

Effects of genotype and some non-genetic factors on pre-weaning growth and survival of crossbred lambs from alternating crosses of Ouled Djellal and D'man sheep

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Received : 03 November 2025 ; Accepted: 22 July 2026

ABSTRACT

The study evaluated the association of genotype and selected non-genetic factors with pre-weaning growth and survival of crossbred lambs produced from Ouled Djellal (OD) and D'man (D). Data consisted of 314 records of crossbred lambs born between 2013 and 2021, including 127 lambs of the first generation (G1: 50% OD, 50% D), 87 lambs of the second generation (G2: 75% OD, 25% D), and 100 lambs of the third generation (G3: 37.5% OD, 62.5% D). Growth was monitored from birth to weaning (90 days). Lambs of G2 showed superior growth performance, with an average weight of 21.17 ± 0.43 kg at 90 days compared to 15.20 ± 0.40 kg (G1) and 15.97 ± 0.39 kg (G3), and surpassing values reported for pure OD (16.92 kg) and D (17.39 kg) lambs. Average daily gain (ADG 0-90 days) was 195.15 ± 4.50 g/day for G2, higher than G1 (127.09 ± 4.22 g/day) and G3 (136.78 ± 4.03 g/day), also exceeding purebred values. Non-genetic factors positively influencing performance included lambing year (2016–2018), male sex, single birth, parity (primiparous) and maternal body condition score (2–3.5). However, genotype was confounded with year, making it difficult to fully disentangle the effects of genotype, year, management, and environmental conditions. The results also showed that lamb viability at birth and at weaning was mainly influenced by birth type, genotype, and, depending on the stage considered, by birth year and the dams' body condition. These results suggest that the G2 group performed best under the present flock conditions; however, validation across additional years, flocks and later generations is needed before recommending a breeding strategy or synthetic breed development.

Keywords: Algeria, Genetic improvement, Growth performance, Local breed, Sheep

In Algeria, OD breed is recognized for its superior meat production traits, while D breed is well known for exceptional prolificacy, offering valuable genetic resources for enhancing sheep production. Previous studies (Sebkhi *et al.* 2024) showed that crossbreeding between these two breeds (OD and D) over three generations (G1–G3) significantly improved ewe fecundity as well as numerical and weight productivity compared to purebred OD ewes. Lamb growth and survival are key performance indicators in sheep farming, directly affecting overall productivity and farm profitability. These traits result from complex interactions between genetic and non-genetic factors. Among genetic influences, lamb genotype strongly affects growth and survival, with heterosis (hybrid vigor) potentially enhancing performance in crossbred generations

(Ünal *et al.* 2007). Maternal factors, including milk yield and body condition, also play critical roles in postnatal lamb development (Atti et Abdennabi 1995, Dwyer *et al.* 2004). Additionally, non-genetic factors such as sex, birth type, and lambing season during the pre-weaning period significantly influence growth and survival probabilities (Tesema *et al.* 2017, Hagan *et al.* 2022, Behrem *et al.* 2025, Mhlongo and Tenza 2025).

The present study aimed to evaluate the effects of genotype, lambing year, sex, birth type, dam parity, and maternal body condition score on growth performance and survival of crossbred lambs from G1, G2, and G3 generations.

MATERIALS AND METHODS

Study site: The study was conducted at Baba Ali experimental sheep farm, owned by Technical Institute of Breeding (ITElv), Algiers, Algeria.

Study population and flock management: The dataset included growth performance and survival records from birth to weaning (90 days) of 314 crossbred lambs from crosses between D and OD breeds

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These lambs were produced in the previous study (Sebkhi *et al.* 2024), following the crossbreeding scheme adopted between the local sheep breeds D and OD and were grouped into three genetic categories based on breed composition:

- G1 : 127 lambs (50% OD genes and 50% D genes);
- G2 : 87 lambs (75% OD genes and 25% D genes);
- G3 : 100 lambs (37.5% OD genes and 62.5% D genes).

Dam ewes were fed *ad libitum* oat hay (with a refusal rate of approximately 20%) and 600 g/day of a concentrated feed during the 90-day lactation period twice daily.

Data collection and traits considered: Data were collected over nine years (2013–2021). Body weight was recorded at birth and every 21 days up to 105 days using electronic scales with an accuracy of ± 10 g. Weights at 10, 30, and 90 days were estimated by linear interpolation. Average daily gains (ADG) were calculated for the periods 0–30 days, 30–90 days, and 0–90 days. Lamb survival was monitored at birth and at weaning (90 days).

Statistical analysis: Growth traits (weights and ADG) were analyzed using a multivariate general linear model (GLM) in SPSS software (Version 24.0., IBM Corp, Armonk, NY). The model included fixed effects of:

- Genetic type (3 levels: G1, G2, G3);
- Year of birth (9 levels: 2013–2021);
- Type of birth (3 levels: single, twin, triplet);
- Lamb sex (2 levels: male, female);

- Ewe parity (2 levels: primiparous, multiparous);
- Ewes body condition score (BCS) (4 levels: 2–2.5, 2.5–3, 3–3.5, 3.5–4).

Ewe live weight (DamWeight) was included as a continuous covariate.

Results are presented as estimated marginal means $\pm$ standard error (SE) adjusted for the covariate. Multiple comparisons were performed using the Bonferroni correction, and differences were considered statistically significant at $p < 0.05$. The interaction between genotype and year of birth was tested. Because lambs were distributed across three successive generations corresponding to different birth periods (G1: 2013–2015, G2: 2016–2018, G3: 2019–2021), this interaction was partly confounded with generation effects. Therefore, genotype effects cannot be completely separated from year/management effects.

Lamb survival at birth and at weaning (binary outcome: 0 = dead, 1 = alive) was analyzed using binary logistic regression. Odds ratios (OR) with 95% confidence intervals (CI) are reported. The same fixed effects and covariate (DamWeight) were included in the model.

RESULTS AND DISCUSSION

Growth performance: The results relating to growth performance of crossbred lambs according to different factors of variation are reported in Tables 1 and 2.

Effect of genetic type: G2 crossbred lambs with 75%

Table 1. Adjusted means $\pm$ standard errors of crossbred lamb weights according to variation factors

Factor / Level	N	Weight at birth (kg)	Weight at 30 days (kg)	Weight at 90 days (kg)
Genotype (<i>p-value</i>)	283	(0.520)	(<0.001)	(<0.001)
G1	109	3.76 $\pm$ 0.09a	8.19 $\pm$ 0.21c	15.20 $\pm$ 0.40b
G2	86	3.60 $\pm$ 0.09a	10.90 $\pm$ 0.23a	21.17 $\pm$ 0.43a
G3	88	3.66 $\pm$ 0.08a	9.08 $\pm$ 0.20b	15.97 $\pm$ 0.39b
BirthYear (<i>p-value</i>)	283	(0.001)	(<0.001)	(<0.001)
2013	31	3.85 $\pm$ 0.14ab	8.45 $\pm$ 0.34bc	15.34 $\pm$ 0.66de
2014	47	3.73 $\pm$ 0.11ab	8.18 $\pm$ 0.27c	16.99 $\pm$ 0.51bcd
2015	31	3.73 $\pm$ 0.16ab	7.99 $\pm$ 0.39bc	12.91 $\pm$ 0.75e
2016	20	3.63 $\pm$ 0.18ab	12.56 $\pm$ 0.43a	26.66 $\pm$ 0.82a
2017	22	4.17 $\pm$ 0.21a	12.27 $\pm$ 0.51a	20.25 $\pm$ 0.98b
2018	44	3.36 $\pm$ 0.11b	9.45 $\pm$ 0.27b	18.63 $\pm$ 0.52bc
2019	36	3.28 $\pm$ 0.13b	8.41 $\pm$ 0.32bc	15.21 $\pm$ 0.61de
2020	18	3.90 $\pm$ 0.16 ab	9.38 $\pm$ 0.38bc	17.48 $\pm$ 0.72bcd
2021	34	3.78 $\pm$ 0.14 ab	9.37 $\pm$ 0.35bc	15.36 $\pm$ 0.67de
Sex (<i>p-value</i>)	283	(0.005)	(0.022)	(0.002)
Male	150	3.81 $\pm$ 0.06a	9.54 $\pm$ 0.16a	17.94 $\pm$ 0.3a
Female	133	3.56 $\pm$ 0.06b	9.05 $\pm$ 0.15b	16.67 $\pm$ 0.29b
BirthType (<i>p-value</i>)	283	(<0.001)	(<0.001)	(<0.001)
Single	181	4.09 $\pm$ 0.06a	10.53 $\pm$ 0.14a	19.72 $\pm$ 0.27a
Twin	96	3.21 $\pm$ 0.08b	7.76 $\pm$ 0.19b	14.05 $\pm$ 0.40b
Triplet	6	2.82 $\pm$ 0.25b	7.50 $\pm$ 0.61b	16.01 $\pm$ 1.16b
Parity (<i>p-value</i>)	283	(0.661)	(<0.001)	(<0.001)

Table 1 Contd...

Table 1 concluded

Factor / Level	N	Weight at birth (kg)	Weight at 30 days (kg)	Weight at 90 days (kg)
Primiparous	100	3.72 ± 0.08	10.13 ± 0.2a	19.09 ± 0.38a
Multiparous	183	3.67 ± 0.07	8.83 ± 0.16b	16.32 ± 0.31b
BCS (<i>p-value</i>)	283	(0.059)	(0.017)	(0.011)
2 - 2.5	88	3.89 ± 0.10a	10.02 ± 0.25a	18.60 ± 0.48a
2.5 - 3	133	3.73 ± 0.07a	9.28 ± 0.16a	17.34 ± 0.31a
3 - 3.5	41	3.40 ± 0.12a	8.95 ± 0.30ab	16.82 ± 0.57a
3.5 - 4	21	3.42 ± 0.22a	7.78 ± 0.54b	14.10 ± 1.03b ¹

Table 2. Adjusted means ± standard errors of ADGs of crossbred lambs according to the factors of variation

Factor / Level	N	ADG (0-30) (g/j)	ADG (30-90) (g/j)	ADG (0-90) (g/j)
Genotype (<i>p-value</i>)	283	(<0.001)	(<0.001)	(<0.001)
G1	109	147.53 ± 6.26c	116.86 ± 4.84b	127.09 ± 4.22b
G2	86	243.18 ± 6.67a	171.14 ± 5.17a	195.15 ± 4.50a
G3	88	180.51 ± 5.97b	114.92 ± 4.62b	136.78 ± 4.03b
BirthYear (<i>p-value</i>)	283	(<0.001)	(<0.001)	(<0.001)
2013	31	153.32 ± 10.16c	114.97 ± 7.87cde	127.75 ± 6.86de
2014	47	148.50 ± 7.95c	146.72 ± 6.15bc	147.31 ± 5.36bcd
2015	31	141.82 ± 11.57c	82.09 ± 8.96e	102.00 ± 7.81e
2016	20	297.88 ± 12.65a	235.00 ± 9.79a	255.96 ± 8.53a
2017	22	270.12 ± 15.18a	132.99 ± 11.75bcde	178.70 ± 10.24b
2018	44	203.14 ± 8.10b	153.04 ± 6.27b	169.74 ± 5.46bc
2019	36	171.19 ± 9.49bc	113.35 ± 7.35de	132.63 ± 6.40de
2020	18	182.80 ± 11.16bc	134.94 ± 8.64bcd	150.90 ± 7.53bcd
2021	34	186.26 ± 10.34bc	99.83 ± 8.01de	128.64 ± 6.98de
Sex (<i>p-value</i>)	283	(0.199)	(0.01)	(0.009)
Male	150	191.20 ± 4.64a	139.96 ± 3.59a	157.04 ± 3.13a
Female	133	182.96 ± 4.52a	127.13 ± 3.50b	145.74 ± 3.05b
BirthType (<i>p-value</i>)	283	(<0.001)	(<0.001)	(<0.001)
Single	181	214.76 ± 4.14a	153.14 ± 3.20a	173.69 ± 2.79a
Twin	96	151.73 ± 5.65b	104.82 ± 4.31b	120.46 ± 3.75b
Triplet	6	155.86 ± 17.93b	141.77 ± 13.88a	146.47 ± 12.09ab
Parity (<i>p-value</i>)	283	(<0.001)	(<0.001)	(<0.001)
Primiparous	100	213.90 ± 5.91a	149.29 ± 4.57a	170.83 ± 3.98a
Multiparous	183	172.27 ± 4.72a	124.85 ± 3.65b	140.65 ± 3.18b
BCS (<i>p-value</i>)	283	(0.031)	(0.122)	(0.014)
2 - 2.5	88	204.19 ± 7.49a	142.91 ± 5.80a	163.33 ± 5.05a
2.5 - 3	133	185.01 ± 4.76a	134.36 ± 3.68a	151.24 ± 3.21a
3 - 3.5	41	185.01 ± 8.82a	131.08 ± 6.83a	149.05 ± 5.95a
3.5 - 4	21	145.17 ± 16.02b	105.40 ± 12.41a	118.66 ± 10.81b ¹

OD breed genes, despite having a slightly lower birth weight ($p>0.05$), at 30 days of age, had a significantly higher weight ($p<0.001$) than G1 and G3 generations, which carried 50% and 37.5% of the same OD genes,

respectively. This improved performance is probably due to better milk production in G2 mothers during the first 30 days of lactation (1.67 ± 0.05 kg/day) compared to those of G1 (1.21 ± 0.04 kg/day) and G3 (1.31 ± 0.04 kg/day) (Sebkhi

et al. unpublished data).

In sheep, there is a high positive correlation between lamb growth and milk consumption (Craplet *et al.* Thibier, 1984). Prache *et al.* (1986), Purroy (1995) and Ünal *et al.* (2007) also emphasized that, regardless of breed, lamb growth up to 45 days of age depends largely on birth weight and milk production in terms of quantity and quality. Beyond 30 days, this correlation decreases, with growth compensating for the decline in lactation through increased consumption of solid feed (Jaime and Purroy 1995).

In our study, growth rate decreased with age from 243.18 ± 6.67 g/day, 147.53 ± 6.26 g/day, and 180.51 ± 5.97 g/day for G2, G1, and G3 during the first 30 days to 171.14 ± 5.17 g/day, 116.86 ± 4.84 g/day, and 114.92 ± 4.62 g/day between 30 and 90 days, respectively with significant superiority ($p < 0.001$) for G2. These observations supported the major role of ewe milk during the early suckling period (Jarrige, 1988) and the progressive influence of the quality of substitute foods (Soltner, 1993).

Compared to purebred parent breeds, lambs from the G2 and G3 generations showed markedly higher viability from birth to weaning, with 100% for G2 and 97.83% for G3, compared to 94% for the OD breed (Benyounes *et al.* 2013) and 90.4% for the D breed (Boubekeur 2017). The birth weight of G2 generation lambs (3.6 kg) was comparable to that of the pure OD breed (3.63 kg; Titaouine 2015) and notably higher than that of lambs of the D breed 1.8 kg and 2.6 kg as reported by Chellig (1992) and Boubekeur (2017), respectively. Furthermore, the average weights of G2 lambs at 30 days (10.90 kg) and 90 days (21.17 kg) far exceeded those of the founding OD (9.5 kg at 30 days and 16.92 kg at 90 days; Titaouine 2015) and D breeds (7.92 kg at 30 days and 17.39 kg at 90 days, Boubekeur, 2017), suggesting beneficial association of breed composition/crossbreeding with pre-weaning.

The favorable effect of OD genes, combined with hybrid vigor (heterosis), observed in the G2 generation (+15.57%, +25.14%, +23.4% respectively for birth weight, weight at 30 days and 90 days of age), could also explain the better weight and survival performance of lambs obtained in G2. The effect of genetic type on lamb growth and survival has been reported by other authors (Mallick *et al.* 2017, Muller *et al.* 2023, Behrem *et al.* 2025).

Year of birth: The lambing year had a highly significant effect ($p < 0.01$) on overall weight performance of the lambs. The elevated weight performance observed between 2016 and 2018 compared to 2013–2015 and 2019–2021 could be explained by the coincidence with the G2 generation, which showed the best results. The lower performance in the other periods coincided with the G1 and G3 generations, respectively, suggesting possible genetic effect and creating a confounding between genotype and year. Therefore, it is not possible to fully separate the effect of genotype from the effect of year, management, or environmental conditions. The effect of year of birth on lamb growth has also been reported in other studies (Gül *et al.* 2020, Noyan and Ceyhan 2021, Tamer and Şirin 2021, Behrem *et al.* 2025).

Lamb sex: The analysis showed that male lambs were significantly ($p < 0.05$) heavier than female lambs, with a difference of +0.25 kg in birth weight, +0.49 kg in weight at 30 days of age, and +1.27 kg in weight at 90 days of age, representing a difference in average daily gain (ADG) of +8.24 g/day (0–30 days), +12.83 g/day (30–90 days), and +16.91+11.3 g/day (0–90 days).

The effect of sex on lamb performance is a general phenomenon reported by several authors (Aktaş *et al.* 2015, Noyan and Ceyhan, 2021, Habtegiorgis *et al.* 2022, Muller *et al.* 2023, Legesse et Alemayehu 2024, Behrem *et al.* 2025). This superior growth observed in male lambs compared to female lambs could be explained by a more efficient endocrine system, particularly the differential role of hormones such as testosterone and estrogen. Testosterone stimulates growth in males, while estrogen tends to limit bone development in females (Assan 2020).

Lamb birth type: Single-born lambs achieved significantly higher weights, average and daily gains ($p < 0.001$) compared to twin and triplet births. This superiority is particularly evident in the +0.88 and +1.27 kg for birth weight, +2.77 and +3.03 kg at 30 days, +5.67 and +3.71 kg at 90 days, and +53.23 and +27.22 g/day for ADG (0–90 days) compared to twins and triplets, respectively. These results were consistent with several studies (Dekhili 2003, Gbangboche *et al.* 2005, Rekik *et al.* 2007, Merghem 2008, El Fadili *et al.* 2009, Noyan and Ceyhan 2021, Behrem *et al.* 2025). The lower milk supply in multiple litters could explain this phenomenon, while single lambs benefited from better nutritional and maternal conditions (Morris and Kenyon 2004, Thomson *et al.* 2004, Mefti Korteby *et al.* 2017).

Parity: Consistent with several previous studies (Di *et al.* 2011, Aktaş *et al.* 2015, Li *et al.* 2022, Behrem *et al.* 2025), our study revealed a significant effect of parity ($p < 0.05$) on growth performance. Lambs born to primiparous females even showed an advantage at weaning (+2.77 kg, corresponding to an ADG of +30.18 g over the 0–90 day period). This difference could be attributed to genetic variability among the studied groups. In contrast, studies on lambs from German Blackhead Meat $\times$ Karacabey Merino and Lori-Bakhtiari crosses found no significant effect of maternal age on growth (Ceyhan *et al.* 2009, Vatankhah and Talebi, 2009).

Body condition score (BCS) / weight of dam: Ewes with a BCS between 2 and 3.5 tended to show improved weight at 90 days of age (+25.4%) and average daily gain (0–90 days) (+30.59%) compared to ewes with a BCS above 3.5. Atti et Abdennabi (1995) showed that maternal body condition at lambing directly affects birth and weaning weights. Our results suggested that while improving body condition is beneficial overall, excessive condition can be detrimental to weight performance and survival.

Viability performance: The results concerning the viability of crossbred lambs at birth and at weaning according to the different sources of variation are presented in Tables 3 and 4.

Table 3. Binary logistic regression model fit for lamb viability

Outcome	N	-2 Log Likelihood	Cox & Snell R ²	Nagelkerke R ²	Model χ^2	df	p-value	Hosmer–Lemeshow p-value	Overall classification
Survival at birth	314	46.679	0.161	0.582	55.204	16	<0.001	0.504	97.1%
Survival at weaning	302	82.519	0.132	0.388	42.629	16	<0.001	0.973	95.7%

Table 4. Adjusted effects of fixed factors and maternal weight covariate on lamb viability

Effect type	Factor	Reference category	Global p-value at birth	Global p-value at weaning
Fixed factor	Genotype	G1	0.972	<0.001
	Birth year	2013	0.783	<0.001
	Sex	Male	0.113	0.136
	Birth type	Single	0.006	<0.001
	Parity	Primiparous	0.094	0.836
	BCS	2–2.5	0.160	0.173
Covariate	Dam weight	Continuous	0.759	0.0098

BCS: Body condition score. Global p-values are shown as birth / weaning. Where SPSS returned unstable parameter estimates, interpretation is based on the omnibus test and the most reliable category contrasts rather than on extreme OR values.

Lamb viability varied according to the outcome considered and the factors included in the adjusted model. At birth, the model was significant and well calibrated, and birth type was the main factor associated with viability, whereas genotype, year of birth, sex, parity, and BCS were not globally significant after adjustment for dam weight. At weaning, the model was also significant and well fitted, with genotype, year of birth, birth type, and dam weight showing the clearest associations with viability.

The most consistent pattern was the adverse effect of multiple births: twins and triplets had lower viability than single-born lambs. In contrast, sex and BCS did not show a robust global effect in either analysis. Because dam weight was fitted as a covariate, these effects should be interpreted as adjusted associations, i.e. after accounting for maternal weight.

The mortality observed in our study, mainly among multiple lambs born to young females, can be explained by their low birth weight and reduced vitality. The survival of lambs in the first hours after birth is influenced by many factors, including maternal nutrition during gestation (Everett-Hincks *et al.* 2005a), the quality of lambing (Barlow *et al.* 1987), maternal behavior (Everett-Hincks *et al.* 2005b), and lamb behavior (Dwyer *et al.* 2004), as well as the physical environment of the birthplace (Mellor and Stafford 2004). Not only does physical condition at birth influence subsequent behavior (Dwyer *et al.* 2004), but also survival, with low birth weight leading to increased vulnerability (Roux 1989).

These results suggested that lamb viability was influenced by both perinatal conditions and maternal characteristics. The poorer survival of lambs from multiple births was biologically plausible, as multiple fetuses usually

face stronger intrauterine competition and a higher risk of neonatal weakness. The effect of year of birth probably reflected differences in management, environmental conditions, health status, or feeding practices across years.

The significant adjusted association of dam weight with survival at weaning suggested that maternal body size or reserves might contribute to postnatal lamb performance, possibly through milk production and maternal ability. The absence of a consistent effect of sex, parity, and BCS indicated that these factors were weaker in this dataset or partly masked by the structure of the data. Overall, the results supported the conclusion that birth type is the most robust determinant of early viability, while genotype and maternal weight become more relevant at weaning.

A limitation of this analysis reported convergence problems and redundancy warnings, which means that some category-specific estimates may be unstable. Therefore, interpretation should rely primarily on the omnibus tests and the most reliable adjusted effects rather than on extreme odds ratios.

The results of the present study showed that alternating genetic crossbreeding between the local Ouled Djellal and D'man breeds can improve the viability and growth performance of lambs, particularly for the second generation (G2), which carries 75% of Ouled Djellal genes. The positive influence of non-genetic factors on lamb growth, such as lambing order or year, sex, mode of birth, and body condition of ewes highlighted the importance of appropriate management to optimize these performances. The results also suggested that lamb viability was influenced not only by genetic background but also by non-genetic factors, especially birth type and maternal weight, while year, sex, parity, and body condition score may contribute

depending on the stage considered. The Ouled Djellal breed, recognized as the most prized by Algerian breeders among local breeds, and with high growth potential appears to be an excellent candidate for strengthening local sheep breeding systems for meat production. Further studies on the fourth generation (G4) and later generations, as well as on multiple flocks exposed to different environmental conditions, are indicated before such a breeding strategy can be proposed.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the technical and administrative staff of ITelv Baba Ali for their invaluable support throughout the study.

FUNDING

Directorate General for Scientific Research and Technological Development (Algeria)

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