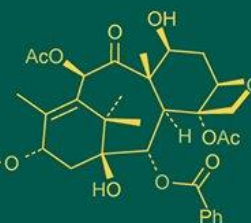
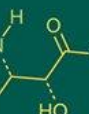
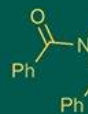


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(9): 129-137
www.biochemjournal.com
Received: 02-07-2026
Accepted: 05-08-2026

AB Gaddam

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

YB Kandalkar

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

DK Kamble

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

DK Deokar

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

SA Dhage

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

Studies on lamb survivability in Deccani sheep

AB Gaddam, YB Kandalkar, DK Kamble, DK Deokar and SA Dhage

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9b.9859>

Abstract

The present investigation entitled “Studies on Lamb Survivability in Deccani Sheep” was conducted under the Network Project on Sheep Improvement (Deccani Farm Based Unit), MPKV, Rahuri, Maharashtra. The study was undertaken to assess lamb survivability at different growth stages and to determine the influence of important non-genetic factors on lamb mortality. The study was based on performance records of 2,942 Deccani lambs born during 2011-2022 and reared under a semi-intensive management system. The data were analysed using least squares analysis, Duncan’s Multiple Range Test (DMRT), chi-square test and logistic regression. Overall survivability ranged from 89.70 to 97.23 percent, while cumulative mortality up to one year was 10.94 percent. The highest mortality (5.54 percent) occurred during the first 90 days. Birth weight and period of birth were the major factors influencing lamb mortality, with lambs weighing less than 3 kg showing higher mortality risk. Season significantly influenced mortality during the later stages, whereas sex and dam age had non-significant effects.

Keywords: Deccani sheep, lamb survivability, lamb mortality, birth weight, period of birth, season, non-genetic factors, logistic regression

Introduction

Sheep production is an important component of Indian agriculture and contributes substantially to the livelihood of rural households through the production of meat, wool and manure. Sheep are well suited to diverse production environments and are particularly valuable under resource-limited and semi-arid farming conditions. Their relatively low input requirements and adaptability make sheep an important livestock enterprise for small and marginal farmers.

Deccani is an important indigenous sheep breed of the Deccan plateau and is well adapted to the harsh climatic conditions and limited feed resources of the region. The breed is predominantly reared for mutton production and is an important source of livelihood for rural farmers in Maharashtra and adjoining regions. Under such production systems, efficient lamb survival is essential for maintaining flock size, replacement stock and overall productivity.

Lamb mortality is one of the major constraints affecting the biological and economic efficiency of sheep production. Early life is particularly critical, and mortality during this stage can substantially reduce the number of lambs available for replacement, sale and meat production. High lamb mortality therefore results in economic losses and adversely affects flock productivity. Improving lamb survivability is consequently an important component of profitable and sustainable sheep production (Dwyer *et al.*, 2016) [10].

Lamb mortality is a major welfare and economic concern in sheep production worldwide. Mortality rates ranging from 10 to 40 percent have been reported under different production systems, resulting in substantial economic losses (Binns *et al.*, 2002; Osteras *et al.*, 2007) [3, 19].

Lamb survivability is influenced by several non-genetic factors, including period and season of birth, sex of lamb, birth weight and age of dam. These factors can affect survival by altering environmental conditions, nutritional availability, maternal care and the ability of lambs to withstand environmental and health-related stresses. Among these factors, birth weight is an important indicator of early-life survival, with lambs having low birth weight generally being more vulnerable to mortality. The magnitude and direction of these effects may vary according to breed, management system and environmental conditions (Bangar *et al.*, 2016; Gaur *et al.*, 2022; Besufkad *et al.*, 2024) [6, 14, 7].

Corresponding Author:**AB Gaddam**

Department of AHDS, Post
Graduate Institute, MPKV,
Rahuri, Maharashtra, India

Although lamb mortality has been investigated in several sheep breeds, information on lamb survivability and the influence of important non-genetic factors in Deccani sheep under organized farm conditions in Maharashtra remains limited. A systematic assessment of survival at different growth stages and identification of factors associated with mortality can provide useful information for improving lamb management and reducing avoidable losses. Therefore, the present study was undertaken to assess lamb survivability at different growth stages and to determine the influence of important non-genetic factors on lamb mortality in Deccani sheep.

Materials and Methods

Study location and data source

The present investigation was conducted using performance records generated at the Network Project on Sheep Improvement (Deccani Farm Based Unit), Department of Animal Husbandry and Dairy Science, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India. The project is located in the scarcity zone of Maharashtra at an elevation ranging from 495 to 589 m above mean sea level. A total of 2,942 Deccani lamb records pertaining to lambs born during 2011-2022 were considered for analysis.

Management practices

The Deccani sheep flock was maintained under a semi-intensive management system, with animals allowed to graze for approximately 5-6 h daily and supplemented with dry and green fodder and concentrate feed according to their requirements. Pregnant and lactating ewes received additional concentrate supplementation, while lambs were provided supplementary feeding and appropriate care according to their age and requirements and were generally weaned at approximately 90 days of age. Routine veterinary care and preventive health management practices were followed at the farm.

Traits studied

Lamb survivability was studied at different age intervals, viz., 0-3, 3-6, 0-6, 6-12 and 0-12 months of age.

Assessment of lamb survivability

Lamb survivability was assessed at five growth-stage intervals: 0-3 months (SR1), 3-6 months (SR2), 0-6 months (SR3), 6-12 months (SR4) and 0-12 months (SR5). Survival rate at each age interval was determined from the performance records of the lambs. The data were further used to assess the influence of important non-genetic factors on lamb survivability and mortality at different growth stages.

Non-genetic factors

The non-genetic factors considered in the analysis were period of birth, season of birth, birth weight, sex of lamb and age of dam at lambing. Period of birth was classified into four periods: 2011-2013 (P1), 2014-2016 (P2), 2017-2019 (P3) and 2020-2022 (P4). Season of birth was classified as main season (October-March) and off-season (April-September). Birth weight was classified into three groups: < 3 kg, 3-3.4 kg and ≥ 3.4 kg. Sex was classified as male and female, while age of dam at lambing was grouped as < 3 years, 3-5 years and ≥ 5 years.

Statistical analysis

Least squares analysis was used to evaluate the effects of period of birth, season of birth, birth weight, sex of lamb and age of dam at lambing on lamb survivability at different growth stages. The least squares method described by Harvey (1990)^[23] was employed to account for unequal and disproportionate subclass frequencies in the data. Least squares means were estimated for different levels of the non-genetic factors.

The statistical model used was

$$Y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + E_m + e_{ijklmn}$$

where, Y_{ijklmn} is the survival rate at the respective age interval; μ is the overall mean; A_i is the effect of the i^{th} period of birth; B_j is the effect of the j^{th} season of birth; C_k is the effect of the k^{th} birth-weight group; D_l is the effect of the l^{th} sex; E_m is the effect of the m^{th} age of dam at lambing; and e_{ijklmn} is the random error attributed to the n^{th} lamb.

When a factor showed a significant effect ($p < 0.05$), the corresponding least squares means were compared using Duncan's Multiple Range Test (DMRT) as modified by Kramer (1957)^[24].

$$(\bar{Y}_i - \bar{Y}_j) \times \sqrt{\frac{2}{C_{ii} + C_{jj} - 2C_{ij}}} > \sigma^2 e Z(P, n_e)$$

Where, $\bar{Y}_i - \bar{Y}_j$ represents the difference between two least squares means; C_{ii} and C_{jj} are the corresponding i^{th} and j^{th} diagonal elements of the C matrix, respectively; C_{ij} is the $(i, j)^{\text{th}}$ element of the C matrix; $\sigma^2 e$ is the root mean square error; $Z(P, n_e)$ is the standardized range value from Duncan's table at the chosen probability level and error degrees of freedom; P is the number of means involved in the comparison; and n_e is the error degrees of freedom.

The chi-square (χ^2) test was used to assess the association between non-genetic factors and lamb mortality at different growth stages.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where, χ^2 is the calculated Chi-square value; O represents the observed frequency; E represents the corresponding expected frequency; and $\sum$ denotes summation over all categories.

Logistic regression analysis was used to identify the factors influencing the probability of lamb mortality. Lamb survival status was coded as alive = 0 and dead = 1. The results were expressed as odds ratios [$\text{Exp}(\beta)$] with 95 percent confidence intervals. The reference categories for period of birth, season, sex, birth weight and age of dam at lambing were 2020-2022, off-season, female, ≥ 3.4 kg and ≥ 5 years, respectively. Statistical significance was considered at $p < 0.05$.

$$\text{Logit}(p) = \log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_i x_i$$

Where, p is the probability of lamb mortality; $\log[p/(1 - p)]$ represents the log odds of mortality; β_0 is the intercept (constant); β_i is the regression coefficient for the i^{th} fixed factor; and X_i represents the explanatory variables, including period of birth, season, sex, birth weight and dam age. The exponential of the regression coefficient, $\text{Exp}(\beta)$, represents the odds ratio (OR), indicating the relative odds of mortality associated with each factor level compared with the reference category.

Significance was tested using the Wald statistic

$$\text{Wald} = \left(\frac{\beta}{SE(\beta)} \right)^2$$

Table 1: Least squares means for lamb survivability in Deccani sheep at different stages

Factor	Level	SR1	SR2	SR3	SR4	SR5
Overall		94.89±0.48 (2942)	96.74±0.37 (2696)	91.9±0.57 (2942)	97.23±0.42 (2328)	89.7±0.65 (2942)
POB	2011-13	95.8±0.92 (646)	96.96±0.72 (589) ^b	93.06±1.1 (646) ^b	96.25±0.81 (524)	90.08±1.25 (646) ^{bc}
	2014-16	94.08±0.79 (880)	97.03±0.62 (791) ^b	91.41±0.95 (880) ^a	96.91±0.7 (692)	88.88±1.08 (880) ^{ab}
	2017-19	93.47±0.86 (811)	94.99±0.67 (736) ^a	88.87±1.03 (811) ^a	96.92±0.77 (636)	86.44±1.17 (811) ^a
	2020-22	96.21±0.97 (605)	98±0.74 (580) ^b	94.28±1.17 (605) ^b	98.83±0.86 (476)	93.41±1.32 (605) ^c
P value		0.072	0.01	0.001	0.132	0.000
Season	Main	94.65±0.51 (2070)	97.8±0.4 (1890) ^b	92.66±0.61 (2070)	96.08±0.45 (1649) ^a	89.47±0.7 (2070)
	Dry	95.13±0.79 (872)	95.69±0.61 (806) ^a	91.15±0.95 (872)	98.38±0.7 (679) ^b	89.94±1.07 (872)
P value		0.602	0.003	0.175	0.006	0.709
Sex	Male	94.72±0.62 (1537)	96.06±0.48 (1405) ^a	91.13±0.75 (1537)	96.86±0.56 (1203)	88.66±0.85 (1537)
	Female	95.06±0.66 (1405)	97.43±0.51 (1291) ^b	92.68±0.79 (1405)	97.6±0.58 (1125)	90.75±0.9 (1405)
P value		0.691	0.039	0.131	0.328	0.073
Birth weight	< 3 kg	92.59±0.75 (1039) ^a	95.41±0.59 (931) ^a	88.45±0.9 (1039) ^a	96.73±0.68 (788)	85.93±1.02 (1039) ^a
	3-3.4 kg	95.42±0.71 (1124) ^b	97.19±0.55 (1044) ^b	92.85±0.85 (1124) ^b	97.72±0.63 (892)	91.08±0.97 (1124) ^b
	≥ 3.4 kg	96.66±0.88 (779) ^b	97.63±0.67 (721) ^b	94.41±1.05 (779) ^b	97.24±0.76 (648)	92.1±1.19 (779) ^b
P value		0.001	0.018	0.000	0.543	0.000
Dam Age	< 3 years	94.99±0.83 (849)	96.24±0.64 (777)	91.56±0.99 (849)	97.52±0.74 (647)	89.7±1.12 (849)
	3-5 years	95.2±0.76 (996)	97.33±0.59 (911)	92.73±0.91 (996)	97.63±0.66 (816)	90.7±1.03 (996)
	≥ 5 years	94.48±0.71 (1097)	96.66±0.55 (1008)	91.42±0.86 (1097)	96.53±0.63 (865)	88.71±0.97 (1097)
P value		0.760	0.410	0.502	0.393	0.343

Different superscripts differ significantly ($p < 0.05$) between different levels of particular factor

Lamb Survivability from Birth to 3 Months (SR1)

The overall survivability from birth to three months was 94.89±0.48 percent. Birth weight significantly influenced survivability ($p < 0.05$), with lambs weighing < 3 kg showing lower survivability (92.59±0.75%) compared with those weighing 3-3.4 kg (95.42±0.71%) and ≥ 3.4 kg (96.66±0.88%). Similar associations between birth weight and lamb survivability have been reported by Bangar *et al.* (2016) [6]. Period of birth, season, sex and dam age had no significant effect on survivability during SR1 ($p > 0.05$).

Lamb Survivability from 3 to 6 Months (SR2)

The overall survivability during SR2 was 96.74±0.37 percent. Period of birth, season, sex and birth weight significantly influenced survivability ($p < 0.05$). Lambs born during 2017-19 had the lowest survivability (94.99±0.67%) compared with those born during the other birth periods. Similar variation in lamb survivability across birth periods has been reported by Besufkad *et al.* (2024) [7]. Survivability was higher among lambs born during the main season (97.80±0.40%) than those born during the dry season (95.69±0.61%). Similar seasonal effects on lamb survivability have been reported by Belay and Haile (2011) [4]. Female lambs exhibited higher survivability (97.43±0.51%) than male lambs (96.06±0.48%). Similar

Results and Discussion

The results obtained in the present study are presented under the following headings.

1. Least Squares Analysis
2. Mortality Distribution by Life Stages
3. Chi-square Analysis
4. Logistic Regression

1. Least Squares Analysis of Lamb Survivability

The results of the least squares analysis of lamb survivability at different growth stages are presented in Table 1. Overall survivability ranged from 89.70±0.65 during SR5 (birth to 12 months) to 97.23±0.42 percent during SR4 (6 to 12 months) across SR1-SR5.

differences in lamb survivability between sexes have been reported by Mandal *et al.* (2007) [16]. Birth weight significantly influenced survivability ($p < 0.05$), with lambs weighing < 3 kg showing lower survivability (95.41±0.59%) compared with those weighing 3-3.4 kg (97.19±0.55%) and ≥ 3.4 kg (97.63±0.67%). Similar associations between birth weight and lamb survivability have been reported by Gaur *et al.* (2022) [14]. Dam age had no significant effect on survivability during SR2 ($p > 0.05$).

Lamb Survivability from Birth to 6 Months (SR3)

The overall survivability during SR3 was 91.90±0.57 percent. Period of birth and birth weight significantly influenced survivability ($p < 0.05$). Lambs born during 2017-19 showed the lowest survivability (88.87±1.03%), compared with those born during the other birth periods. Similar variation in lamb survivability across birth periods has been reported by Besufkad *et al.* (2024) [7]. Birth weight significantly influenced survivability ($p < 0.05$), with lambs weighing < 3 kg showing lower survivability (88.45±0.90%) compared with those weighing 3-3.4 kg (92.85±0.85%) and ≥ 3.4 kg (94.41±1.05%). Similar associations between birth weight and lamb survivability have been reported by Gaur *et al.* (2022) [14]. Season, sex and dam age had no significant effect on survivability during SR3 ($p > 0.05$).

Lamb Survivability from 6 to 12 Months (SR4)

The overall survivability during SR4 was 97.23 ± 0.42 percent. Season of birth significantly influenced survivability ($p < 0.05$), with lambs born during the dry season showing higher survivability ($98.38 \pm 0.70\%$) compared with those born during the main season ($96.08 \pm 0.45\%$). The influence of seasonal conditions on lamb survival has also been reported by Belay and Haile (2011)^[4]. Period of birth, sex, birth weight and dam age had no significant effect on survivability during SR4 ($p > 0.05$).

Lamb Survivability from Birth to 12 Months (SR5)

The overall survivability during SR5 was 89.70 ± 0.65 percent. Period of birth and birth weight significantly influenced survivability ($p < 0.05$). Lambs born during 2020-22 had the highest survivability ($93.41 \pm 1.32\%$),

whereas those born during 2017-19 had the lowest survivability ($86.44 \pm 1.17\%$). Similar variation in lamb survivability across birth periods has been reported by Besufkad *et al.* (2024)^[7]. Birth weight significantly influenced survivability ($p < 0.05$), with lambs weighing < 3 kg showing lower survivability ($85.93 \pm 1.02\%$) compared with those weighing 3-3.4 kg ($91.08 \pm 0.97\%$) and ≥ 3.4 kg ($92.10 \pm 1.19\%$). Similar associations between birth weight and lamb survivability have been reported by Bangar *et al.* (2016)^[6]. Season, sex and dam age had no significant effect on survivability during SR5 ($p > 0.05$).

2. Mortality Distribution by Life Stages

The study examined lamb mortality in Deccani sheep across different life stages: 0-90 days, 90-180 days, 180-365 days, 0-180 days and 0-365 days.

Table 2: Distribution of lamb mortality in Deccani sheep during different life stages

Stage	Total lambs	Number of died	Mortality (%)
0-90 days	2942	163	5.54
90-180 days	2696	80	2.97
0-180 days	2942	243	8.26
180-365 days	2328	78	3.35
0-365 days	2942	322	10.94

Mortality was highest during the pre-weaning period (0-90 days) at 5.54%, followed by 2.97% during 90-180 days and 3.35% during 180-365 days. Cumulative mortality was 8.26% up to six months (0-180 days) and increased to 10.94% up to one year (0-365 days), indicating that mortality was predominantly concentrated during early life. Similar patterns of higher early-life mortality have been reported in sheep (Mandal *et al.*, 2007; Dwyer, 2008)^[16, 9].

Table 3: Distribution of lamb mortality during birth to weaning stage (0-90 days) in Deccani sheep

Factor	Total lambs	Number of died	Mortality (%)
Overall	2942	163	5.54
POB ($P = 0.016$)			*
2011-13	646	25	3.87
2014-16	880	56	6.36
2017-19	811	57	7.03
2020-22	605	25	4.13
Season ($P = 0.559$)			NS
Main	2070	118	5.70
Dry	872	45	5.16
Sex ($P = 0.892$)			NS
Male	1537	86	5.60
Female	1405	77	5.48
Birth weight ($P = 0.000$)			**
< 3 kg	957	82	8.57
3-3.4 kg	1071	53	4.95
≥ 3.4 kg	751	28	3.73
Dam Age ($P = 0.764$)			NS
< 3 years	849	48	5.65
3-5 years	996	51	5.12
≥ 5 years	1097	64	5.83

NS = Non-significant ($p > 0.05$); ** = Highly significant ($p < 0.01$).

Distribution of Lamb Mortality in Deccani Sheep (0-90 Days)

Overall pre-weaning mortality was 5.54% among 2,942 Deccani lambs. Period of birth significantly affected

mortality ($p < 0.05$), with mortality ranging from 3.87% during 2011-13 to 7.03% during 2017-19. Similar variation in lamb mortality across birth periods has been reported by Besufkad *et al.* (2024)^[7]. Birth weight also significantly affected mortality ($p < 0.01$), with the highest mortality observed among lambs weighing < 3 kg (8.57%), followed by those weighing 3-3.4 kg (4.95%) and ≥ 3.4 kg (3.73%). Similar associations between birth weight and lamb mortality have been reported by (Dwyer, 2008; Morel *et al.*, 2008)^[9, 17]. Season, sex and dam age had no significant effect on mortality during the pre-weaning period.

Table 4: Distribution of lamb mortality during Weaning to six months of age (90-180 days) in Deccani sheep

Factor	Total lambs	Number of died	Mortality (%)
Overall	2696	80	2.97
POB ($P = 0.008$)			**
2011-13	589	14	2.38
2014-16	791	23	2.91
2017-19	736	34	4.62
2020-22	580	9	1.55
Season ($P = 0.006$)			**
Main	1890	45	2.38
Dry	806	35	4.34
Sex ($P = 0.059$)			NS
Male	1405	50	3.56
Female	1291	30	2.32
Birth weight ($P = 0.012$)			*
< 3 kg	891	40	4.49
3-3.4 kg	1019	25	2.45
≥ 3.4 kg	706	15	2.12
Dam Age ($P = 0.427$)			NS
< 3 years	777	27	3.47
3-5 years	911	22	2.41
≥ 5 years	1008	31	3.08

NS = Non-significant ($p > 0.05$); ** = Highly significant ($p < 0.01$).

Distribution of Lamb Mortality in Deccani Sheep (90-180 Days)

Overall mortality during 90-180 days was 2.97% among 2,696 lambs, lower than that observed during 0-90 days. Period of birth significantly affected mortality ($p < 0.05$), with the highest mortality observed during 2017-19 (4.62%). Similar variation in lamb mortality across birth periods has been reported by Besufkad *et al.* (2024) [7]. Season also significantly affected mortality ($p < 0.05$), with the highest mortality observed during the dry season (4.34%). Similar seasonal variation in lamb mortality has been reported by Belay and Haile (2011) [4]. Birth weight significantly affected mortality ($p < 0.05$), with the highest mortality observed among lambs weighing < 3 kg (4.49%) and the lowest among those weighing ≥ 3.4 kg (2.12%). Similar associations between birth weight and lamb mortality have been reported by Turkson and Sualisu (2005) [21]. Sex and dam age had no significant effect on mortality during this period.

Table 5: Distribution of lamb mortality during birth to six months of age (0-180 days) in Deccani sheep

Factor	Total lambs	Number of died	Mortality (%)
Overall	2942	243	8.26
POB ($P = 0.000$)			**
2011-13	646	39	6.04
2014-16	880	79	8.98
2017-19	811	91	11.22
2020-22	605	34	5.62
Season ($P = 0.242$)			NS
Main	2070	163	7.87
Dry	872	80	9.17
Sex ($P = 0.225$)			NS
Male	1537	136	8.85
Female	1405	107	7.62
Birth weight ($P = 0.000$)			**
< 3 kg	917	122	13.30
3-3.4 kg	1046	78	7.46
≥ 3.4 kg	736	43	5.84
Dam Age ($P = 0.419$)			NS
< 3 years	849	75	8.83
3-5 years	996	73	7.33
≥ 5 years	1097	95	8.66

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

Distribution of Lamb Mortality in Deccani Sheep (0-180 Days)

Overall mortality from birth to six months (0-180 days) was 8.26% among 2,942 lambs. Period of birth significantly affected mortality ($p < 0.05$), with the highest mortality recorded during 2017-19 (11.22%). Similar variation in lamb mortality across birth periods has been reported by (Abegaz *et al.*; 2005) [1]. Birth weight also significantly affected mortality ($p < 0.05$), with the highest mortality observed among lambs weighing < 3 kg (13.30%) and the lowest among those weighing ≥ 3.4 kg (5.84%). Similar associations between birth weight and lamb mortality have been reported by Swarnkar and Sonawane (2024) [20]. Season, sex and dam age did not significantly influence mortality during this period. Thus, period of birth and birth weight were the major factors associated with lamb mortality during the first six months of life.

Table 6: Distribution of lamb mortality during six months to twelve months of age (180-365 days) in Deccani sheep

Factor	Total lambs	Number of died	Mortality (%)
Overall	2328	78	3.35
POB ($P = 0.151$)			NS
2011-13	524	21	4.01
2014-16	692	25	3.61
2017-19	636	24	3.77
2020-22	476	8	1.68
Season ($P = 0.006$)			**
Main	1649	66	4.00
Dry	679	12	1.77
Sex ($P = 0.279$)			NS
Male	1203	45	3.74
Female	1125	33	2.93
Birth weight ($P = 0.376$)			NS
< 3 kg	758	30	3.96
3-3.4 kg	868	24	2.76
≥ 3.4 kg	624	24	3.85
Dam Age ($P = 0.483$)			NS
< 3 years	647	20	3.09
3-5 years	816	24	2.94
≥ 5 years	865	34	3.93

NS = Non-significant ($p > 0.05$); ** = Highly significant ($p < 0.01$).

Distribution of Lamb Mortality in Deccani Sheep (180-365 Days)

Overall mortality during 180-365 days was 3.35% among 2,328 lambs. Season had a highly significant effect ($p < 0.01$), with higher mortality during the main season (4.00%) than the dry season (1.77%). Similar seasonal variation in lamb mortality has been reported by (Ceyhan and Kozakli, 2023) [8]. In contrast, period of birth, sex, birth weight and dam age did not significantly affect mortality during this stage. Thus, mortality during 180-365 days appeared to be influenced predominantly by seasonal factors.

Table 7: Distribution of lamb mortality during birth to six months of age (0-365 days) in Deccani sheep

Factor	Total lambs	Number of died	Mortality (%)
Overall	2942	322	10.94
POB ($P = 0.000$)			**
2011-13	646	60	9.29
2014-16	880	105	11.93
2017-19	811	115	14.18
2020-22	605	42	6.94
Season ($P = 0.656$)			NS
Main	2070	230	11.11
Dry	872	92	10.55
Sex ($P = 0.103$)			NS
Male	1537	182	11.84
Female	1405	140	9.96
Birth weight ($P = 0.000$)			**
< 3 kg	886	153	17.27
3-3.4 kg	1022	102	9.98
≥ 3.4 kg	712	67	9.41
Dam Age ($P = 0.359$)			NS
< 3 years	849	95	11.19
3-5 years	996	98	9.84
≥ 5 years	1097	129	11.76

NS = Non-significant ($p > 0.05$); ** = Highly significant ($p < 0.01$).

Distribution of Lamb Mortality in Deccani Sheep (0-365 Days)

Overall mortality during the first year of life (0-365 days) was 10.94% among 2,942 Deccani lambs. Period of birth had a highly significant effect on mortality ($p < 0.01$), with mortality ranging from 6.94% during 2020-22 to 14.18% during 2017-19. Similar variation in lamb mortality across birth periods has been reported by Besufkad *et al.* (2024)^[7]. Birth weight also had a highly significant effect on mortality ($p < 0.01$), with the highest mortality observed among lambs weighing < 3 kg (17.27 percent), compared with mortality rates of 9.98 percent and 9.41 percent in the 3-3.4 kg and $\geq$

3.4 kg groups, respectively. Similar associations between birth weight and lamb mortality have been reported by Gaur *et al.* (2022)^[14] and Besufkad *et al.* (2024)^[7]. In contrast, season, sex and dam age did not significantly affect mortality. Thus, period of birth and birth weight were the major factors associated with lamb mortality during the first year of life.

3. Chi-square Analysis

The results of the Chi-square analysis of different factors associated with lamb mortality at various life stages in Deccani sheep are presented in Table 8.

Table 8: Chi-square of P values of different factors associated with lamb mortality of lamb at various life stages in Deccani sheep

Factors	Life stages				
	0-3 months	3-6 months	0-6 months	6-12 months	0-12 months
Period of Birth	10.30 (0.02)	11.74 (0.01)	19.76 (0.001)	5.30 (0.15)	21.35 (0.001)
Season	0.34 (0.559)	7.55 (0.01)	1.368 (0.24)	7.42 (0.01)	0.19 (0.66)
Sex	0.02 (0.892)	3.56 (0.06)	1.47 (0.22)	1.17 (0.28)	2.65 (0.10)
Birth weight	18.08 (0.001)	8.87 (0.01)	26.93 (0.001)	1.957 (0.37)	23.66 (0.001)
Dam age	0.54 (0.764)	1.70 (0.42)	1.74 (0.41)	1.456 (0.48)	2.048 (0.34)

Chi-square analysis revealed that period of birth was significantly associated with lamb mortality during 0-3 months ($\chi^2 = 10.30$; $P = 0.02$), 3-6 months ($\chi^2 = 11.74$; $P = 0.01$), 0-6 months ($\chi^2 = 19.76$; $p < 0.001$) and 0-12 months ($\chi^2 = 21.35$; $p < 0.001$), but not during 6-12 months ($P = 0.151$). Similar variation in lamb mortality across birth periods has been reported by Besufkad *et al.* (2024)^[7]. Season of birth showed significant associations during 3-6 months ($\chi^2 = 7.55$; $P = 0.01$) and 6-12 months ($\chi^2 = 7.42$; $P = 0.01$), but not during the other stages. Similar seasonal effects on lamb survival have been reported by Kenyon *et al.* (2014)^[18]. Birth weight was significantly associated with mortality during 0-3 months ($\chi^2 = 18.08$; $p < 0.001$), 3-6

months ($\chi^2 = 8.87$; $P = 0.01$), 0-6 months ($\chi^2 = 26.93$; $p < 0.001$) and 0-12 months ($\chi^2 = 23.66$; $p < 0.001$), but not during 6-12 months ($P = 0.37$). Similar associations between birth weight and lamb mortality have been reported by Morel *et al.* (2008)^[17]. In contrast, sex and dam age showed no significant association with mortality at any stage. Overall, period of birth and birth weight were the major factors associated with lamb mortality, particularly during the first six months, while seasonal effects were evident during later stages.

4. Logistic Regression

Table 9: Risk factor analysis for lamb mortality (0-3 months) in Deccani sheep using logistic regression

Factor	Level	B	S.E.	Wald	Exp (B)	95% C.I. for EXP (B)		P value
POB	2011-13	0.07	0.29	0.05	1.07	0.60	1.89	0.82
	2014-16	0.44	0.25	3.07	1.55	0.95	2.54	0.08
	2017-19	0.54	0.25	4.70	1.71	1.05	2.77	0.03
	2020-22				1.00			
Season	Main	0.10	0.18	0.30	1.11	0.77	1.58	0.58
	Dry				1.00			
Sex	Male	0.06	0.16	0.13	1.06	0.77	1.47	0.72
	Female				1.00			
Birth weight	< 3 kg	0.79	0.23	11.67	2.19	1.40	3.44	<0.001
	3-3.4 kg	0.30	0.25	1.51	1.35	0.84	2.19	0.22
	≥ 3.4 kg				1.00			
Dam Age	< 3 years	-0.10	0.20	0.25	0.91	0.61	1.34	0.62
	3-5 years	-0.13	0.19	0.48	0.88	0.60	1.28	0.49
	≥ 5 years				1.00			
Constant		-3.63	0.34	111.52	0.03			< 0.001

SE: Standard error; Exp: Exponential function; CI: Confidence interval

Logistic Regression Analysis of Lamb Mortality (0-3 Months)

Logistic regression analysis showed that period of birth and birth weight significantly influenced lamb mortality during 0-3 months. Lambs born during 2017-19 had 1.71 times the

odds of mortality compared with those born during 2020-22 (OR = 1.71; 95% CI = 1.05-2.77; $P = 0.03$), while 2011-13 and 2014-16 did not differ significantly. Similar variation in lamb mortality across birth periods has been reported by Gaur *et al.* (2022)^[14]. Lambs weighing < 3 kg had 2.19

times the odds of mortality compared with those weighing ≥ 3.4 kg (OR = 2.19; 95% CI = 1.40-3.44; $p < 0.01$), whereas the 3-3.4 kg group did not differ significantly. Similar associations between birth weight and lamb mortality have

been reported by Mellor and Stafford (2004). Season, sex and dam age had no significant effect on mortality ($p > 0.05$).

Table 10: Risk factor analysis for lamb mortality (3-6 months) in Deccani sheep using logistic regression

Factor	Level	B	S.E.	Wald	Exp (B)	95% C.I. for EXP (B)		P value
POB	2011-13	0.52	0.44	1.42	1.68	0.72	3.96	0.23
	2014-16	0.51	0.40	1.59	1.66	0.75	3.66	0.21
	2017-19	1.11	0.38	8.40	3.02	1.43	6.38	< 0.001
	2020-22				1.00			
Season	Main	-0.68	0.23	8.49	0.51	0.32	0.80	< 0.001
	Dry				1.00			
Sex	Male	0.49	0.24	4.15	1.63	1.02	2.60	0.04
	Female				1.00			
Birth weight	< 3 kg	0.74	0.32	5.39	2.09	1.12	3.89	0.02
	3-3.4 kg	0.20	0.34	0.33	1.22	0.63	2.37	0.56
	≥ 3.4 kg				1.00			
Dam Age	< 3 years	0.14	0.27	0.27	1.15	0.68	1.96	0.61
	3-5 years	-0.25	0.29	0.77	0.78	0.45	1.36	0.38
	≥ 5 years				1.00			
Constant		-4.31	0.50	75.66	0.01			< 0.001

SE: Standard error; Exp: Exponential function; CI: Confidence interval

Logistic Regression Analysis of Lamb Mortality (3-6 Months)

Mortality during 3-6 months was significantly influenced by period of birth, season, sex and birth weight. Lambs born during 2017-19 had 3.02 times the odds of mortality compared with those born during 2020-22 (OR = 3.02; 95% CI = 1.43-6.38). Similar variation in lamb mortality across birth periods has been reported by Bahri Binabaj *et al.* (2013)^[5] and Gowane *et al.* (2018)^[12]. Lambs born in the main season had lower odds of mortality than those born in the dry season (OR = 0.51; 95% CI = 0.32-0.80; $p < 0.001$).

Similar seasonal effects on lamb mortality have been reported by Gowane *et al.* (2020)^[13]. Male lambs had 1.63 times the odds of mortality compared with females (OR = 1.63; 95% CI = 1.02-2.60; $P = 0.04$). Similar effects of sex on lamb mortality have been reported by Gaur *et al.* (2022)^[14]. Lambs weighing < 3 kg had 2.09 times the odds of mortality compared with those weighing ≥ 3.4 kg (OR = 2.09; 95% CI = 1.12-3.89; $p < 0.05$). Similar associations between birth weight and lamb mortality have been reported by and Morel *et al.* (2008)^[17] and Abdelqader *et al.* (2017)^[2]. Dam age had no significant effect on mortality.

Table 11: Risk factor analysis for lamb mortality (0-6 months) in Deccani sheep using logistic regression

Factor	Level	B	S.E.	Wald	Exp (B)	95% C.I. for EXP (B)		P value
POB	2011-13	0.19	0.25	0.58	1.21	0.75	1.95	0.45
	2014-16	0.44	0.22	4.12	1.55	1.02	2.37	0.04
	2017-19	0.73	0.21	12.08	2.07	1.37	3.13	<0.001
	2020-22				1.00			
Season	Main	-0.19	0.15	1.78	0.82	0.62	1.10	0.18
	Dry				1.00			
Sex	Male	0.20	0.14	2.17	1.23	0.94	1.60	0.14
	Female				1.00			
Birth weight	< 3 kg	0.79	0.19	17.20	2.19	1.51	3.18	<0.001
	3-3.4 kg	0.26	0.20	1.68	1.30	0.87	1.93	0.20
	≥ 3.4 kg				1.00			
Dam Age	< 3 years	-0.02	0.16	0.01	0.98	0.71	1.35	0.91
	3-5 years	-0.18	0.16	1.15	0.84	0.61	1.16	0.28
	≥ 5 years				1.00			
Constant		-3.15	0.28	122.79	0.04			<0.001

SE: Standard error; Exp: Exponential function; CI: Confidence interval

Logistic Regression Analysis of Lamb Mortality (0-6 Months)

Mortality during 0-6 months was significantly influenced by period of birth and birth weight. Compared with 2020-22, lambs born during 2014-16 had 1.55 times the odds of mortality (OR = 1.55; 95% CI = 1.02-2.37; $p < 0.05$), while those born during 2017-19 had 2.07 times the odds of mortality (OR = 2.07; 95% CI = 1.37-3.13; $p < 0.001$); 2011-13 did not differ significantly. Similar variations in

lamb mortality across birth periods have been reported by Bahri Binabaj *et al.* (2013)^[5] and Gowane *et al.* (2018)^[12]. Lambs weighing < 3 kg had 2.19 times the odds of mortality compared with those weighing ≥ 3.4 kg (OR = 2.19; 95% CI = 1.51-3.18; $p < 0.001$), whereas the 3-3.4 kg group did not differ significantly. Similar associations between birth weight and lamb mortality have been reported by Morel *et al.*, (2008)^[17] and Abdelqader *et al.* (2017)^[2]. Season, sex and dam age had no significant effect.

Table 12: Risk factor analysis for lamb mortality (6-12 months) in Deccani sheep using logistic regression

Factor	Level	B	S.E.	Wald	Exp (B)	95% C.I. for EXP (B)		P value
POB	2011-13	0.97	0.43	5.19	2.64	1.15	6.07	0.02
	2014-16	0.78	0.42	3.52	2.18	0.97	4.93	0.06
	2017-19	0.78	0.41	3.53	2.18	0.97	4.90	0.06
	2020-22				1.00			
Season	Main	0.86	0.32	7.20	2.36	1.26	4.41	0.01
	Dry				1.00			
Sex	Male	0.23	0.24	0.90	1.26	0.79	2.01	0.34
	Female				1.00			
Birth weight	< 3 kg	0.16	0.29	0.29	1.17	0.66	2.06	0.59
	3-3.4 kg	-0.16	0.31	0.28	0.85	0.47	1.55	0.60
	≥ 3.4 kg				1.00			
Dam Age	< 3 years	-0.29	0.29	1.00	0.75	0.43	1.32	0.32
	3-5 years	-0.32	0.27	1.40	0.72	0.42	1.24	0.24
	≥ 5 years				1.00			
Constant		-4.68	0.54	75.46	0.01			0.001

SE: Standard error; Exp: Exponential function; CI: Confidence interval

Logistic Regression Analysis of Lamb Mortality (6-12 Months)

Mortality during 6-12 months was significantly influenced by period of birth and season. Compared with 2020-22, lambs born during 2011-13 had 2.64 times the odds of mortality (95% CI = 1.15-6.07; $P = 0.02$), whereas the 2014-16 and 2017-19 periods were non-significant. Similar effects of period of birth on lamb survival have been reported by

Gaur *et al.* (2022) ^[14] and Besufkad *et al.* (2024) ^[7]. Lambs born during the main season had 2.36 times the odds of mortality compared with those born during the dry season (95% CI = 1.26-4.41; $P = 0.01$). Similar seasonal effects on lamb mortality have been reported by Turkson and Sualisu (2005) ^[21] and Tibbo *et al.* (2010) ^[22]. Sex, birth weight and dam age had no significant effect on mortality.

Table 13: Risk factor analysis for lamb mortality (0-12 months) in Deccani sheep using logistic regression

Factor	Level	B	S.E.	Wald	Exp (B)	95% C.I. for EXP (B)		P value
POB	2011-13	0.42	0.21	3.91	1.52	1.00	2.31	0.05
	2014-16	0.55	0.19	8.01	1.73	1.18	2.54	0.01
	2017-19	0.77	0.19	16.48	2.16	1.49	3.14	< 0.001
	2020-22				1.00			
Season	Main	0.05	0.13	0.16	1.05	0.81	1.37	0.69
	Dry				1.00			
Sex	Male	0.21	0.12	3.08	1.24	0.98	1.57	0.08
	Female				1.00			
Birth weight	< 3 kg	0.61	0.16	14.67	1.85	1.35	2.53	<0.001
	3-3.4 kg	0.11	0.17	0.44	1.12	0.80	1.56	0.51
	≥ 3.4 kg				1.00			
Dam Age	< 3 years	-0.10	0.15	0.48	0.90	0.68	1.20	0.49
	3-5 years	-0.20	0.14	2.02	0.82	0.62	1.08	0.16
	≥ 5 years				1.00			
Constant		-2.94	0.25	136.72	0.05			<0.001

SE: Standard error; Exp: Exponential function; CI: Confidence interval

Logistic Regression Analysis of Lamb Mortality (0-12 Months)

Mortality during 0-12 months was significantly influenced by period of birth and birth weight. Compared with 2020-22, lambs born during 2011-13, 2014-16 and 2017-19 had 1.52, 1.73 and 2.16 times the odds of mortality, respectively ($p < 0.05$). Similar variation in lamb mortality across birth periods has been reported by Gowane *et al.* (2018) ^[12]. Lambs weighing < 3 kg had 1.85 times the odds of mortality compared with those weighing ≥ 3.4 kg (OR = 1.85; 95% CI = 1.35-2.53; $p < 0.001$), whereas the 3-3.4 kg group did not differ significantly. Similar associations between birth weight and lamb mortality have been reported by Abdelqader *et al.* (2017) ^[2]. Season, sex and dam age had no significant effect on mortality.

Conclusion

The present study demonstrated that period of birth and birth weight were the major factors influencing lamb survivability in Deccani sheep. Overall survivability ranged from 89.70±0.65 percent from birth to 12 months to 97.23±0.42 percent during 6-12 months, while the highest mortality was observed during the 0-90-days period (5.54%). Lambs weighing < 3 kg at birth consistently exhibited lower survivability and higher mortality, while lambs born during 2017-19 generally showed poorer survival than those born during the other periods. Season and sex had stage-specific effects, whereas dam age showed no significant influence. These findings emphasize the importance of improving maternal nutrition and providing

targeted management to low-birth-weight lambs to reduce mortality and enhance lamb survivability in Deccani sheep.

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