons based on climatic conditions as spring (February–March), summer (April–June), monsoon (July–August), autumn (September–October), and winter (November–January). The non-genetic effects studied were period and season of birth, type of birth, sex, parity and dam's milk yield in the first 90 days. Growth data were analyzed using the least-squares and maximum likelihood program (Harvey 1990) and mortality rate through chi-square analysis using the SPSS program (SPSS 2004). The differences between different non-genetic factors such as period of birth were tested for significance with the Duncan Multiple Range Test (DMRT) as modified by Kramer (1957). The following statistical model was used to analyze the data for pre-weaning body weight and weight gains:

$$Y_{ijklmno} = \mu + Y_i + S_j + P_k + B_l + L_m + X_n + e_{ijklmno}$$

where, Y_{ijklmn} , body weight/daily weight gain of kid born in i^{th} period, j^{th} season of birth, k^{th} sex, l^{th} type of birth, m^{th} parity (1 – 6) and n^{th} group of 90 d milk yield; μ, population mean and e_{ijklmn} , the residual random error associated with $Y_{ijklmno.}$

The data was grouped in various sub-classes such as period, season, age group, birth weight, dam's milk yield, parity, etc. to study the effect of these non-genetic factors, which were analyzed using χ^2 and F-statistics.

RESULTS AND DISCUSSION

Effect of period of birth on pre-weaning growth and mortality: Significant variation was observed over the periods of birth (Table 1) attributed mainly to variation in incidences of multiple births, the proportion of primiparous and multiparous goats in the flock, body weight of the doe at kidding, sire's breeding value, and variation in feeding management, morbidity and climatic conditions. The highest multiple births and litter size was recorded in period 5 and 4 which might be major reasons for lower birth weight during these periods. However, the body weight of kids with respect to type of birth was changed at 3 months of age and might be due to changes in pre-weaning weight gain with the maximum body weights of kids at 3 months in period 4 (Table 1). The maximum average daily weight gain was also recorded in period 4 followed by periods 3 and 5. The large influence of year/ period of birth on birth weight and pre-weaning gain were also reported by Singh *et al.* 2009, Rout *et al.* 2018 and Singh *et al.* 2021 in different goat breeds.

The effect of the period of birth on pre-weaning survival was significant ($P<0.05$) and a consistent decrease was observed in mortality rate over the years (Fig. 1) from 16.50% (period 2) to 2.71% (period 5) (Table 2). Variation in mortality rate over the periods might be due to variations in flock management, neo-natal kid's management, variation in age and weight at first kidding, kidding interval (service period), milk yield of doe, climatic factors, besides the prevalence of disease incidences and parasite infestation. It was also observed that there was a heavy incidence of certain diseases in some of the years, however, in the next year, the virulence of diseases went down due to effective preventive management and resistance developed by the goats. Significantly ($P<0.05$) higher incidences of kid mortality during periods 2, 1 and 3 might be attributed to the occurrence of higher incidences of kidding in inclement weather (18–29%) such as summer, monsoon and winter besides sizable kiddings of under-age and under-weight does. Significantly ($P<0.01$) low mortality rate in periods 4 and 5 (Table 2) despite higher incidences of multiple births, indicate better prenatal and post-natal care for the kids. The large influence of year/ period of birth on pre-weaning mortality was also reported by Husain *et al.*(1995), Hailu *et al.* (2006), Singh *et al.* (2008) and Chauhan *et al.* (2019).

Major causes of mortality in pre-weaning kids were diseases involving the digestive system (colibacillosis, gastro-enteritis and acidosis), respiratory system (pneumonia, pneumo-enteritis and lung abscess) and miscellaneous causes such as septicemia, toxemia, peritonitis, anemia, etc. which accounted for 45.06%, 32.34%, and 22.6% of total mortality, respectively.

Effect of season of birth on pre-weaning growth and mortality: The effect of season of birth was significant ($P<0.05$) on birth and 3 month weight and AWG. Kids with maximum birth weight were observed in the spring season and lowest in the autumn season. However, the pattern of kids' body weight changed at 3 months of age and kids born in winter attained maximum weight followed by kids born in spring and autumn (Table 1). This change might happen due to maximum pre-weaning weight gain in kids which were born in winter, followed by autumn and spring. The effect of the season of birth on birth and 3-month body

Table 1. Kids' birth weight, 3-month weight and average daily weight gain in Barbari kids during 1995–2020

Factor	Pre-weaning growth performance of Barbari kids		
	Birth weight (kg)	3 month weight (kg)	ADG (g/d)
Overall mean	1.81±0.01 (10013)	7.74±0.03 (9035)	65.78±0.35 (9035)
Period of birth	**	**	**
1 (1995-2000)	1.77^{a}±0.01 (1261)	7.05^{a}±0.06 (1072)	58.40^{a}±0.60 (1072)
2 (2001-2005)	1.82^{b}±0.01 (2509)	7.68^{b}±0.04 (2094)	64.38^{b}±0.45 (2094)
3 (2006-2010)	1.83^{c}±0.01 (2316)	7.94^{c}±0.05 (2084)	67.78^{c}±0.48 (2084)
4 (2011-2015)	1.81^{d}±0.01 (2083)	8.17^{d}±0.05 (1997)	70.72^{d}±0.50 (1997)
5 (2016-2020)	1.79^{e}±0.01 (1844)	7.98^{e}±0.05 (1788)	67.81^{c}±0.53 (1788)
Season of birth	**	**	**
Spring (Feb-March)	1.83^{a}±0.01 (3200)	7.90^{a}±0.04 (2899)	67.26^{a}±0.40 (2899)
Summer (April-June)	1.82^{b}±0.01 (950)	7.60^{b}±0.06 (800)	64.07^{b}±0.64 (800)
Monsoon (July-Aug)	1.81^{c}±0.02 (449)	7.39^{c}±0.09 (356)	62.03^{c}±0.97 (356)
Autumn (Sept-Oct)	1.78^{d}±0.01 (4334)	7.88^{d}±0.03 (4017)	67.66^{a}±0.35 (4017)
Winter (Nov-Jan)	1.81^{c}±0.01 (1080)	7. 94^{e}±0.06 (963)	67.87^{a}±0.61 (963)
Type of birth	**	**	**
Single	2.03^{a}±0.01 (3465)	8.67^{a}±0.04 (3169)	73.71^{a}±0.40 (3169)
Twin	1.83^{b}±0.01 (5936)	7.59^{b}±0.03 (5336)	63.90^{b}±0.32 (5336)
≥ Triplet	1.57^{c}±0.01 (612)	6.97^{c}±0.07 (530)	59.73^{c}±0.77 (530)
Sex of kids	**	**	**
Male	1.90^{a}±0.01 (5131)	8.13^{a}±0.04 (4622)	69.12^{a}±0.39 (4622)
Female	1.73^{b}±0.01 (4882)	7.36^{b}±0.04 (4413)	62.43^{b}±0.39 (4413)
Parity of doe's	*	*	*
Pa-1	1.68^{a}±0.01 (3062)	7.20^{a}±0.04 (2698)	61.09^{a}±0.47 (2698)
Pa-2	1.77^{b}±0.01 (2244)	7.58^{b}±0.05 (2039)	64.40^{b}±0.49 (2039)
Pa-3	1.83^{c}±0.01 (1629)	7.87^{c}±0.05 (1493)	67.01^{c}±0.53 (1493)
Pa-4	1.84^{d}±0.01 (1160)	7.85^{c}±0.06 (1048)	66.58^{c}±0.60 (1048)
Pa-5	1.87^{e}±0.01 (760)	8.05^{d}±0.07 (678)	68.55^{c}±0.72 (678)
Pa ≥ 6	1.87^{e}±0.01 (1158)	7.91^{e}±0.06 (1079)	67.04^{c}±0.58 (1079)
Dam's 90 day milk yield (litre)	*	*	*
≤ 45.0	1.75^{a}±0.01 (2905)	7.06^{a}±0.04 (2451)	58.74^{a}±0.47 (2451)
45.1-60.0	1.81^{b}±0.01 (2886)	7.74^{b}±0.04 (2776)	65.77^{b}±0.44 (2776)
60.1-75.0	1.81^{b}±0.01 (2296)	7.89^{c}±0.04 (2100)	67.46^{b}±0.47 (2100)
≥ 75.1	1.87^{c}±0.01 (1926)	8.28^{d}±0.05 (1708)	71.15^{c}±0.52 (1708)

**, Significant at $P<0.01$; *, Significant at $P<0.05$; ADG, Average daily weight gain (gram per day).

weight was partly explained by the climatic conditions and partly by variation in green and dry fodder offered to goats. The highest 3 month body weight in these kids was observed in winter and lowest in summer-born kids. Singh *et al.* (2009) and Andries (2013) also reported season as a significant and pronounced source of variation in kids' growth. Fluctuation in an ambient temperature between day and night and temperature extreme limits pre-disposes the kids for various infections and diseases and subsequently decrease in weight gain and an increase in mortality rate.

Season of birth also significantly ($P<0.05$) affected pre-weaning kids' survival. Kids born in monsoon (July–August) had the highest mortality followed by summer, winter, spring and lowest in autumn in this Barbari flock (Table 2). Higher mortality in monsoon and summer seasons might be due to inclement weather conditions (humidity, temperature and fluctuating climates even within a day) which might have put high stress on newly born and neo-natal kids. The 25 years mean monthly maximum temperature during summer reached 43.11°C and 41.41°C in May and June respectively. Climatic harshness and stress lower the immunity of kids and predisposes them to various infections/diseases and subsequent mortality. Similarly, the rainfall pattern in the study area showed that most of the rainfall occured in July (123.89 mm) and August (122.69 mm). The milk yield of goats was also drastically reduced during the rainy season, unlike other large ruminants. Moreover, all kind of infections and infestations was at their peak in the rainy season followed by summer and winter, thus neo-natal kids with very low passive immunity could not withstand infection arising from climatic stresses. Age × season interaction analysis also revealed that maximum mortality occurred up to 15 days in summer, monsoon, and winter-born kids. Maximum kids mortality of total pre-weaning was recorded in July followed by June, August, May, January, and December (Fig. 2). Kids with low to very low birth weight were more susceptible to such infections and infestations. The most comfortable months for kidding from

Table 2. Non-genetic factors affecting pre-weaning kids' mortality rate in Barbari kids

Factor	Pre-weaning survival performance of Barbari kids			
	Kids born (n)	Survive kids (n)	Kids died (n)	Mortality (%)
Overall mean	10013	9050	963	9.62
Period of birth				
1 (1995-2000)	1261	1073	188	14.91
2 (2001-2005)	2509	2095	414	16.50
3 (2006-2010)	2316	2085	231	9.97
4 (2011-2015)	2083	2003	80	3.84
5 (2016-2020)	1844	1794	50	2.71
$\chi^2_{8d.f.} = 20.00$, $P<0.05$				
Season of birth				
Spring (Feb-March)	3200	2900	300	9.38
Summer (April-June)	950	804	146	15.37
Monsoon (July-Aug)	449	361	88	19.60
Autumn (Sept-Oct)	4334	4021	313	7.22
Winter (Nov-Jan)	1080	964	116	10.74
$\chi^2_{8d.f.} = 20.00$, $P<0.05$				
Type of birth				
Single	3465	3169	296	8.54
Twin	5936	5351	585	9.86
≥ Triplet	612	530	82	13.40
$\chi^2_{4d.f.} = 12.00$, $P<0.05$				
Sex of kids				
Male	5131	4631	500	9.74
Female	4882	4419	463	9.48
$\chi^2_{2d.f.} = 2.00$, NS				
Parity (Pa) of doe's				
Pa-1	3062	2705	357	11.66
Pa-2	2244	2037	207	9.22
Pa-3	1629	1494	135	8.29
Pa-4	1160	1050	110	9.48
Pa-5	760	685	75	9.87
Pa ≥ 6	1158	1079	79	6.82
$\chi^2_{10d.f.} = 30.00$, $P<0.01$				
Kid's dam 90 day milk yield group (litre)				
Group 1 (≤ 45.0)	2905	2415	490	16.87
Group 2 (45.1-60.0)	2886	2680	206	7.14
Group 3 (60.1-75.0)	2296	2168	128	5.57
Group 4 (≥ 75.1)	1926	1787	139	7.21
$\chi^2_{6d.f.} = 12.60$, $P<0.05$				
Kids birth weight group				
1 (< 1.0 kg)	47	30	17	36.22
2 (1.0-1.5 kg)	2022	1703	319	15.78
3 (1.6-2.0 kg)	6086	5588	498	8.18
4 (2.1-2.5 kg)	1686	1577	109	6.46
5 (> 2.5 kg)	172	152	20	11.63
$\chi^2_{8d.f.} = 20.00$, $P<0.05$				
Kids age group				
1 (0-15 day)	10013	9513	500	4.99 (51.9)
2 (16-30 day)	9513	9330	183	1.92 (19.0)
3 (31-45 day)	9330	9248	82	0.88 (8.5)
4 (46-60 day)	9248	9194	54	0.58 (5.6)
5 (61-75 day)	9194	9122	72	0.78 (7.5)
6 (76-90 day)	9122	9050	72	0.79 (7.5)
$\chi^2_{8d.f.} = 24.00$, $P< 0.01$				

Significant at $P<0.01$; Significant at $P<0.05$.

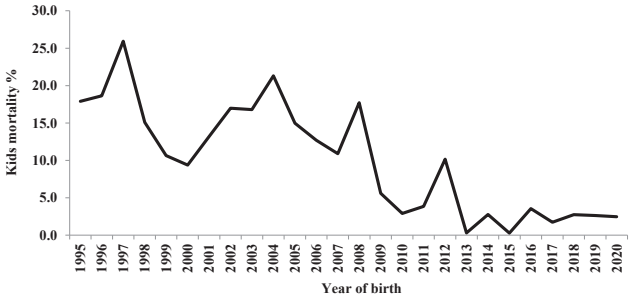

Fig. 1. Pre-weaning kids' mortality (%) in Barbari kids over the years (1995 to 2020).

a pre-weaning survivability point of view were September, October, November, February and March recorded with lower kids mortality of total pre-weaning mortality (Fig. 2). Season's effects on mortality were also reported by Husain *et al.* (1995) in Black Bengal, Singh *et al.* (2008) in Jamunapari, Subramaniyan *et al.* (2016) in Tellichery and Chauhan *et al.* (2019) in Sirohi kids.

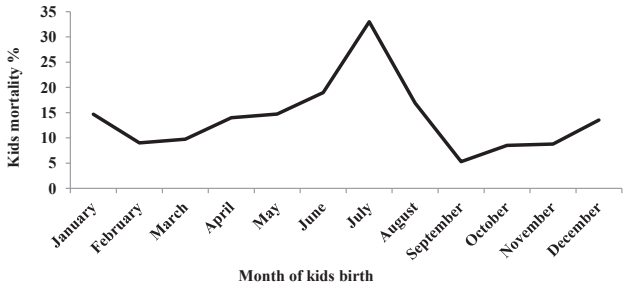

Fig. 2. Pre-weaning kids' mortality (%) in Barbari kids over the season (1995 to 2020).

Kids up to 75 days of age were grouped according to the season of birth at the fortnightly interval. Results indicated that very hot (summer) and hot-humid (monsoon) climate had a severe effect on pre-weaned kids' health and survivability up to the first 15 days followed by 16 days to 30th day of age. Highest survival was recorded in autumn followed by spring (Table 2). The effect of season on kids' mortality gets diluted and becomes very weak with the advancement of age. Significant effect of season of birth or inclement weather was also reported by Hailu *et al.* (2006) in Borana and Arsi- Bale goats.

Effect of parity on pre-weaning growth and mortality: The effect of parity was significant (P<0.01) on birth weight, litter size, weight gain and body weight at 3 months (Table 1). Kids born from primiparous goats were significantly (P<0.01) lighter in weight than multiparous goats. There was a linear association in birth weight of kids with the parity order, however, the magnitude of difference became quite narrow (small) after the 2nd parity, and almost similar trends in body weight at 3 months were observed for parity order. The average daily weight gain of kids born from primiparous goats was significantly (P<0.01) less but the magnitude of the difference was small and no consistent trend was observed with parity order. Similar results were also reported by Singh *et al.* (2009) and Rout *et al.* (2018).

The effect of parity on pre-weaning mortality was significant (P<0.05), however, the magnitude of parity was small in this flock and no pattern was observed with the increase in parity order (Table 2). Kids born from 1st parity showed the highest mortality followed by 5th. A higher incidence of mortality in 1st parity born kids might be due to their dam's physiological immaturity, ability to produce less milk and poor mothering ability. Moreover, parity × type of birth interaction revealed that multiple-born kids belonging to 1st parity have higher mortality than those born from multiparous does. Singh *et al.* (2008) and Chauhan *et al.* (2019) also reported high mortality in kids born from 1st parity doe. Thus, adequate feeding with balanced nutrition is of utmost importance during the entire gestation period to meet the growing demand of the fetus as well as the immature dam. These measures allow proper growth of the dam and fetus and make the dam able to produce sufficient colostrum and milk for kids. Whereas, slightly more mortality in 5th and 6th parity might be due to high incidences of multiple births (varied from 79 to 87% from 3rd to 6th parity) associated along with a low birth weight of kids.

Effect of dam's milk yield on pre-weaning growth and mortality: Effect of dam's milk yield was significant (P<0.05) source of variation in body weight at birth and 3 months of age. Doe's with less than 45 litres of milk in the first 90 days produced kids with significantly (P<0.01) less birth weight than their counterparts (Table 1). There was a linear association between milk yield and the body weight of kids at birth and 3 months. A similar trend was also obtained for average daily weight gain. The magnitude of difference in body weight at birth in 1st (< 45.0 L milk) and 4th milk yield group (>75.0 L) was 6.86% which increased to 17.28% at 3 months of age. The higher birth weight in high milk-yielding dams might be attributed to their higher parity order or more age because of physical maturity. Present results are in agreement with those reported earlier in Jamunapari goats (Singh *et al.* 2009).

Significantly (P<0.05) higher mortality was recorded in the group (Ist) with the lowest dam's milk yield (≤ 45), however, the mortality rate was also a little higher in dam's group (IVth) with highest milk yield >75 kg based on 90 days milk yield (Table 2). Doe's with less milk yield (< 45.0 L milk) might also produce less colostrum, which is essential for pre-natal kids' survival and growth. Doe's in their 1st parity have a comparatively small body size and body weight, and these could also be reasons for higher mortality in low milk yielding groups. The lower kids' mortality recorded in Groups 3, 2 and 4 indicated that optimum milk is necessary not only for growth but also for the survival of kids. However, slightly high mortality in highest milk - yielding goats (IVth) was attributed to higher incidences of diarrhea in kids on account of over suckling and partial digestion of casein of milk and resulting in scouring due to hind-gut fermentation. Thus, kids from very high milk-yielding doe's should be properly monitored during suckling to avoid extra feeding/suckling of milk as it leads to indigestion of casein and results in scouring due to hindgut fermentation. Similar results were

also reported by Husain *et al.*(1995), Singh *et al.* (2008), Subramaniyan *et al.* (2016) and Chauhan *et al.* (2019). Advance pregnant and lactating goats should be provided adequate and nutritious concentrate to obtain proper birth weight and sufficient milk to nourish their kids.

Effect of sex on pre-weaning growth and mortality: The effect of sex was significant (P<0.01) for all growth traits (Table 1). Males were heavier at birth, grew faster than females due to better AWG. The magnitude of differences between males and females at birth was 9.82%, which was also maintained (10.45%) at weaning. Higher pre-weaning growth in males is attributed to mainly the influence of their hormones as an androgen in males is associated with better skeletal growth. The average pre-weaning weight gain remains high in males to their counterparts to the tune of almost 10.70%. Present results were comparable to the finding of Turkson *et al.* (2004) and Singh *et al.* (2009). The χ^2 analysis revealed a non-significant effect of sex on pre-weaning mortality (Table 2).

Effect of type of birth on pre-weaning growth and mortality: Effect of type of birth was significant on body weight at birth, 3 months and AWG. Single-born kids were significantly (P<0.01) heavier at birth and 3 months than twin and triplet-born kids (Table 1). The magnitude of differences in body weight between single and twin-born kids and between singles and triplets at birth was 10.93 and 29.30%, respectively. This difference gradually became 14.23 and 24.39% at 3 months of age. The average daily weight gain was also higher in singles by 15.35% than twins and by 23.4% higher than in triplet kids. Present results were in agreement with those reported by Singh *et al.* (2009) and Andries (2013).

The χ^2 analysis revealed a significant (P<0.05) effect of type of birth on pre-weaning mortality (Table 2). The kids born as multiples showed higher (P<0.01) mortality than single-born kids. Multiple births are in general associated with low birth weights. It may be, therefore, suggested that special care during suckling/feeding, cleanliness, and protection from climatic fluctuations be followed most sincerely up to 15 days of age, especially for kids with low birth weights. If a dam is not able to meet the milk requirement of their kid(s), another doe preferably of a similar stage may be allowed to feed such kids. Higher kids mortality in multiple-born kids was reported by Hailu *et al.* (2006), Singh *et al.* (2008), Subramaniyan *et al.* (2016) and Chauhan *et al.* (2019) in kids of different breeds.

Effect of body weight at birth on pre-weaning mortality: The birth weight of kids is one of the most important factors (P<0.05) substantially affecting kids' survivability. Kids with lower birth weight, mainly from <1.0 kg and ≥ 1.0 to 1.5 kg birth weight groups showed maximum mortality (Table 2). However, kids with >2.5 kg birth weight also showed higher than average pre-weaning mortality which might be due to diarrhea as a result of excess milk suckling thus, care of kids for the first 15–20 days is very important for proper feeding of milk. The other reason for the low survivability of kids with >2.5 kg body weight could be due to inadequate milk of those dams belonging to 1st parity or that produced twins. A similar result was also reported by Husain *et al.* (1995), Singh *et al.* (2008), Subramaniyan *et al.* (2016) and Chauhan *et al.* (2019). Proper doe feeding during pregnancy is necessary for proper growth and development of the fetus and mammary system. Results indicated that an increase in kids' birth weight conclusively decreases the pre-weaning mortality rate in kids.

Age × body weight interaction analysis revealed that the risk of mortality of low birth weight born kids remained very high up to the first 15 days as maximum mortality (51.9% of total pre-weaning) occurred in the first 15 days followed by 16 to 30 days age group (Table 2). The major reasons for high mortality in low birth weight born kids were the low level of immunity on account of reduced adipose tissue and loss of body temperature due to larger surface area in low weight kids as compared to heavier ones. Such kids died early due to their weak resistance to infectious diseases and harsh climates. Therefore, proper feeding of doe during late gestation, hygienic kidding followed by prompt colostrum feeding and sanitized housing were important to reduce the risk of mortality of newly born kids, especially with less birth weight.

Effect of age on pre-weaning mortality: The χ^2 analysis revealed a significant effect (P<0.01) of age on mortality and an almost linear association was observed in kids' survival with the advancement in age (Table 2). Thus, the first 15 days after birth were the most critical period from kids' survival and care point of view, as maximum loss (51.9% of total losses) occurred in the first 15 days of birth, followed by 16–30 days (19.0% of total losses). Higher mortality up to one month of age was due to more susceptibility of newly born kids for infectious diseases as the immunity status of these kids remains very low. Similar results were also reported by Singh *et al.* (2008) and Subramaniyan *et al.*(2016).

Overall, the data of the present study demonstrates the significant effect of non-genetic factors [period (year), season (month), type of birth, sex of kid, parity and milk yield of the dam] on birth, 3-month weight, pre-weaning ADG and pre-weaning mortality of Barbari kids under a semi-intensive management system.

The present results showed that non-genetic factors pronouncedly affect birth weight and 3-month body weight, average daily weight gain and pre-weaning survival of kids in Barbari goats. Judicious breeding and healthcare strategies may play an important role to increase kids growth and survival performance such as body weight of females at first service and kidding, adequate and nutritious concentrated feeding during pregnancy and lactation period, breeding of doe in autumn and summer season and more selection pressure to increase birth weight. To maximize the pre-weaning survival of kid's, adequate care is suggested for the first 15 days. Kids born in harsh and stressful seasons, with lesser milk yield of doe and lesser birth weight need special attention up to one month of age. Age-specific management practices such as care for

overcrowding, over or low milk suckling, clean and dry housing of kids specifically with well protection against inclement weather conditions, timely colostrum and milk feeding should be implemented. Health measures like deworming, vaccination of doe and kids, and grazing of kids in low burden land also help in minimizing kids morbidity and mortality.

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