Effect of non-genetic factors on pre-weaning and post-weaning survival of Malpura lamb

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Journal of Livestock Science (ISSN online 2277-6214) 17: 967-976
Received on 12/1/26; Accepted on 30/10/26; Published on 6/11/26
doi. 10.33259/JLivestSci.2026.967-976

Abstract

Lamb survival is a critical aspect of sheep production, directly influencing the economic returns of sheep farmers. This study investigated the effects of non-genetic factors on pre- and post-weaning mortality in Malpura sheep using records from three age groups: 0–3 months (S1 phase), 3–6 months (S2 phase), and 6–12 months (S3 phase), covering the period from 2001 to 2024. Data were collected from Malpura sheep maintained under the Mega Sheep Seed Project at the Animal Genetics and Breeding Division, ICAR–Central Sheep and Wool Research Institute, Avikanagar, Rajasthan. The effects of period of lambing, season of lambing, sex of lamb, type of birth, dam weight at lambing, and lamb birth weight on mortality were investigated. Data were analyzed using cross-tabulation, and the significance of associations was assessed using the chi-square test in SPSS version 25.0. Survival probabilities were estimated using the Kaplan–Meier product-limit method. The observed mortality rates in the S1, S2, and S3 phases were 7.67%, 2.68%, and 2.16%, respectively. Period, season, and birth weight had highly significant effects ($P < 0.01$) on mortality across all three age groups. Type of birth and dam weight at lambing had highly significant effects ($P < 0.01$) in the S1 and S2 phases but non-significant effects in the S3 phase. Sex had a significant effect on mortality in the S1 phase ($P < 0.05$) and a highly significant effect in the S3 phase ($P < 0.01$), but its effect was non-significant in the S2 phase. Male lambs exhibited higher mortality than female lambs, while lambs with higher birth weights and those born to heavier dams generally showed better survival. Single-born lambs had lower mortality than twins and triplets, and mortality was generally higher among lambs born during winter. Pneumonia was the leading cause of mortality during the post-weaning phases, accounting for 30.71% and 26.00% of deaths in the S2 and S3 phases, respectively. During the pre-weaning phase, septicaemia/ toxaemia was the most frequently recorded cause of death (24.73%), followed by pneumonia (21.91%). These findings highlight the importance of appropriate nutritional and health management, particularly during the early stages of life and winter, to improve lamb survival in Malpura sheep.

Keywords: Malpura sheep, weaning, pneumonia, survival, septicaemia, mortality

Introduction

Small ruminants, particularly sheep, play an important role in both temperate (Martinez et al., 2012) and tropical (Djimon et al., 2024) livestock production systems . In India, sheep contribute substantially to the rural economy, particularly in semi-arid regions, by providing meat, wool, skin, and other by-products (Gowane et al., 2018; Saravanan et al., 2021). India has 46 recognized sheep breeds (NBAGR, 2023), and sheep production plays a pivotal role in supporting rural livelihoods. Rajasthan is one of the major sheep-producing states in India, where eight important breeds—Malpura, Magra, Chokla, Jaisalmeri, Marwari, Sonadi, Pugal, and Nali—are reared. Malpura sheep are an indigenous medium- to heavy-sized mutton breed known for their adaptability to harsh environmental conditions and potential for meat production, although their coarse wool has limited commercial value. Successful lamb rearing is essential for profitable sheep production because it ensures the availability of replacement animals and supports the maintenance of productive flocks. Pre-weaning lamb mortality is a major concern in the livestock industry, resulting in substantial economic losses. Numerous studies have investigated lamb mortality and have consistently reported higher mortality rates in young lambs than in adult sheep (Gowane et al., 2018; Flinn et al., 2020). Globally, lamb mortality rates have been reported to range from 10% to 30%, resulting in considerable economic losses to sheep producers (Swarnkar et al., 2019; Flinn et al., 2020).

Survival analysis has been widely used to investigate genetic and non-genetic factors affecting lamb survival in different sheep breeds, including Romney sheep (Everett-Hincks et al., 2014), Iranian Kermani sheep (Barazandeh et al., 2012), Ethiopian sheep (Getachew et al., 2015), Deccani sheep (Bangar et al., 2016), Awassi sheep (Abdelqader et al., 2017; Inal et al., 2021), Dorper × Tumele sheep (Tesema et al., 2020), Mecheri sheep (Balasundaram et al., 2021), and Harnali sheep (Gaur et al., 2022).

Ensuring lamb survival is a primary concern in sheep production systems. Against this background, the present study investigated lamb survival in Malpura sheep maintained under farm conditions in the semi-arid region of Rajasthan. The primary objective was to identify the non-genetic factors associated with pre- and post-weaning mortality in Malpura lambs. The findings are expected to provide useful insights into improving lamb survival and optimizing sheep management practices.

Materials and Methods

Location of the study and management of the animals

The study was conducted at ICAR–Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India, located at 75°28′ E longitude and 26°17′ N latitude, at an altitude of 320 m above mean sea level. The region has a semi-arid, subtropical climate, with annual extreme temperatures ranging from approximately 4°C to 45°C. Mean annual rainfall during the study period was 615.93 mm. The animals were maintained under a semi-intensive management system. The flock was closed, with approximately 300 breeding ewes maintained over the study period. At lambing, the weights of the lambs and their dams, date of lambing, sex of the lamb, and type of birth were recorded. After birth, lambs remained with their dams for approximately 3–5 days. From the second week of age until weaning at three months, lambs were separated from their dams during the daytime while the ewes grazed in the pasture. Lambs were allowed to suckle twice daily and remained with their dams in the shed at night. After weaning, male and female lambs were housed separately. In addition to 8–10 hours of grazing and dry fodder supplementation, a concentrate mixture was provided according to age, sex, and physiological or production stage. During periods of fodder scarcity, green fodder, including oats and pearl millet (bajra), was supplied as required. Lambing generally occurred during two periods: January–March (spring) and August–September (autumn). Vaccination against enterotoxaemia and sheep pox was carried out annually, whereas vaccination against peste des petits ruminants (PPR) was administered once every three years. Deworming was performed annually during the monsoon season. Other routine management practices included housing, feeding, health care, and general flock management.

Data collection and analysis

Data were obtained from the database of Malpura sheep maintained under the Mega Sheep Seed Project at ICAR–Central Sheep and Wool Research Institute, Avikanagar, Rajasthan. Records covering the period from 2001 to 2024 were classified into three age-specific phases: birth to 3 months (S1), 3–6 months (S2), and 6–12 months (S3). The numbers of records available for the S1, S2, and S3 phases were 6,012, 5,224, and 4,634, respectively. The non-genetic factors investigated included period of lambing, season of lambing, sex of lamb, type of birth, dam weight at lambing, and lamb birth weight. The study period was divided into six periods: P1 (2001–2004), P2 (2005–2008), P3 (2009–2012), P4 (2013–2016), P5 (2017–2020), and P6 (2021–2024). Season of lambing was classified as winter

$$S_t = \Pi_{t_i \le t}\left(1 - \frac{d_i}{n_i}\right)$$

(November–January) or other seasons (February–October). Sex was classified as male or female, and type of birth as single, twin, or triplet. Dam weight at lambing was classified into four categories: ≤30 kg, >30–35 kg, >35–40 kg, and >40 kg. Lamb birth weight was classified into three categories: ≤3.0 kg, >3.0–3.5 kg, and >3.5 kg. The survival time was estimated in terms of product-limit method of Kaplan and Meier (1958).

Where t_i is the duration of study at any point i. d_i and n_i refer to the mortality up to point i and number of individuals at r is k just prior to t_i(Kaplan and Meier,1958).

Mortality percentages were calculated separately for the three age-specific phases. The causes of death were expressed as percentages of the total deaths recorded within each phase. Associations between non-genetic factors and mortality were evaluated using the least square analysis in SPSS version 25.0. Survival probabilities were estimated using the Kaplan–Meier product-limit method (Kaplan and Meier, 1958). Survival analysis was performed using the *survival* package (Therneau et al., 2000; Therneau, 2022) in R version 4.1.2 (R Core Team, 2021). Survival curves were generated using the *ggfortify* package (Tang et al., 2016; Horikoshi and Tang, 2016). The survival analysis accounted for right censoring, including exits from the flock for reasons other than death, where appropriate. This also included the animals that were alive at the end of weaning period. Adjustments for left truncation were applied to the post-weaning phases.

Results

Survival analysis

Lamb mortality is a major source of economic loss in sheep production because it reduces the number of animals available for replacement and limits the number of lambs reaching marketable age. Following birth, lambs face several physiological, behavioural, and immunological challenges that may affect neonatal survival (Dyer et al., 2016). In the present study, the numbers of exits due to death and other causes in the S1, S2, and S3 phases were 461 and 23, 140 and 589, and 100 and 867, respectively. The corresponding observed mortality rates were 7.67%, 2.68%, and 2.16%, while the proportions of records classified as censored were 92.33%, 97.32%, and 97.84%, respectively (Table 1). During the S1 phase, 461 deaths were recorded among 6,012 lambs, corresponding to a mortality rate of 7.67%. The observed mortality rate was lower during the S2 and S3 phases, at 2.68% and 2.16%, respectively. The numbers and categories of exits for reasons other than death are presented in Table 2.

Kaplan–Meier curve for birth to weaning (S1)

The observed mortality rate from birth to weaning was 7.67% (Table 1). The Kaplan–Meier survival curve for this phase (Figure 1) showed a steep decline in survival during the early postnatal period. Approximately 39.94% and 60.33% of the total deaths recorded during the S1 phase had occurred by the end of the first and second weeks after birth, respectively. The curve indicated a sharp initial decline in survival, followed by a more gradual, nonlinear decrease.

Table 1. Summary of mortality and censoring statistics

Traits/Age groups	Culling	Slaughter	Sold	Transfer	Missing	Total
Birth-3 months (S1)	13	-	-	9	1	23
3-6 months(S2)	245	11	215	118	-	589
6-12 months(S3)	169	47	341	310	-	867

Table 2. Exits due to other reasons

Traits/Age groups	Exits due to death (A)	Exits due to other reasons (Details in the Table2) (B)	Total exits(C)	Censored records (D)	Total number of records (E) (A+D)	Mortality % (F) [(A/E)*100]	Censoring %(G) [(D/E)*100]
Birth-3months (S1)	461	23	484	5551	6012	7.67	92.33
3-6 months (S2)	140	589	729	5084	5224	2.68	97.32
6-12 months (S3)	100	867	967	4534	4634	2.16	97.84

Table is showing different reasons of exits of animals other than death.

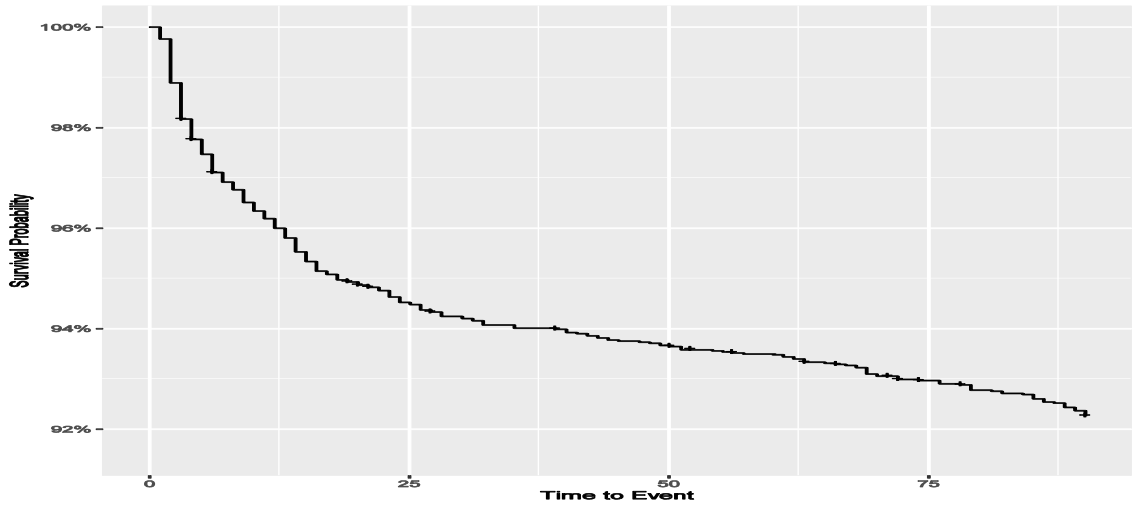


Figure 1. Kaplan–Meier survival curve for Malpura lambs from birth to weaning (0–3 months)

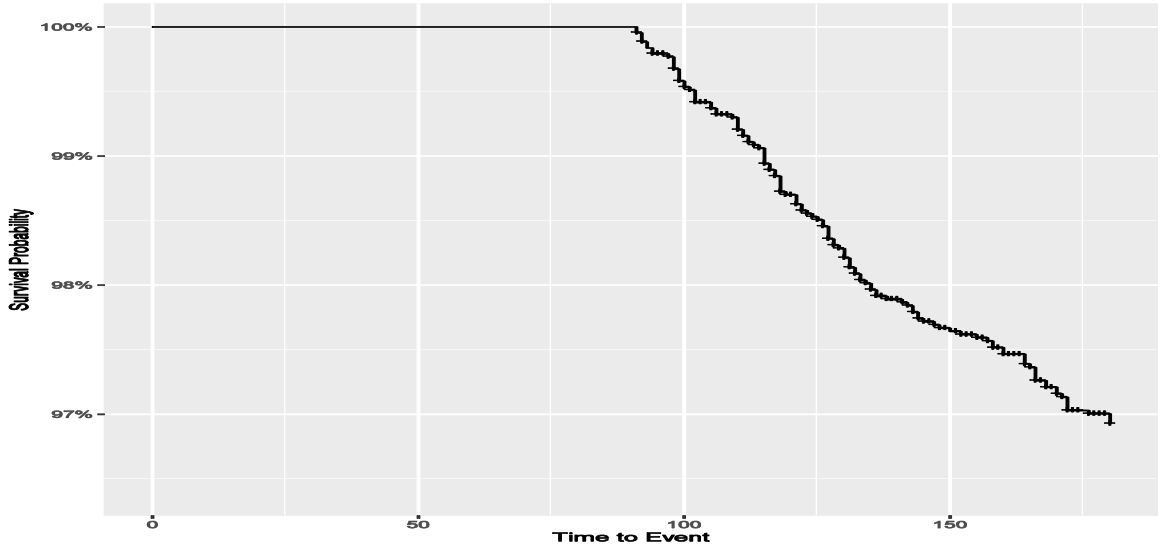


Figure 2. Kaplan–Meier survival curve for Malpura lambs from weaning to six months of age (3–6 months), accounting for left truncation.

Kaplan–Meier curve of weaning to six months (S2)

During the S2 phase, the observed mortality rate was 2.68%, while 97.32% of records were classified as censored (Table 1). The Kaplan–Meier survival curve for the period from weaning to six months is presented in Figure 2. The curve showed a gradual decline in survival over this period. Left truncation was accounted for in the analysis, and the horizontal segment represented the period before individuals entered the risk set.

Kaplan–Meier curve of six to twelve months (S3)

During the S3 phase, the observed mortality rate was 2.16% (Table 1). The Kaplan–Meier survival curve for the period from six to twelve months is presented in Figure 3. After accounting for left truncation, the curve showed a gradual decline in survival throughout the observation period. As in the S2 phase, the horizontal segment represented the period before individuals entered the risk set.

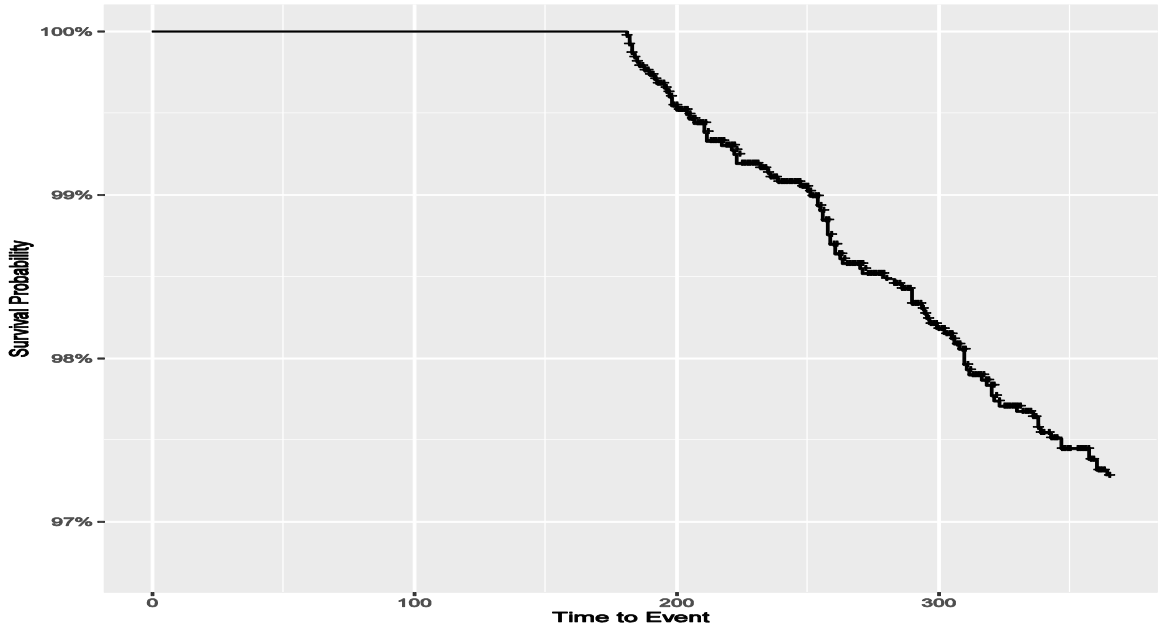


Figure 3. Kaplan–Meier survival curve for Malpura sheep from six to twelve months of age (6–12 months), accounting for left truncation.

Discussion

Effect of non-genetic factors on lamb mortality

Effect of period of birth at lambing

The period of lambing had a highly significant effect ($P < 0.01$) on mortality in all three age groups (S1, S2, and S3; Table 3). During the S1 phase, mortality rates for periods P1 to P6 were 5.08%, 8.45%, 8.69%, 3.70%, 9.58%, and 8.78%, respectively. The highest mortality rate occurred during P5 (2017–2020), whereas the lowest was recorded during P4 (2013–2016). The elevated mortality during P5 was associated with a severe disease outbreak that occurred in early February 2018. The causative agent was initially unidentified but was subsequently confirmed to be *Pasteurella*, accompanied by multisystem organ dysfunction associated with *Clostridium* species. During the S2 phase, mortality rates across P1–P6 were 1.84%, 3.89%, 4.87%, 1.07%, 3.84%, and 1.84%, respectively. The highest mortality occurred during P3, while the lowest occurred during P4. During the S3 phase, mortality rates were 2.85%, 4.56%, 2.09%, 1.04%, 2.66%, and 0.87%, respectively, with the highest rate observed during P2 and the lowest during P6. Bangar et al. (2022) reported higher mortality during earlier periods of observation, particularly 2001–2004 and 2005–2008, than during subsequent periods. Differences in mortality between periods may reflect changes in management, feeding practices, environmental conditions, disease occurrence, and other time-dependent factors affecting flock health and survival.

Effect of season of lambing

Season of lambing had a highly significant effect ($P < 0.01$) on mortality in all three age groups (Table 3). During the S1 phase, mortality was higher among lambs born in winter (8.49%) than among those born during the other seasons (5.58%). A similar pattern was observed during the S2 phase, with mortality rates of 3.19% and 2.00% for winter-born lambs and lambs born during other seasons, respectively. During the S3 phase, mortality was also slightly higher among winter-born lambs (2.22%) than among lambs born during other seasons (1.99%).

These findings indicate that winter-born lambs experienced higher mortality across all three age groups. Exposure to low temperatures and wind chill, particularly during the neonatal period, may contribute to reduced survival. Raghavendra et al. (2017), in an epidemiological survey of lamb mortality in the Rayalaseema region of Andhra Pradesh, reported a similar influence of season. Swarnkar et al. (2018) also reported an association between increasing wind chill and lamb mortality. However, seasonal effects on lamb survival vary among production systems.

Table 3. Effect of non-genetic factors of lamb survivability on pre-weaning and post weaning period of Malpura Sheep

Factor	Birth-3months (S1)		3-6months (S2)		6-12months (S3)	
	No. of animal	No. died%	No. of animal	No. died%	No. of animal	No. died%
Overall	**6012**	**461(7.67)**	**5224**	**140(2.68)**	**4634**	**100(2.16)**
Period	**		**		**	
P1(2001-2004)	689	35(5.08)	653	12(1.84)	632	18(2.85)
P2(2005-2008)	852	72(8.45)	771	30(3.89)	702	32(4.56)
P3(2009-2012)	702	61(8.69)	637	31(4.87)	575	12(2.09)
P4(2013-2016)	974	36(3.70)	937	10(1.07)	868	9(1.04)
P5(2017-2020)	1462	140(9.58)	808	31(3.84)	713	19(2.66)
P6(2021-2024)	1333	117(8.78)	1418	26(1.84)	1144	10(0.87)
Season	**		**		**	
W(Nov-Jan)	4310	366(8.49)	3825	122(3.19)	3476	77(2.22)
O(Feb-Oct)	1702	95(5.58)	1399	28(2.00)	1158	23(1.99)
Sex of lamb	*		NS		**	
Male	3023	241(7.97)	2623	84(3.20)	2074	62(2.98)
Female	2989	220(7.36)	2601	56(2.15)	2560	38(1.48)
Type of birth		**	**		NS	
Single	5373	387(7.20)	4617	113(2.44)	4142	87(2.10)
Twin	584	61(10.44)	573	27(4.71)	466	12(2.57)
Triplet	55	13(23.63)	34	-	26	1(3.84)
Ewe wt at lambing (kg)	**		**		NS	
≤30	1902	187(9.83)	1507	37(2.45)	1154	26(2.25)
>30≤35	2623	173(6.60)	2379	63(2.64)	2175	44(2.02)
>35≤40	1128	76(6.74)	1015	28(2.75)	994	21(2.11)
>40	359	25(6.96)	323	12(3.71)	311	9(2.89)
Birth wt at lambing (kg)	**		**		**	
≤3.0	2174	263(12.10)	1870	56(2.99)	1468	42(2.86)
>3≤3.5	2148	129(6.01)	1894	53(2.79)	1756	31(1.76)
>3.5	1690	69(4.08)	1460	31(2.12)	1410	22(1.56)

* = $p < 0.05$; ** = $p < 0.01$; NS = non-significant ($p > 0.05$)

Soundarajan (2014) and Mane (2015) reported higher mortality during summer than during winter or the rainy season, whereas Bangar et al. (2016) and Woldemariam (2014) reported higher mortality during the rainy season. These differences suggest that the effect of season may depend on local climatic conditions, lambing management, disease prevalence, and the availability of feed and shelter.

Effect of sex of lamb

Sex had a significant effect on mortality during the S1 phase ($P < 0.05$) and a highly significant effect during the S3 phase ($P < 0.01$), whereas its effect during the S2 phase was non-significant (Table 3). During the S1 phase, mortality was 7.97% in males and 7.36% in females. During the S2 phase, the corresponding rates were 3.20% and 2.15%, respectively. During the S3 phase, mortality was 2.98% in males and 1.48% in females. Thus, mortality was consistently higher in male lambs than in female lambs across all three phases.

These findings are consistent with previous studies reporting higher mortality among male lambs than female lambs (Binabaj et al., 2013; Bangar et al., 2016, 2022; Gowane et al., 2020; Gaur et al., 2022). However, Mustafa et al. (2014), and Raghavendra et al. (2017) reported higher mortality among female lambs in their respective study populations. The higher mortality observed among male lambs may be associated with sex-related differences in physiology, growth, or susceptibility to disease, although the mechanisms underlying these differences require further

investigation (Mandal et al., 2007). A similar pattern has been reported in Sirohi goats, in which male kids exhibited higher mortality than females (Chauhan et al., 2019).

Effect of type of birth

Type of birth had a highly significant effect ($P < 0.01$) on mortality during the S1 and S2 phases but a non-significant effect during the S3 phase (Table 3). During the S1 phase, mortality was highest among triplet-born lambs (23.63%), followed by twins (10.44%) and single-born lambs (7.20%). During the S2 phase, mortality was 2.44% among single-born lambs and 4.71% among twins; no deaths were recorded among the 34 triplet-born lambs in this phase. During the S3 phase, mortality was 2.10%, 2.57%, and 3.84% among single-, twin-, and triplet-born lambs, respectively.

The higher mortality observed among multiple-born lambs may be related to competition for milk, lower individual milk intake, and differences in maternal care. Single-born lambs may receive more colostrum and milk than their multiple-born counterparts, potentially improving their immunity and early growth. Similar associations between type of birth and lamb mortality have been reported by Mousa-Balabel (2010), Binabaj et al. (2013), and Woldemariam et al. (2014).

Effect of dam weight at lambing

Dam weight at lambing had a highly significant effect ($P < 0.01$) on mortality during the S1 and S2 phases, whereas its effect during the S3 phase was non-significant (Table 3). During the S1 phase, mortality was highest among lambs born to dams weighing ≤30 kg (9.83%) and lowest among those born to dams weighing >30–35 kg (6.60%). During the S2 phase, mortality ranged from 2.45% among lambs born to dams weighing ≤30 kg to 3.71% among lambs born to dams weighing >40 kg. These results indicate that the association between dam weight and lamb mortality was not uniform across all weight categories or age groups. Chauhan et al (2019) and Swarnkar et al. (2019) reported an association between ewe body weight and lamb survival. Adequate nutrition of ewes can improve reproductive performance and support maternal body condition and lamb birth weight, potentially reducing lamb mortality. Gowane et al. (2018, 2020) also reported that lower dam body weight was associated with poorer lamb survival. Swarnkar et al. (2019), in a study of Malpura sheep, reported substantially higher mortality among lambs born to ewes weighing less than 20 kg than among those born to heavier ewes. Collectively, these findings highlight the importance of maintaining adequate maternal body condition and nutritional status. However, the present results should be interpreted in the context of the observed mortality patterns across individual dam-weight categories.

Effect of lamb birth weight

Lamb birth weight had a highly significant effect ($P < 0.01$) on mortality during all three phases (S1, S2, and S3; Table 3). During the S1 phase, mortality was highest among lambs weighing ≤3.0 kg at birth (12.10%) and lowest among those weighing >3.5 kg (4.08%). During the S2 phase, mortality rates in these two categories were 2.99% and 2.12%, respectively. Similarly, during the S3 phase, mortality was 2.86% among lambs weighing ≤3.0 kg at birth and 1.56% among those weighing >3.5 kg. Overall, higher birth weight was associated with lower observed mortality across the three age groups.

These findings agree with previous studies identifying birth weight as an important determinant of lamb survival (Dwyer, 2008; Mousa-Balabel, 2010; Bangar et al., 2016; Abdelqader et al., 2017; Hinch and Brien, 2014; Gaur et al., 2022). Lambs with low birth weights may have reduced vigour, impaired thermoregulation, and a lower ability to obtain sufficient colostrum, increasing their susceptibility to hypothermia and infectious diseases such as pneumonia and septicaemia. Adequate colostrum intake and effective maternal care are therefore essential for neonatal survival. Similar findings have been reported in Lori-Bakhtiari sheep (Vatankhah and Talebi, 2009), Sangsari sheep (Lima et al., 2019), and Avikalin, Chokla, and Malpura sheep (Gowane et al., 2018). However, extremely high birth weights may also increase the risk of dystocia and neonatal mortality. Sawalha et al. (2007) and Binabaj et al. (2012) therefore recommended selecting for an optimum birth weight rather than simply maximizing birth weight. Abdelqader et al. (2017) also reported an increased risk of early mortality among Awassi lambs with birth weights of 4–5 kg. Bangar et al. (2022) observed that the highest proportion of mortality occurred among lambs with a birth weight of less than 3 kg compared with their heavier counterparts. Thus, lamb survival may depend on an appropriate birth-weight range that balances neonatal vigour against the risks associated with excessive birth weight.

Causes of mortality and their percentage contributions

The distribution of causes of death differed across the three age-specific phases (Table 4). During the S1 phase, septicaemia/toxaemia was the most frequently recorded cause of death, accounting for 24.73% of deaths, followed by pneumonia (21.91%), hepatitis (12.36%), and enteritis (8.46%). These findings are consistent with those of Swarnkar et al. (2019), who investigated lamb mortality in Malpura sheep. Mandal et al. (2007) also identified pneumonia as an important cause of early lamb mortality, particularly during the first 15 days after birth. During the post-weaning phases, pneumonia was the leading individually specified cause of death, accounting for 30.71% of

Table 4. Causes of overall pre-weaning, post-weaning and overall mortality and their % contribution in Malpura sheep

Cause	Birth-3months (S1)	3-6months (S2)	6-12months (S3)
	died%	died%	died%
No of died	**461(7.67)**	**140(2.68)**	**100(2.16)**
Asphyxia	-	-	2(2.0)
Acidosis	1(0.22)	-	-
Atresia ani	3(0.65)	-	-
Autolysed change	**30(6.51)**	**12(8.57)**	**6(6.0)**
Bloat	-	-	5(5.0)
Chronic enteritis JD	5(1.08)	4(2.86)	-
Cold exposure	4(0.87)	-	-
Cystitis	4(0.87)	-	3(3.0)
Enteritis	**39(8.46)**	**7(5.43)**	**6(6.0)**
Hepatitis	**57(12.36)**	**3(2.14)**	**6(5.0)**
Haemorrhagic- enteritis	6(1.30)	-	**5(5.0)**
Hypothermia	5(1.08)	-	-
Impaction	2(0.43)	3(2.14)	1(1.0)
Inanition	18(3.90)	-	-
Internal hemorrhage	8(1.74)	4(2.86)	1(1.0)
Intestinal torsion	-	2(1.43)	2(2.0)
Neonatal death	7(1.52)	-	-
Nephritis	4(0.87)	-	-
Peritonitis	3(0.65)	2(1.43)	-
Pneumonia	**101(21.91)**	**43(30.71)**	**26(26.0)**
Red gut	1(0.22)	-	2(2.0)
Ruminitis	5(1.08)	-	
Septicemia /toxemia	**114(24.73)**	**8(5.71)**	**10(10.0)**
Shock	7(1.52)	-	3(3.0)
Stomach rapture	7(1.52)	-	-
Stunted growth	6(1.30)	6(4.29)	-
Tetanus	2(0.43)	-	-
Urolithiasis	-	7(5.00)	-
Others(JD, predation ,infection, etc)	**22(4.77)**	**39(27.86)**	**22(22.0)**

deaths during the S2 phase and 26.00% during the S3 phase. Septicaemia/toxaemia accounted for 5.71% and 10.00% of deaths during the S2 and S3 phases, respectively. Other recorded causes included enteritis, hepatitis, autolysed changes, and miscellaneous conditions. The predominance of septicaemia/toxaemia and pneumonia during the early stages of life highlights the importance of appropriate neonatal care, adequate colostrum intake, hygiene, timely disease recognition, and effective veterinary intervention. The relatively high contribution of pneumonia during the post-weaning phases also emphasizes the need for continued health monitoring after weaning.

Conclusion

The present study identified several non-genetic factors associated with lamb mortality in Malpura sheep. Mortality was highest during the pre-weaning phase, particularly during the first two weeks after birth. Period and season of lambing, sex, type of birth, dam weight at lambing, and lamb birth weight were associated with mortality to varying degrees across the three age groups. Winter-born lambs, male lambs, multiple-born lambs, and lambs with lower birth weights generally exhibited higher mortality. Septicaemia/toxaemia was the leading recorded cause of pre-weaning mortality, whereas pneumonia was the most frequently recorded cause of death during the post-weaning phases.

Reducing lamb mortality requires improved nutritional management of pregnant and lactating ewes, prompt assistance and monitoring around lambing, adequate colostrum intake, and early detection and treatment of disease. Providing clean, sheltered lambing pens and additional protection during winter may help reduce exposure to cold stress and infectious agents. Supplementary milk should be provided when maternal milk intake is inadequate. Continued health monitoring after weaning is also important, particularly for lambs with low birth weights or those born as twins or triplets. Implementation of these management practices may improve lamb survival and contribute to greater productivity in Malpura sheep flocks.

Acknowledgement

The author gratefully acknowledges the Animal Genetics and Breeding Division of the Central Sheep and Wool Research Institute for providing data on Malpura sheep under the Network Project on Sheep Improvement and also "Research was supported by the lndian Council of Agricultural Research, Department of Agricultural Research and Education, Government of lndia".

References

1) Abdelqader, A., Irshaid, R,, Tabbaa, M. J,, Abuajamieh, M., Titi, H., Al-Fataftah, A.R. (2017). Factors influencing Awassi lambs survivorship under fields conditions. Livestock Science. 199(**5**):1-6.https://doi.org/10.1016/j.livsci.2017.03.007

2) Balasundaram, B., Thiruvenkadan, A. K., Mural, N., Muralidharan, J. and Cauveri, D. (2021). Potential Hazardous Factors Affecting Survival of Mecheri Lambs. Biological Forum – An International Journal. 13**(4)**: 392-397.

3) Bangar, Y. C., Pachpute, S.T. and Nimase, R.G. (2016). The survival analysis of the potential risk factors affecting lamb mortality in Deccani sheep. Journal of Dairy Veterinary Animal Research. 4**(2)**: 266-270.

4) Barazandeh, A., Molaei Moghbeli, S., Vatankhah, M. and Ghavi Hossein-Zadeh, N. (2012). Lamb survival analysis from birth to weaning in Iranian Kermani sheep. Tropical Animal Health and Production. 44**(10)**: 929-934.

5) Binabaj, F.B., Tahmoorespur, M., Aslaminejad, A.A., Vatankhah M. (2013).The investigation of non-genetic factors affecting survival of Karakul lambs from birth to one year of age using linear and nonlinear models. Small Ruminants Research. 113**(1)**: 34-39

6) Chauhan, I. S., Misra, S. S., Kumar, A. and Gowane, G. R. (2019). Survival analysis of mortality in pre-weaning kids of Sirohi goat. Animal. 13**(12)**: 2896-2902

7) Djimon, A.M., Offoumon, O.T.L.F., Worogo, H.S.S., Worogo, J.S.B.S., Alabi, C.A.D., Idrissou, Y., Soulé, F., Alimi, N., Yacoubou, A.M., Assani, A.S. 2024. Profitability of sheep farming in Benin. Journal of Livestock Science 15: 267-275 doi. 10.33259/JLivestSci.2024.267-275

8) Dyer, C M., Conington, J., Corbiere, F., Holmoy, I.H., Muri, K., Nowak, R., Rooke, J., Vipond J. and Gautier J. M. (2016). Invited review: Improving neonatal survival in small ruminants: science into practice. Animal. 10**(3)**: 449-459. https://doi.org/10.1017/S1751731115001974

9) Everett-Hincks, J M., Mathias-Davis, H C., Greer, G J., Auvray, B A., Dodds, K. G. (2014). Genetic parameters for lamb birth weight, survival and death risk traits. Journal of Animal Science 92(**7**):2885-95. https://doi.org/10.2527/jas.2013-7176

10) Flinn, T., Kleemann, D. O., Swinbourne, A. M., Kelly, J.M., Weaver, A.C., Walker, S.K., Gatford, K. L., Kind, K. L., van- Wettere, W. H. E. J. (2020). Neonatal lamb mortality: major risk factors and the potential ameliorative role of melatonin. Journal of Animal Science and Biotech. 11**(1)**:107. https://doi.org/10.1186/s40104-020-00510-w

11) Gaur, P., Malik, Z. S., Bangar, Y. C., Magotra, A., Chauhan, A. (2022). Survival analysis for estimating lamb survival up to weaning in Harnali sheep. Zygote 30 **(6)**:797–800. https://doi.org/10.1017/s0967199422000272.

12) Getachew, T., Gizaw, S., Wurzinger, M., Haile, A., Rischkowsky, B., Okeyo, A. M., Sölkner, J., Mészáros, G. (2015). Survival analysis of genetic and non-genetic factors influencing ewe longevity and lamb survival of Ethiopian sheep breeds. Livestock Science.176**(6)**:22-32 https://doi.org/10.1016/j.livsci.2015.03.021

13) Gowane, G. R., Swarnkar, C. P., Prince, L. L. L., Kumar, A. (2018). Genetic parameters for neonatal mortality in lambs at semi-arid region of Rajasthan India. Livestock Science. 210**(4)**: 85-92. https://doi.org/10.1016/j.livsci.2018.02.003

14) Gowane, G.R., Swarnkar C.P., Narula H.K., Chopra A. (2020). Better Odds of Lamb Survival in Sheep at Dry Arid Tropical Region of India. Indian Journal of Animal Science. 90**(4)**: 628-635.

15) Hinch, G.N. and Brien, F. (2014). Lamb survival in Australian flocks: A review. Animal Production and Science. 54**(6)**: 656-666

16) Horikoshi, M. and Tang, Y. (2016). Ggfortify: Data Visualization Tools for Statistical Analysis Results. https://CRAN.R-project.org/package=ggfortify

17) Inal, S., Coskun, B., Dinc, D.A., Cam, M.2021. Reproductive parameters of primiparous Awassi sheep and mortality rates of their lambs in Steppe climates. Journal of Livestock Science 12: 262-267doi. 10.33259/JLivestSci.2021.262-267

18) Mane, P. M., Nimase, R. G., Pachpute, S. T., Modad, V. D. and Rasane, D. S. (2015). Mortality pattern of Deccani lambs in organized farm condition. The Indian Journal of Small Ruminants. 21:132-134.

19) Martínez, M.E., Calderón, C., Uribe, H., de la Barra, R. 2012. Effect of management practices in the productive performance of three sheep breeds in the Chiloé Archipelago, Chile. Journal of Livestock 3:57-66
20) Mustafa, M.I., Mehmood, M M., Muhammad, A L., Muhammad, B. and Khalid A R. (2014) Factors influencing lamb mortality from birth to weaning in Pakistan. Pakistan Journal of Life and Social Science.12:139-143.
21) NBAGR (National Bureau of Animal Genetic Resources). 2023. Registered breeds of sheep. Available from: https://nbagr.icar.gov.in/en/registered-sheep/ (Accessed 2 September)
22) R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.https://www.R-project.org/.
23) Raghavendra, S.V., Kumar, A A., Amaravathi, P.S.L.D.L., Somasekhar, S., Babu, A. J. and Rao T. M .(2017). Epidemiological survey on lamb mortality in Rayalaseema region of Andhra Pradesh in India. The Pharma Innovation Journal. 6**(9)**: 470-474.
24) Saravanan, K. A., Panigrahi, M., Kumar, H., Bhushan, B., Dutt, T., Mishra, B. P. (2021). Genome-wide analysis of genetic diversity and selection signatures in three Indian sheep breeds. Livestock Science.243**(2021):**104367 https://doi.org/10.1016/j.livsci.2020.104367
25) Soundararajan, C. (2014). Study on mortality pattern of Madras red sheep under semi arid tropic region. International Journal of Agricultural Science and Veterinary Medicine. 2 **(8)**: 25-30.
26) Swarnkar, C. P., Narula, H. K. and Chopra A. (2019).Risk factor analysis for neonatal lamb mortality at an organized farm of arid Rajasthan. The Indian Journal of Small Ruminants. 25: 59-69.
27) Tang,Y., Masaaki, Horikoshi. and Wenxuan, Li. (2016). ggfortify: Unified Interface to Visualize Statistical Results of Popular R Packages. The R Journal 8 : 474-485
28) Tesema, Z., Deribe, B., Kefale, A., Lakew, M., Tilahun, M., Shibesh, M., Belayneh, N., Zegeye, A., Worku, G., Yizengaw, L. 2020. Survival analysis and reproductive performance of Dorper x Tumele sheep. Heliyon.6(4):e03840. https://doi.org/10.1016/j.heliyon.2020.e03840.
29) Therneau, T. M. and Grambsch, P.M. (2000). Modeling Survival Data: Extending the Cox Model. Springer, New York. ISBN 0-387-98784-3.
30) Therneau, T.M. (2022). A Package for Survival Analysis in R. R package version 3.3-1, <https://CRAN.R-project.org/package=survival>.
31) Woldemariam, S., Sileshi, Z., Desta, H. and Almaz, H. (2014). Major causes of lamb mortality at Ebinat woreda, Amhara National Regional State, North-western. Ethiopia Veterinary Journal. 18**(1)**: 57-71.