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REGULAR ARTICLES

Some morphological characteristics, growth performance and survival rate in Gurcu goat kids

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Abstract
In this study, the growth performance, some morphological traits, and survival rate of Gurcu goat kids were investigated. The study consisted of 40 Gurcu kids monitored for nine months. Dam age (DA) affected only birth weight, while sex and birth type (BT) were effective from days 90 and 15, respectively. The average live weights of Gurcu kids at birth, and at day 90, and day 270 were 2.49 kg, 24.7 kg, and 32.9 kg, respectively. Sex (from 165 days) and BT (from 45 days) influenced body length. Both sex and BT affected withers height at several stages of growth, whereas sex had a stronger effect on rump height. The effect of DA on chest depth was significant between birth and 30 days of age, and BT significantly affected chest circumference after 60 days. The effect of sex on head length was significant from day 60, and that of BT from day 75 (including day 15). After 60 days, both sex and BT influenced forehead length. Birth type had a stronger effect on testicular measurements than DA, particularly on scrotal volume, which was affected at almost all stages of growth. Strong correlations were found between live weight and measured morphological traits. The overall survival rate of Gurcu goat kids was 88.09%. In conclusion, the effect of DA on the studied traits was limited, whereas sex and BT had more pronounced influences. Male and single-born kids were more advantageous in terms of growth and several morphological characteristics.

Keywords Gurcu goat · Kids · Morphological characteristics · Live weight

Introduction

Goat and sheep farming in Türkiye is predominantly carried out in the Southeastern, Mediterranean, and Aegean regions. The main reasons for its prevalence in these areas include the economic and social structure of farmers involved in animal husbandry, traditional livestock preferences, and the geographical features of the region (Gundemir et al. 2023; Kuru and Boğa Kuru 2020; Özdemir and Keskin 2018). Goat farming, which is a primary livelihood for low-income families, can be conducted under pasture-based or intensive conditions. Goats effectively utilize pastures and grazing lands and can graze comfortably in hilly and mountainous areas. Compared to other animal species, goats can graze on steep hills and slopes, making them suitable for regions where agricultural activities are minimal. Additionally, goats are preferred because they can consume plants that other animals do not eat (Kaymakçı 2013; Kuru and Boğa Kuru 2020; Yahia et al. 2024). Although small ruminant production is most intensive in the southern regions of Türkiye, several locally adapted goat breeds such as the Gurcu goat are maintained in the northeastern provinces, particularly Kars and Ardahan, due to their strong adaptation to harsh climate and pasture conditions.

The Gurcu goat is one of the local genetic resources in Türkiye that has adapted to very challenging conditions in terms of the region where it is bred, its climate, and terrain (Sezgin et al. 2010). Currently, their numbers have

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significantly decreased. However, it is believed that promoting their breeding could open up a new source of income for the region (Kuru et al. 2017).

The Gurcu goat, originating from the Caucasus region, is also known locally as the Tiflis goat and internationally as the Caucasian goat (Batu 1951; Kuru and Boğa Kuru 2020). Although once more widespread, this breed has undergone a marked decline over recent decades, and only small remnant populations are currently maintained in limited areas of the Kars province and the Çıldır district of Ardahan (Daskiran et al. 2018; Yilmaz et al. 2012). According to the most recent national statistics, the goat population in Türkiye increased from 5.1 million in 2009 to a peak of 12.3 million in 2021, before slightly declining to 10.8 million in 2024 (TÜİK 2024). This updated national information supports the continued relevance of local goat breeds within the livestock sector. Furthermore, recent national syntheses examining goat production systems in Türkiye provide comprehensive insights into the structural and socio-economic importance of the sector (Daskiran et al. 2018). Unlike many goat breeds raised in Türkiye, Gurcu goats have high adaptability not only to mountainous areas but also to plain and pasture conditions (Kuru and Boğa Kuru 2020).

Gurcu goats typically come in black, grey, and white colors. They are descended from the wild goat species *Capra falconeri*, which is characterized by distinctive spiral horns (Batu 1951; Kuru et al. 2024; Ölmez et al. 2020; Sezgin et al. 2010; Yilmaz et al. 2012). Gurcu goats are characterized by their high withers and robust build. Their coat structure and ear and tail shapes can resemble those of Angora goats. Gurcu goats typically have drooping ears, though some may have ears that point sideways and upwards (Batu 1951; Kuru et al. 2017; Sezgin et al. 2010). It has been reported that Gurcu goats are primarily hornless, with very few horned females (Batu 1951). Their body weight ranges from 40 to 55 kg (Kuru et al. 2018, 2024). When considering general body measurements of Gurcu goats, their wither height is approximately 71.8 cm, body length 73 cm, chest circumference 85.2 cm, shin circumference 9.4 cm, tail length 18.9 cm, ear length 15.25 cm, and ear width 7.3 cm (Batu 1951; Kuru and Boğa Kuru 2020). Gurcu goats typically lactate for about 5 months with a daily milk yield of 1.5 kg (Batu 1951; Sezgin et al. 2010; Yilmaz et al. 2012). The estrus period lasts approximately 31.9 h, and gestation lasts 150 ± 3 days in Gurcu goats (Kuru et al. 2017). Around 40% of births are twins, and about 5% are triplets. After estrus synchronization practices, Gurcu goats have shown increased rates of triplet births (Kuru et al. 2017; Kuru and Boğa Kuru 2020). Neonatal mortality among kids born to Gurcu goats is reported to be approximately 6.25% (Kuru et al. 2017). Existing studies on the growth and development characteristics of the Gurcu goat are limited in scope, despite the breed's strong adaptation to the harsh climatic conditions of the region and its potential as an alternative to cattle farming. In addition, the data obtained from these goats raised under such challenging environmental conditions can be compared with those of other local breeds. Although one recent study has reported body weight and withers height up to 12 months of age at 2–3-month intervals (Boğa Kuru et al. 2024), detailed longitudinal assessments based on more frequent sampling—particularly monthly tracking of morphometric traits during the critical early growth period up to 9 months—are still lacking. This gap highlights the need for more comprehensive evaluations of growth patterns in this local breed.

Material and method

Ethical approval

Approval for this study was received from the Kafkas University Animal Experiments Ethics Committee (KAÜ-HADYEK/2020 − 178), Kars, Türkiye. Moreover, the necessary authorization was received from the Kafkas University Faculty of Veterinary Medicine, Prof. Dr. Ali Rıza Aksoy Education-Research and Application Farm (Session no: 2020/2021-07, Decision no: 16).

Location and environmental conditions

The present study was conducted in the Education-Research and Application Farm, which is affiliated with the Faculty of Veterinary Medicine of Kafkas University in Kars province, Türkiye.

The geographical coordinates of the research site are 40°34'23" N and 43°02'27" E, with an altitude of 1751 m above sea level. The region has a harsh continental climate characterized by long, cold winters and short, mild summers. Annual climatic averages recorded in the study area include winter temperatures frequently falling below − 20 °C, summer temperatures reaching up to 30–32 °C, relative humidity ranging between 50 and 90%, and daylight duration varying from 9.5 h in winter to more than 15 h in summer.

The study was carried out between September 2021 and June 2022, covering both indoor (winter) and outdoor (pasture) management periods. During the cold season (November–March), goats were kept in a closed barn system equipped with natural ventilation through adjustable side windows and ridge openings. The barn had a concrete floor covered with straw bedding, which was refreshed regularly, and stocking density was kept at approximately 1.5–2 m^2 per animal. During the warm months (April–October), the

goats grazed on pasture during the day and were kept in sheltered barns at night. Water was provided ad libitum throughout the year.

Kids were housed with their mothers in a sheltered barn during the neonatal period. From birth to 3 months of age, kids were kept in group pens with dry bedding and adequate natural ventilation; thereafter, from 3 to 9 months, they were maintained in larger pens with access to outdoor areas depending on weather conditions. During extremely cold winter nights, supplemental heating was provided in the kid barn to prevent cold stress, and bedding depth was increased to improve thermal comfort.

Animal material

Forty clinically healthy, multiparous purebred Gurcu goats, aged 3–4 years, weighing 40–50 kg with a body condition score of 3.0–3.5, were selected from the same herd at the Kafkas University Education, Research and Application Farm. The Gurcu goat is a local breed originating from the Caucasus region and is characterized by its adaptability to harsh climatic conditions and medium-sized body structure. All eligible animals within this age group were included to ensure representativeness under uniform management conditions.

A total of 40 goats underwent estrus synchronization. Of these, 30 became pregnant and were included in the study, while 10 goats were excluded for the following reasons: seven did not conceive, one experienced early embryonic loss, one expelled the intravaginal sponge prematurely, and one did not accept mating despite showing estrus behavior.

From the 30 pregnant does, a total of 45 kids were born (15 single-born and 30 twin-born; 20 females and 25 males). Of these, 40 kids (14 single-born and 26 twin-born; 18 females and 22 males) survived and were included in the longitudinal growth analyses.

Prior to the commencement of the study, all goats received endoparasitic treatment (250 mg Oxfendazole and 750 mg Oxyclozanide, Okzan-F®, Ceva, Türkiye) and ectoparasitic treatment (10 mg Ivermectin and 100 mg Clorsulon, Avromec-Fac®, Topkim, Türkiye). Additionally, the newborn kids underwent regular antiparasitic and vaccination procedures according to farm protocols.

Table 1 Content and composition of the concentrated feed that goats and kids are fed

Ingredient	%	
Goats		
Barley	28.00	
Wheat bran	16.65	
Corn	40.00	
Cottonseed meal (38 CP)	6.00	
Soybean meal (48 CP)	5.28	
Marble dust	2.77	
Salt	1.00	
Vitamin-mineral premix*	0.30	
Ingredient, g/kg DM	**0–3 months**	**3–9 months**
Kids		
Meadow hay	0.140	0.200
Barley	0.050	0.100
Corn	0.030	0.200
Sunflower oil	0.001	0.050
Wheat bran	0.050	0.050
Molasses, beet	0.010	0.010
Cottonseed meal, 37%	0.050	0.030
Soybean meal, 44%	0.070	0.090
Dicalcium phosphate	0.001	-
Limestone	0.001	0.013
Salt	0.001	0.001
Vitamin-mineral premix*	0.001	0.001
Calculated nutrient content, %DM		
ME, kcal/kg	2565	2825
Crude protein, %	19.80	17.60
Ca, %	0.99	0.89
P, %	0.45	0.40

DM: Dry matter, ME: Metabolizable energy. *: Contents of vitamin and mineral premix in 1 kg: 100 g of Na, 33 mg of I, 7 mg of Ca, 27 mg of Se, 3,000 mg of Fe, 2,660 mg of Mn, 167 mg of Cu, 10,000 mg of α-tocopherol, 300,000 IU of cholecalciferol, and 3,000,000 IU of retinol

Feeding

During the cold months (November to March), the goats were housed indoors due to the severe winter conditions of Eastern Anatolia, whereas during the warmer months they grazed on pasture during the day and were kept in closed barns at night. Newborn kids were also brought into the barn at night during warm months while spending the daytime on pasture.

During the indoor feeding period, meadow hay and wheat straw were offered ad libitum, while concentrate feed was provided in fixed daily amounts according to the farm's standard protocol. In line with the nutritional program of the Kafkas University Research Farm, kids received approximately 140 g of meadow hay and 261 g of concentrate feed per head per day from 0 to 3 months, and 200 g of meadow hay and 530 g of concentrate feed per head per day from 3 to 9 months. The ingredient composition and nutritional values of the concentrate ration (barley, corn, soybean meal, sunflower meal, and vitamin–mineral premix; 16% crude protein and 2700 kcal/kg ME) are presented in Table 1. Water was supplied *ad libitum* to all goats and kids throughout the study.

Individual feed intake was not recorded; refusals were monitored at the group level. As the aim of the study was to evaluate growth performance under routine farm conditions

rather than quantify feed efficiency, detailed individual consumption measurements were not collected.

It should be noted that goats were allowed to graze on pasture during daytime whenever weather conditions permitted, which may naturally introduce variation in individual activity and forage intake. Additionally, as the study was conducted in a university application farm operating under controlled management practices, the findings may not fully reflect conditions in commercial herds.

Estrus synchronization protocol and pregnancy diagnosis

To synchronize kidding, the goats were synchronized during the breeding season (September). Progesterone-containing sponges (60 mg medroxyprogesterone acetate, Esponjavet®, Hipra, Türkiye) were inserted on day 0. On day 5, 500 IU of equine chorionic gonadotropin (eCG, Oviser®, Hipra, Türkiye) was administered intramuscularly. On day 7, the sponges were removed, and prostaglandin F2 alpha (12.5 mg dinoprost, Dinolytic®, Zoetis, Türkiye) was administered immediately after sponge removal. Teaser bucks were introduced into the herd every 6 h for approximately 30 min to monitor estrus. Does that allowed mounting (standing estrus) were identified as being in estrus and were immediately separated from the herd and transferred to the pens containing breeding bucks for mating. All dates and times of estrus detection and mating were recorded (Kuru and Boğa Kuru 2024).

Goats confirmed to have mated underwent transrectal ultrasonography between days 30–35 post-mating using a 5-7.5 MHz ultrasound device (Draminski iScan®, Draminski, Poland). Pregnancy was confirmed by the visualization of the embryo within the uterine lumen (Kuru et al. 2018).

A total of 40 does underwent estrus synchronization during the breeding season. Of these, 38 (95.0%) exhibited estrus, while one doe expelled the progesterone sponge prematurely and one failed to show estrus. Among the 38 does that exhibited estrus, 30 conceived, resulting in a conception rate of 78.9% and a pregnancy rate of 75.0% based on all synchronized does. One doe experienced early embryonic loss (3.2%), and no abortions were observed throughout gestation. A total of 30 does kidded, corresponding to a kidding rate of 75.0%.

Determining live weight, morphological characteristics, and survival rates

For the monitored kids, live weight and morphological characteristics (body length, withers height, rump height, chest depth, chest circumference, head length, forehead length, front and rear shin circumference, testicular diameter, testicular length, scrotal volume) were determined starting from their birthday and subsequently measured every 15 days for the first 6 months, and monthly from 6 months to 9 months of age.

A 15-day measurement interval was chosen during the first 6 months to capture the rapid early-life growth dynamics typical of goat kids, especially in local breeds for which detailed growth curves are lacking. After 6 months of age, when growth rate slows, a monthly interval was considered sufficient and methodologically appropriate.

Live weight was recorded using a digital livestock scale, while linear body measurements were obtained with a flexible tape measure with the kids standing calmly on a flat surface. All measurements were taken by the same trained operator to minimize inter-observer variability. Testicular diameter and length were measured using a tape measure, and scrotal volume was determined using the water displacement method based on Archimedes' principle, by submerging the testes in a graduated cylinder and recording the displaced water volume (Kulaksiz et al. 2020).

All weighing and measurements were conducted in the morning, immediately before feeding. Kids were not fasted prior to measurements; however, measurements were performed before the first daily feeding to minimize variation related to rumen fill.

During the study, five kids died: four within the first month of life (three due to neonatal diarrhea and one due to inadequate maternal milk production) and one at six months of age due to pneumonia. For this study, neonatal mortality was defined as death occurring within the first 30 days of life. Kid survival was monitored daily by farm staff and the research team, and all deaths were recorded in the farm journal along with clinical observations.

All kids were recorded at birth (birth type, sex, and body weight); however, complete morphometric follow-up data were only available for the 40 surviving kids. Therefore, repeated-measures growth analyses were performed using these 40 kids, and the low, mostly disease-related mortality is unlikely to have introduced substantial survivorship bias.

Statistical analysis

In the study, the monitored live weight and some morphological characteristics were reported as mean ± standard deviation (SD). Data were determined to follow a normal distribution based on Shapiro-Wilk tests conducted on measurement days. The effects of dam age, gender, and birth type on the examined traits were evaluated using General Linear Model (GLM).

The GLM used to assess fixed effects was structured as follows:

$$Y_{ijk} = \mu + S_i + BT_j + DA_k + (S \times BT)_{ij} + (S \times DA)_{ik} + (BT \times DA)_{jk} + (S \times BT \times DA)_{ijk} + e_{ijk}$$

where.

- $\mathbf{Y_{(ijk)}}$ = observed trait (live weight or morphological measurement),
- **μ** = overall mean,
- **Si** = fixed effect of sex,
- $\mathbf{BT_j}$ = fixed effect of birth type,
- $\mathbf{DA_k}$ = fixed effect of dam age,
- $\mathbf{e_{(ijk)}}$ = random error term.

All main factors (sex, birth type, dam age) and their possible interaction terms (sex × birth type, sex × dam age, birth type × dam age, and sex × birth type × dam age) were initially included in the model. However, none of the interaction terms were statistically significant across measurement days; therefore, the interpretation focused on the main effects.

Coefficients of variation (CV%) for each trait were calculated using the formula CV = (SD / mean) × 100, and reported in the summary table to illustrate the extent of variability within traits.

Pearson correlation coefficients were used to determine relationships among traits, and only valid measurement pairs were included in the correlation analysis. Statistical analysis was performed using SPSS® (Version 26.0, SPSS Inc./IBM Group, Chicago, IL, USA). Results with $P<0.05$ were considered statistically significant.

Results

Growth performance and body length

The variation in growth performance of kids according to sex and birth type is presented in Table 2. Dam age had a significant effect on the birth weight of kids ($P<0.05$). Sex affected live weight gain in kids from day 90 onwards ($P<0.05$), meaning that the difference between males and females became significant beginning at day 90 and remained significant thereafter. In addition, birth type influenced live weight from day 15 onwards ($P<0.05$), indicating that single-born and twin-born kids started to differ in weight beginning on day 15.

The average birth weight of Gurcu goat kids was 2.49 kg, and their average live weights at day 90, day 180, and day 270 of age were 13.7 kg, 24.7 kg, and 32.9 kg, respectively (Table 2).

Sex had a significant effect on body length from day 165 onward ($P<0.05$), whereas birth type affected body length from day 45 onward. Maternal age had no statistically significant effect on body length at any measurement time ($P>0.05$, Table 2).

Live weight gain

Dam age did not significantly affect daily live weight gain in goat kids at any measurement time. However, sex had a significant effect on daily live weight gain from day 90 onward ($P<0.05$), indicating that differences between males and females emerged beginning at day 90. Birth type significantly influenced daily live weight gain at all measurement times ($P<0.05$), with single-born and twin-born kids differing consistently throughout the study period (Table 3).

Withers and rump height

Dam age significantly affected withers height at both birth and day 60 ($P<0.05$). Sex had a significant effect on withers height on all measurement days except birth, day 15, and day 45 ($P<0.05$). Birth type significantly influenced withers height at all measurement days except birth and day 15 ($P<0.05$, Table 4).

For rump height, dam age had a significant effect at birth ($P<0.05$). Birth type significantly affected rump height at day 75 ($P<0.05$). Sex had significant effects on rump height at day 30, between day 60 and day 90, and from day 165onward ($P<0.05$, Table 4).

Chest depth and circumference

In goat kids, dam age significantly affected chest depth from birth until day 30. Sex influenced chest depth only day 270 ($P<0.05$). Birth type demonstrated significant effects on chest depth starting from day 30 onward ($P<0.05$, Table 5).

For chest circumference, dam age had significant effects at day 15, day 30, day 60, day 75, day 180, and day 210 ($P<0.05$). Sex significantly affected chest circumference from day 180 onward ($P<0.05$). Birth type had a statistically significant effect on chest circumference from day 60 onward ($P<0.05$, Table 5).

Head and forehead length

Sex had a significant effect on head length from day 60 onward ($P<0.05$). Birth type significantly affected head length from day 75 onward. The effect of dam age on head length was not significant at any measurement time ($P>0.05$, Table 6).

Table 2 Effect of dam age, sex, and birth type on live weight and body length between measurements in different growth periods of Gurcu goat kids

Days	Dam age (year)		Sex		Birth type		Significance			Overall ($n=40$)
	3 ($n=19$)	4 ($n=21$)	Female ($n=18$)	Male ($n=22$)	Single ($n=14$)	Twin ($n=26$)	Dam age	Sex	Birth type	
Live weight (kg)										
Birth	2.29±0.40	2.68±0.28	2.46±0.29	2.53±0.46	2.53±0.27	2.47±0.44	*	-	-	2.49±0.38
15	4.37±0.66	4.60±0.69	4.29±0.60	4.65±0.72	4.75±0.71	4.35±0.63	-	-	*	4.49±0.68
30	6.42±0.93	6.47±0.94	6.31±0.91	6.56±0.94	6.91±0.91	6.20±0.85	-	-	*	6.45±0.93
45	8.75±2.24	8.24±1.18	8.09±1.15	8.61±1.71	9.03±1.56	8.03±1.36	-	-	**	8.38±1.49
60	10.38±2.59	10.44±1.95	10.03±1.54	10.72±2.68	11.59±2.40	9.77±1.92	-	-	**	10.45±2.21
75	11.69±3.46	11.88±2.43	11.36±1.93	12.15±3.55	13.51±2.97	10.87±2.50	-	-	**	11.79±2.93
90	13.61±5.06	13.79±3.13	13.00±2.66	14.28±4.98	16.04±4.28	12.44±3.47	-	*	**	13.70±4.11
105	15.13±6.26	15.05±3.52	14.16±3.03	15.85±6.06	18.04±5.18	13.50±4.09	-	*	**	15.08±4.95
120	16.18±6.78	16.30±3.75	15.16±3.35	17.14±6.47	19.54±5.56	14.48±4.36	-	*	**	16.25±5.33
135	18.17±7.36	18.57±4.00	17.08±3.58	19.44±6.98	22.14±5.88	16.36±4.66	-	*	**	18.38±5.77
150	20.45±7.15	20.61±3.82	18.67±3.38	22.06±6.67	24.29±5.78	18.51±4.36	-	**	**	20.54±5.58
165	22.65±6.48	22.98±3.33	21.34±3.19	24.03±5.92	26.40±4.74	20.90±4.06	-	**	**	22.82±5.01
180	24.39±6.15	24.91±34.24	22.73±3.24	26.25±5.95	28.74±4.65	22.47±4.03	-	***	***	24.67±5.17
210	27.39±6.00	27.83±4.20	25.32±3.10	29.50±5.64	31.75±4.47	25.40±3.89	-	***	***	27.62±5.02
240	29.82±5.37	30.40±4.34	28.34±3.22	31.58±5.42	34.16±4.28	27.95±3.51	-	**	***	30.12±4.80
270	32.65±5.05	33.02±4.16	31.29±3.06	34.12±5.20	36.58±4.23	30.84±3.31	-	**	***	32.85±4.55
Body length (cm)										
Birth	23.50±1.81	24.02±2.18	23.92±1.89	23.66±2.13	23.57±2.16	23.88±1.95	-	-	-	23.78±2.00
15	33.32±2.83	34.07±1.87	33.33±2.06	34.02±2.62	34.64±2.25	33.21±2.33	-	-	-	33.71±2.38
30	37.66±2.66	38.21±2.06	37.11±1.50	38.64±2.71	38.43±2.23	37.69±2.41	-	-	-	37.95±2.35
45	41.00±1.98	41.90±2.87	40.83±2.01	42.00±2.78	42.71±2.75	40.81±2.12	-	-	*	41.48±2.50
60	44.66±3.97	45.38±3.86	44.28±2.87	45.66±4.52	47.57±4.04	43.67±3.08	-	-	**	45.04±3.88
75	45.97±4.57	47.69±4.05	46.61±3.53	47.09±4.98	49.82±4.50	45.29±3.37	-	-	**	46.88±4.34
90	47.53±5.38	48.95±4.63	47.72±3.96	48.73±5.74	51.86±4.86	46.35±3.93	-	-	***	48.28±4.99
105	49.13±6.06	50.62±4.83	49.69±4.11	50.09±6.41	54.04±5.28	47.69±4.11	-	-	***	49.91±5.43
120	50.95±5.96	52.17±5.44	50.81±4.16	52.23±6.66	55.89±5.54	49.27±4.23	-	-	***	51.59±5.65
135	53.11±5.66	53.98±5.09	52.72±3.86	54.25±6.27	57.50±5.24	51.44±4.06	-	-	***	53.56±5.32
150	55.21±6.56	55.79±5.90	54.25±4.12	56.55±7.35	59.50±6.92	53.37±4.51	-	-	**	55.51±6.15
165	56.82±5.94	57.52±5.38	55.92±3.57	58.23±6.73	60.89±6.25	55.19±4.07	-	*	**	57.19±5.59
180	58.58±5.73	59.40±4.93	57.28±3.04	60.43±6.29	62.18±5.91	57.31±4.07	-	*	*	59.01±5.27
210	60.66±5.27	61.40±4.65	59.25±2.64	62.52±5.83	63.86±5.51	59.54±3.87	-	**	***	61.05±4.91
240	62.47±4.20	63.12±4.31	61.19±2.86	64.14±4.72	65.96±4.61	61.12±2.84	-	**	***	62.81±4.21
270	63.47±4.12	64.21±4.21	62.17±2.50	65.25±4.70	67.00±4.85	62.17±2.43	-	**	***	63.86±4.13

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

Forehead length was significantly affected by dam age at day 30 and between day 60 and day 90 ($P<0.05$). After day 60, both sex and birth type had a statistically significant effect on forehead length ($P<0.05$, Table 6).

Front and rear shin circumference

Dam age significantly affected front shin circumference only at day 240 ($P<0.05$). Sex had a statistically significant effect on front shin circumference from day 165 onwards ($P<0.05$). Birth type significantly influenced front shin circumference at birth, day 75, day 135, and from day 165 onward ($P<0.05$, Table 7).

Dam age did not affect rear shin circumference at any measurement time ($P>0.05$). However, sex had a significant effect on rear shin circumference from day 165 onward ($P<0.05$). Birth type showed a statistically significant effect on rear shin circumference from day 30 onward, except at day 75 ($P<0.05$, Table 7).

Testicular measurements

In Gurcu goat kids, dam age significantly affected testicular diameter from day 90 to day 150, except at day 135 ($P<0.05$). Birth type significantly influenced testicular diameter at day 105 and from day 210 to day 270.

Testicular length was affected by the dam age only at day 60 ($P<0.05$). Birth type had a significant effect on testicular length from day 210 to day 270 ($P<0.05$).

Scrotal volume was significantly affected by the dam age at day 45 and day 60. Birth type influenced scrotal volume at

Table 3 Effect of dam age, sex, and birth type on daily and monthly live weight gain until measurement

Ages	Dam age (year)		Sex		Birth type		Significance			Overall (n=40)
	3 (n=19)	4 (n=21)	Female (n=18)	Male (n=22)	Single (n=14)	Twin (n=26)	Dam age	Sex	Birth type	
Days	**Daily live weight gain between measurements (g)**									
Birth-15	139.06±25.86	127.56±41.04	122.08±31.63	141.97±35.27	148.29±38.91	124.79±29.89	-	-	*	133.02±34.73
15–30	150.90±47.34	124.92±31.39	134.18±43.18	127.30±26.72	143.61±33.15	123.28±34.12	-	-	-	130.40±34.77
30–45	138.95±80.26	117.59±45.87	118.19±42.29	135.55±78.44	139.57±78.31	121.36±56.51	-	-	-	127.73±64.57
45–60	124.49±74.93	147.56±83.01	129.81±69.85	142.15±87.22	172.57±82.36	117.23±71.60	-	-	*	136.60±79.13
60–75	87.93±76.84	96.03±68.09	88.74±70.66	95.00±73.80	128.00±59.51	72.90±70.99	-	-	*	92.18±71.55
75–90	126.60±118.35	126.89±103.64	109.41±107.50	140.94±111.41	168.24±115.01	104.41±101.56	-	*	-	126.75±109.42
90–105	101.33±87.77	83.97±58.26	76.67±49.85	104.94±87.12	132.86±85.89	70.33±55.88	-	-	**	92.22±73.30
105–120	71.40±42.13	83.65±58.57	67.41±40.29	86.36±58.11	100.48±65.16	65.64±37.85	-	-	-	77.83±51.16
120–135	132.63±63.99	150.79±68.61	128.15±44.14	153.64±79.16	173.33±70.60	125.39±58.45	-	*	-	142.17±66.24
135–150	151.75±76.11	136.67±90.96	105.93±50.98	174.85±92.79	144.05±75.20	143.72±89.11	-	*	-	143.83±83.51
150–165	147.02±88.60	157.46±70.37	177.96±77.03	131.67±75.38	140.47±91.99	158.97±71.64	-	*	-	152.50±78.68
165–180	115.96±52.41	129.20±120.11	92.59±48.35	147.73±113.36	155.71±112.25	105.26±78.16	-	-	-	122.92±93.33
180–210	199.82±93.01	194.60±97.29	172.59±87.01	217.12±96.84	200.95±108.88	195.00±87.37	-	-	-	197.08±94.09
210–240	162.11±94.33	171.11±96.66	201.48±78.07	138.48±98.80	160.95±79.65	170.00±102.89	-	-	-	166.83±94.44
240–270	188.77±57.31	175.24±74.75	196.67±49.64	169.39±76.67	160.95±65.99	192.82±65.37	-	-	-	181.67±66.54
Days	**Daily live weight gain (g) until measurement**									
Birth-15	139.06±25.86	127.56±41.04	122.08±31.63	141.97±35.27	148.29±38.91	124.79±29.89	-	-	*	133.02±34.73
Birth-30	137.76±23.76	126.24±29.28	128.13±31.07	134.64±23.70	145.95±24.96	124.04±25.42	-	-	*	131.71±27.09
Birth-45	138.15±33.40	123.35±24.96	124.81±25.29	134.94±32.97	143.83±31.65	123.14±26.69	-	-	*	130.38±29.84
Birth-60	134.74±38.32	129.41±32.25	126.07±25.02	136.74±41.26	151.01±38.75	121.67±28.39	-	-	**	131.94±34.90
Birth-75	125.38±42.40	122.73±32.11	118.60±24.48	128.40±44.67	146.41±38.65	111.91±30.20	-	-	**	123.99±36.88
Birth-90	125.58±53.22	123.42±35.19	117.07±28.87	130.48±53.38	150.05±46.80	110.66±36.45	-	*	**	124.45±44.08
Birth-105	122.12±57.20	117.79±33.81	111.30±28.17	126.84±56.09	147.59±48.73	104.90±37.14	-	*	**	119.84±45.84
Birth-120	115.78±54.37	113.52±31.37	105.81±27.44	121.78±52.38	141.70±45.53	99.99±34.74	-	*	**	114.59±43.25
Birth-135	117.65±52.76	117.66±29.71	108.29±26.00	125.32±50.43	145.22±42.73	102.82±33.27	-	*	***	117.66±41.68
Birth-150	121.06±46.12	119.56±25.54	108.06±22.04	130.27±42.66	145.10±37.78	106.90±27.95	-	**	***	120.27±36.29
Birth-165	123.42±37.71	123.01±20.13	114.41±18.80	130.40±34.61	144.68±24.95	111.64±23.34	-	**	***	123.20±29.40
Birth-180	122.80±32.85	123.52±23.41	112.59±17.62	131.84±31.95	145.60±24.98	111.11±21.40	-	***	***	123.18±27.91
Birth-210	119.53±27.37	119.78±19.90	108.84±14.32	128.52±25.89	139.15±20.53	109.16±17.59	-	***	***	119.66±23.43
Birth-240	114.72±21.46	115.50±18.11	107.82±13.10	121.11±22.03	131.82±17.25	106.14±14.13	-	**	***	115.13±19.52
Birth-270	112.46±18.00	112.40±15.55	106.77±11.11	117.06±18.92	126.11±15.18	105.06±12.06	-	**	***	112.43±16.54
Months	**Monthly live weight gain (kg)**									
Birth-1	4.13±0.71	3.79±0.88	3.84±0.93	4.04±0.71	4.38±0.75	3.72±0.76	-	-	*	3.95±0.81
Birth-2	4.04±1.15	3.88±0.97	3.78±0.75	4.10±1.24	4.53±1.16	3.65±0.85	-	-	**	3.96±1.05
Birth-3	3.77±1.60	3.70±1.06	3.51±0.87	3.91±1.60	4.50±1.40	3.32±1.09	-	*	**	3.73±1.32
Birth-4	3.48±1.63	3.41±0.94	3.18±0.82	3.66±1.57	4.25±1.37	3.00±1.04	-	*	**	3.44±1.30
Birth-5	3.63±1.38	3.59±0.77	3.24±0.66	3.91±1.28	4.35±1.13	3.21±0.84	-	**	***	3.61±1.09
Birth-6	3.68±0.99	3.71±0.70	3.38±0.53	3.96±0.96	4.37±0.75	3.33±0.64	-	***	***	3.70±0.84
Birth-7	4.18±0.96	4.19±0.70	3.81±0.50	4.50±0.91	4.87±0.72	3.82±0.62	-	***	***	4.19±0.82
Birth-8	4.59±0.86	4.62±0.72	4.31±0.52	4.84±0.88	5.27±0.69	4.25±0.57	-	**	***	4.60±0.78
Birth-9	5.06±0.81	5.06±0.70	4.80±0.50	5.27±0.85	5.68±0.68	4.73±0.54	-	**	***	5.06±0.74

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

Table 4 Effect of dam age, sex, and birth type on withers height and rump height

Days	Dam age (year)		Sex		Birth type		Significance			Overall ($n=40$)
	3 ($n=19$)	4 ($n=21$)	Female ($n=18$)	Male ($n=22$)	Single ($n=14$)	Twin ($n=26$)	Dam age	Sex	Birth type	
Withers height (cm)										
Birth	26.61±2.83	28.55±2.29	27.42±2.59	27.80±2.85	27.82±3.28	27.52±2.42	*	-	-	27.63±2.71
15	33.05±2.70	34.36±1.71	33.42±1.83	34.00±2.64	34.63±2.52	33.25±2.07	-	-	-	33.74±2.30
30	36.87±1.93	37.56±2.06	36.44±1.70	37.88±2.04	38.21±2.18	36.70±1.72	-	**	*	37.23±2.00
45	39.55±2.01	40.83±2.58	39.72±1.71	40.64±2.79	41.75±2.53	39.40±1.88	-	-	**	40.23±2.38
60	41.11±2.33	43.17±2.40	41.50±2.12	42.75±2.79	43.50±2.78	41.48±2.17	*	*	*	42.19±2.56
75	42.66±3.78	44.45±2.68	42.81±2.16	44.25±3.98	45.39±4.31	42.64±2.21	-	*	*	43.60±3.33
90	44.79±3.93	45.98±3.61	44.44±2.28	46.20±4.55	47.29±4.57	44.40±2.94	-	*	*	45.41±3.77
105	46.00±4.60	47.33±3.83	45.83±2.63	47.41±5.12	49.43±4.51	45.23±3.28	-	*	**	46.70±4.22
120	47.39±4.51	48.74±3.85	46.97±2.68	49.02±4.96	51.04±4.14	46.52±3.30	-	*	**	48.10±4.18
135	48.58±4.44	49.88±4.00	48.08±2.65	50.23±5.01	51.96±4.23	47.81±3.48	-	*	**	49.26±4.21
150	50.21±5.16	51.36±3.84	49.39±2.31	51.98±5.48	53.68±4.69	49.27±3.61	-	*	**	50.81±4.49
165	51.34±4.78	53.48±3.81	50.94±2.24	53.70±5.29	55.25±4.57	50.96±3.52	-	*	**	52.46±4.38
180	52.55±4.70	54.81±3.89	51.92±2.23	55.23±5.16	56.36±4.44	52.33±3.73	-	**	**	53.74±4.39
210	54.24±4.62	56.67±3.87	53.53±2.49	57.14±4.92	58.61±4.79	53.85±3.09	*	***	***	55.51±4.36
240	57.13±4.94	58.93±4.17	55.69±2.66	60.02±4.94	61.39±4.62	56.29±3.49	-	***	***	58.08±4.58
270	58.97±4.90	60.50±4.59	57.17±2.70	61.91±5.02	63.00±4.88	58.04±3.70	-	***	***	59.78±4.74
Rump height (cm)										
Birth	28.63±2.98	30.26±2.08	29.31±2.47	29.64±2.83	29.96±2.82	29.23±2.57	*	-	-	29.49±2.65
15	34.21±2.63	35.14±2.11	34.39±2.08	34.95±2.63	35.18±2.53	34.44±2.31	-	-	-	34.70±2.39
30	38.24±2.05	38.45±1.89	37.75±1.68	38.84±2.04	39.25±1.71	37.87±1.92	-	*	-	38.35±1.95
45	40.95±1.86	41.88±2.16	41.00±1.82	41.80±2.19	42.79±2.06	40.71±1.66	-	-	-	41.44±2.05
60	42.76±1.77	43.90±2.57	42.61±1.88	43.98±2.43	44.07±2.78	42.98±1.91	-	*	-	43.36±2.28
75	44.63±3.34	45.43±3.06	44.28±2.16	45.68±3.75	46.32±4.34	44.37±2.14	-	*	*	45.05±3.18
90	46.58±3.58	47.40±3.66	46.11±2.23	47.75±4.33	48.68±4.55	46.12±2.65	-	*	-	47.01±3.60
105	47.89±4.30	48.21±3.94	47.39±2.56	48.61±4.96	50.25±4.69	46.88±3.19	-	-	-	48.06±4.06
120	48.97±4.81	49.33±4.19	48.44±2.74	49.75±5.45	51.36±5.25	47.98±3.51	-	-	-	49.16±4.44
135	50.21±4.95	50.86±4.06	49.92±2.71	51.07±5.51	52.71±5.19	49.38±3.60	-	-	-	50.55±4.46
150	52.03±5.30	52.55±4.02	51.53±2.88	52.93±5.65	54.39±5.31	51.17±3.85	-	-	-	52.30±4.62
165	53.63±5.29	54.43±3.82	52.94±2.65	54.94±2.65	55.75±5.25	53.13±3.91	-	*	-	54.05±4.54
180	54.79±4.67	55.71±3.86	54.03±2.62	56.30±5.03	57.07±4.69	54.31±3.71	-	*	-	55.28±4.23
210	56.82±4.43	57.60±3.85	55.53±2.28	58.61±4.75	59.43±4.62	56.04±3.31	-	**	-	57.23±4.10
240	58.63±4.24	59.07±3.79	57.00±2.61	60.39±4.28	61.32±4.27	57.54±3.14	-	***	-	58.86±3.96
270	59.95±4.47	60.57±4.27	58.06±2.59	62.09±4.64	62.64±4.72	59.00±3.56	-	***	-	60.28±4.32

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

all measurement times except day 15 and day 150 ($P<0.05$, Table 8).

Summary of significant fixed effects and trait variability

To provide a clearer and more concise overview of the statistical findings, a summary table was prepared (Table 9). This table compiles all statistically significant fixed effects ($P<0.05$) of dam age, sex, and birth type across the examined growth and morphological traits. In addition, the overall mean and coefficient of variation (CV%) for each trait are presented to illustrate the extent of variability within the population. This summary offers an integrated view of how the main factors influenced different traits throughout the study period and helps improve the readability of the Results section.

Survival rate

The survival rate of the kids was 91.1% (41/45) at day 30 and 97.6% (40/41) at day 180. No additional mortalities occurred after day 180. Mortality in the first 30 days consisted of two male twin kids and two female twin kids, while one male single-born kid died at day 180 due to pneumonia. The overall survival rate of Gurcu goat kids at day 270 was 88.9% (40/45).

Table 5 Effect of dam age, sex, and birth type on chest depth and chest circumference

Days	Dam age (year)		Sex		Birth type		Significance			Overall ($n=40$)
	3 ($n=19$)	4 ($n=21$)	Female ($n=18$)	Male ($n=22$)	Single ($n=14$)	Twin ($n=26$)	Dam age	Sex	Birth type	
Chest depth (cm)										
Birth	9.82±1.23	10.74±1.17	10.22±1.10	10.36±1.42	10.64±1.41	10.12±1.18	*	-	-	10.30±1.27
15	12.66±1.26	13.62±1.02	13.14±1.12	13.18±1.33	13.89±1.33	12.77±0.98	*	-	**	13.16±1.23
30	15.13±1.33	16.19±1.10	15.83±1.41	15.57±1.25	16.43±1.04	15.29±1.29	*	-	**	15.69±1.31
45	16.42±1.36	17.43±1.34	17.22±1.67	16.73±1.18	17.82±0.97	16.48±1.43	-	-	**	16.95±1.43
60	17.74±1.38	18.40±1.19	18.11±1.11	18.07±1.48	19.04±1.29	17.58±1.03	-	-	***	18.09±1.31
75	18.39±1.64	19.24±1.35	18.83±1.22	18.84±1.53	19.86±1.47	18.29±1.28	-	-	**	18.84±1.53
90	18.87±1.62	19.81±1.26	19.17±1.11	19.52±1.77	20.25±1.66	18.89±1.19	-	-	**	19.36±1.50
105	19.66±1.80	20.60±1.54	20.00±1.15	20.27±2.09	21.36±1.78	19.50±1.30	-	-	**	20.15±1.71
120	20.50±2.32	21.40±1.73	20.72±1.41	21.18±2.48	22.36±2.02	20.23±1.68	-	-	**	20.98±2.05
135	21.55±2.66	22.45±1.88	21.69±1.41	22.30±2.84	23.39±2.57	21.29±1.80	-	-	**	22.03±2.30
150	22.37±2.75	23.07±1.97	22.28±1.33	23.11±2.94	24.14±2.63	21.98±1.86	-	-	**	22.74±2.37
165	23.16±2.52	23.76±2.00	22.97±1.36	23.89±2.75	24.82±2.52	22.75±1.76	-	-	**	23.48±2.26
180	23.89±2.38	24.69±1.71	23.83±1.11	24.70±2.57	25.43±2.78	23.71±1.71	-	-	*	24.31±2.07
210	24.79±2.11	25.74±1.48	24.92±1.13	25.59±2.26	26.32±1.75	24.73±1.68	-	-	*	25.29±1.85
240	25.79±1.64	26.45±1.62	25.69±1.34	26.50±1.80	27.50±1.30	25.40±1.31	-	-	***	26.14±1.64
270	26.45±1.67	26.95±1.77	26.25±1.46	27.09±1.86	28.25±1.11	25.89±1.40	-	*	***	26.71±1.72
Chest circumference (cm)										
Birth	30.00±2.09	30.76±1.12	30.64±1.38	30.20±1.89	30.68±1.03	30.25±1.94	-	-	-	30.40±1.68
15	35.84±2.30	37.74±2.50	36.58±2.37	37.05±2.75	38.11±2.36	36.15±2.44	*	-	*	36.84±2.56
30	40.84±2.77	42.95±2.49	42.03±2.35	41.89±3.18	42.93±2.64	41.42±2.80	*	-	-	41.95±2.81
45	45.16±3.18	46.86±3.19	45.78±2.89	46.27±3.58	47.25±3.16	45.40±3.18	-	-	-	46.05±3.26
60	47.03±3.39	49.88±3.62	48.06±4.37	48.91±2.37	50.79±3.80	47.31±3.18	*	-	**	48.53±3.76
75	48.79±4.00	51.45±3.77	49.78±3.58	50.52±4.47	52.46±3.94	48.96±3.63	*	-	*	50.19±4.06
90	50.34±5.06	53.07±5.24	50.67±3.69	52.68±6.22	54.57±6.12	50.27±4.14	-	-	*	51.78±5.27
105	52.18±6.11	54.55±4.66	52.25±3.96	54.39±6.36	56.14±5.90	51.96±4.69	-	-	*	53.43±5.46
120	53.76±7.04	55.71±5.06	53.67±4.53	55.70±7.08	57.57±6.48	53.28±5.40	-	-	*	54.79±6.08
135	55.95±7.48	58.31±5.15	55.83±4.88	58.30±7.33	60.00±6.59	55.67±5.86	-	-	*	57.19±6.39
150	58.21±7.71	60.33±4.81	58.14±4.99	60.30±7.27	62.04±5.97	57.87±6.19	-	-	*	59.33±6.36
165	61.00±7.03	63.69±3.69	61.22±4.18	63.39±6.51	65.46±4.93	60.77±5.36	-	-	*	62.41±5.62
180	62.53±6.28	65.86±3.54	62.94±4.08	65.36±5.90	67.39±4.26	62.60±5.01	*	*	**	64.28±5.24
210	65.55±4.90	68.45±3.66	65.67±3.59	68.23±4.88	70.46±3.88	65.25±3.69	*	**	***	67.08±4.48
240	68.53±3.68	70.95±4.15	68.64±3.43	70.75±4.37	73.71±2.61	67.69±3.02	-	*	***	69.80±4.07
270	69.95±3.74	72.00±4.41	69.61±3.45	72.18±4.44	74.96±2.84	68.90±3.12	-	**	***	71.03±4.18

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

Correlation

Strong positive correlations were found between body weight and all major morphological traits at day 270 ($P<0.01$, Table 10). In particular, chest circumference, body length, and withers height showed the highest correlations coefficients with body weight in both male and female kids ($P<0.01$, Table 10). Similar strong correlations were also detected within both single-born and twin-born kids (Table 10).

Discussion

Gurcu goats, originating from the Caucasus and classified among Türkiye's local breeds, have successfully adapted to harsh geographical conditions and severe climates of their habitat (Kuru et al. 2017; Sezgin et al. 2010). Similar to other geographically restricted local breeds, limited ecological adaptation areas and harsh climatic stressors have contributed to their numerical decline over time (Kuru and Boğa Kuru 2020; Sezgin et al. 2010). Unfortunately, the numbers of this local breed have shown a rapid decline in recent years. Conservation and support programs have been implemented to mitigate this decline. Such preservation approaches are also emphasized for other endangered local goat breeds in the region (Kheirabadi and Rashidi 2019). For comparison with other local breeds, Gurcu goats

Table 6 Effect of dam age, sex, and birth type on head length and forehead length

Days	Dam age (year)		Sex		Birth type		Significance			Overall ($n=40$)
	3 ($n=19$)	4 ($n=21$)	Female ($n=18$)	Male ($n=22$)	Single ($n=14$)	Twin ($n=26$)	Dam age	Sex	Birth type	
Head length (cm)										
Birth	10.90±0.70	11.05±0.69	11.11±0.74	10.86±0.64	11.07±0.70	10.92±0.69	-	-	-	10.98±0.69
15	12.19±0.95	12.29±1.18	12.31±1.23	12.18±0.92	12.75±1.01	11.96±0.99	-	-	*	12.24±1.06
30	13.55±0.59	13.47±0.89	13.53±0.74	13.50±0.76	13.71±0.91	13.40±0.62	-	-	-	13.51±0.74
45	14.24±0.93	14.29±0.79	14.08±0.75	14.41±0.92	14.46±0.69	14.15±0.92	-	-	-	14.26±0.85
60	14.93±1.31	15.11±1.51	14.36±1.15	15.55±1.36	15.50±1.59	14.75±1.22	-	*	-	15.01±1.39
75	15.36±1.42	15.50±1.21	14.78±0.91	15.95±1.37	16.14±1.34	15.04±1.34	-	**	**	15.43±1.31
90	15.64±1.39	15.79±1.43	15.03±0.85	16.27±1.51	16.64±1.05	15.21±1.31	-	***	***	15.71±1.39
105	16.17±1.38	16.11±1.39	15.61±0.68	16.57±1.64	17.00±1.09	15.67±1.29	-	**	**	16.14±1.37
120	16.67±2.00	16.61±1.90	15.78±1.31	17.34±2.10	17.89±1.43	15.96±1.84	-	**	***	16.64±1.93
135	17.36±2.03	17.58±2.20	16.56±1.50	18.20±2.23	18.96±1.49	16.65±1.92	-	*	***	17.46±2.09
150	17.81±1.94	18.16±2.60	17.00±1.38	18.77±2.53	19.68±2.02	17.06±1.82	-	**	***	17.98±2.25
165	18.43±1.93	18.63±2.29	17.64±1.25	19.25±2.36	20.00±1.86	17.73±1.76	-	**	***	18.53±2.08
180	18.79±1.99	19.08±2.15	17.89±1.36	19.77±2.15	20.25±1.93	18.21±1.76	-	**	***	18.93±2.05
210	19.81±1.76	19.92±1.91	19.06±1.19	20.52±1.98	20.68±2.04	19.42±1.53	-	**	*	19.86±1.81
240	20.17±1.71	20.26±1.81	19.31±1.13	20.95±1.82	21.00±2.03	19.79±1.43	-	***	*	20.21±1.74
270	20.62±1.75	20.84±1.83	19.64±1.16	21.61±1.70	21.71±1.95	20.19±1.44	-	***	**	20.73±1.77
Forehead length (cm)										
Birth	5.97±0.60	6.13±0.74	6.00±0.59	6.09±0.73	6.29±0.73	5.92±0.61	-	-	-	6.05±0.67
15	6.88±0.47	6.87±0.37	6.83±0.45	6.91±0.40	7.07±0.33	6.77±0.43	-	-	-	6.88±0.42
30	7.10±0.46	7.29±0.35	7.11±0.44	7.25±0.40	7.36±0.41	7.10±0.40	*	-	-	7.19±0.42
45	7.36±0.59	7.63±0.66	7.31±0.46	7.64±0.73	7.79±0.80	7.33±0.45	-	-	-	7.49±0.64
60	7.55±0.65	7.95±0.78	7.50±0.62	7.93±0.78	8.25±0.87	7.46±0.47	*	*	**	7.74±0.73
75	7.64±0.69	8.00±0.87	7.56±0.59	8.02±0.88	8.39±0.96	7.50±0.45	*	**	***	7.81±0.79
90	7.86±0.78	8.13±0.80	7.69±0.57	8.23±0.87	8.54±0.95	7.69±0.49	*	**	**	7.99±0.79
105	7.97±0.89	8.16±0.96	7.69±0.69	8.36±0.98	8.64±1.12	7.75±0.60	-	**	*	8.06±0.91
120	7.98±0.97	8.24±0.93	7.72±0.60	8.41±1.08	8.79±1.19	7.73±0.51	-	**	**	8.10±0.95
135	8.33±0.97	8.37±1.14	7.97±0.78	8.66±1.14	9.11±1.16	7.94±0.70	-	**	**	8.35±1.04
150	8.36±1.11	8.61±1.47	7.83±0.51	9.00±1.48	9.46±1.60	7.95±0.62	-	***	***	8.48±1.28
165	8.62±1.07	8.87±1.37	8.14±0.48	9.23±1.41	9.71±1.42	8.21±0.65	-	***	***	8.74±1.21
180	8.71±1.07	9.05±1.30	8.17±0.49	9.45±1.27	9.88±1.49	8.44±0.68	-	***	***	8.88±1.18
210	9.12±1.24	9.37±1.18	8.44±0.57	9.89±1.20	10.00±1.30	8.83±0.94	-	***	***	9.24±1.20
240	9.38±1.24	9.58±1.08	8.61±0.58	10.18±1.03	10.14±1.25	9.12±0.95	-	***	***	9.48±1.16
270	9.52±1.36	9.68±1.00	8.78±0.65	10.27±1.12	10.36±1.28	9.19±0.94	-	***	***	9.60±1.19

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

are considered a geographically restricted population with limited published data on their growth and development. Previous studies have reported only baseline morphological descriptions and small-scale evaluations for this breed (Kuru et al. 2017; Kuru and Boğa Kuru 2020). This study aimed to determine some morphological characteristics, growth performance, and survival rates in Gurcu goat kids. There are very few more comprehensive studies on growth, development characteristics, and morphological data specific to Gurcu goats (Kuru et al. 2017; Kuru and Boğa Kuru 2020). Given the scarcity of detailed studies on this breed, the present findings offer new baseline values that may assist both scientific documentation and practical flock management.

Growth performance

Birth weight can be effective in predicting early growth performance in goats (Atta et al. 2024; Tekin and Arlı 2019). The birth and weaning weights of Damani kids were 2.71 kg and 6.50 kg, respectively, and the growth rates of these kids at day 150, day 210, and day 270 were 12.01 kg, 16.30 kg, and 23.56 kg, respectively. High birth weights were directly associated with increased growth rates in later periods (Din et al. 2019). For comparison, birth weight and day 270 live weight of Teddy goats were 1.66 kg and 16.69 kg, respectively (Kuthu et al. 2013), while these values were 2.81 kg and 15.70 kg, respectively, in Mehsana goats (Patel and Pandey 2013). Indian local breeds of goats live weights at birth and day 270 are between 1.30 and 3.00 kg and 8.80–24.00 kg, respectively (Hegde and Deo 2020). While the

Table 7 Effect of dam age, sex, and birth type on front Shin and Rear Shin length

Days	Dam age (year)		Sex		Birth type		Significance			Overall ($n=40$)
	3 ($n=19$)	4 ($n=21$)	Female ($n=18$)	Male ($n=22$)	Single ($n=14$)	Twin ($n=26$)	Dam age	Sex	Birth type	
Front shin (cm)										
Birth	5.76±0.39	5.76±0.41	5.64±0.41	5.86±0.35	5.61±0.40	5.85±0.37	-	-	*	5.76±0.39
15	6.13±0.23	6.24±0.30	6.14±0.29	6.23±0.25	6.14±0.31	6.21±0.25	-	-	-	6.19±0.27
30	6.61±0.39	6.67±0.40	6.56±0.38	6.70±0.40	6.71±0.43	6.60±0.37	-	-	-	6.64±0.39
45	6.89±0.54	7.12±0.50	7.03±0.47	7.00±0.58	7.14±0.57	6.94±0.50	-	-	-	7.01±0.52
60	7.00±0.41	7.21±0.46	7.11±0.37	7.11±0.51	7.29±0.47	7.02±0.41	-	-	-	7.11±0.45
75	7.16±0.41	7.26±0.54	7.14±0.38	7.27±0.55	7.46±0.50	7.08±0.42	-	-	*	7.21±0.48
90	7.29±0.38	7.40±0.58	7.33±0.49	7.36±0.52	7.57±0.51	7.23±0.45	-	-	-	7.35±0.50
105	7.26±0.54	7.50±0.55	7.33±0.45	7.43±0.62	7.61±0.49	7.27±0.55	-	-	-	7.39±0.55
120	7.50±0.44	7.67±0.58	7.53±0.47	7.64±0.56	7.79±0.51	7.48±0.50	-	-	-	7.59±0.52
135	7.63±0.50	7.83±0.66	7.67±0.49	7.80±0.67	8.07±0.58	7.56±0.52	-	-	*	7.74±0.59
150	7.74±0.61	7.93±0.69	7.67±0.49	7.98±0.75	8.18±0.70	7.65±0.56	-	-	*	7.84±0.65
165	7.89±0.54	8.12±0.71	7.78±0.46	8.20±0.70	8.32±0.58	7.85±0.61	-	*	*	8.01±0.64
180	7.97±0.54	8.21±0.66	7.81±0.42	8.34±0.64	8.43±0.65	7.92±0.52	-	**	*	8.10±0.61
210	8.24±0.45	8.40±0.60	8.03±0.47	8.57±0.47	8.68±0.42	8.13±0.50	-	***	**	8.33±0.54
240	8.32±0.34	8.57±0.60	8.17±0.42	8.68±0.45	8.82±0.46	8.25±0.41	*	***	***	8.45±0.50
270	8.50±0.55	8.69±0.64	8.28±0.49	8.86±0.56	9.07±0.51	8.35±0.49	-	***	***	8.60±0.60
Rear shin (cm)										
Birth	5.76±0.45	5.76±0.34	5.72±0.35	5.80±0.43	5.64±0.41	5.83±0.37	-	-	-	5.76±0.39
15	6.13±0.28	6.19±0.29	6.17±0.30	6.16±0.28	6.21±0.26	6.13±0.30	-	-	-	6.16±0.29
30	6.50±0.44	6.67±0.40	6.58±0.39	6.59±0.45	6.86±0.31	6.44±0.41	-	-	**	6.59±0.42
45	6.84±0.58	7.02±0.49	6.94±0.45	6.93±0.60	7.25±0.47	6.77±0.49	-	-	*	6.94±0.53
60	6.95±0.47	7.10±0.52	6.97±0.40	7.07±0.56	7.32±0.46	6.87±0.44	-	-	*	7.03±0.49
75	7.13±0.52	7.21±0.56	7.08±0.46	7.25±0.59	7.43±0.43	7.04±0.55	-	-	-	7.18±0.54
90	7.32±0.61	7.33±0.53	7.25±0.52	7.39±0.60	7.68±0.50	7.13±0.50	-	-	**	7.33±0.56
105	7.24±0.65	7.36±0.48	7.28±0.49	7.32±0.63	7.61±0.45	7.13±0.56	-	-	*	7.30±0.56
120	7.34±0.53	7.50±0.59	7.36±0.54	7.48±0.59	7.79±0.51	7.23±0.49	-	-	**	7.43±0.56
135	7.53±0.59	7.69±0.60	7.50±0.45	7.70±0.68	7.96±0.60	7.42±0.50	-	-	*	7.61±0.59
150	7.68±0.63	7.88±0.69	7.61±0.44	7.93±0.78	8.21±0.67	7.56±0.54	-	-	**	7.79±0.66
165	7.92±0.53	8.10±0.82	7.67±0.42	8.30±0.75	8.39±0.63	7.81±0.65	-	**	*	8.01±0.69
180	8.03±0.56	8.07±0.69	7.72±0.43	8.32±0.65	8.50±0.65	7.81±0.47	-	***	***	8.05±0.63
210	8.24±0.42	8.29±0.64	7.92±0.39	8.55±0.49	8.64±0.50	8.06±0.45	-	***	***	8.26±0.54
240	8.32±0.38	8.40±0.66	8.03±0.47	8.64±0.44	8.79±0.43	8.13±0.46	-	***	***	8.36±0.54
270	8.39±0.49	8.52±0.64	8.08±0.39	8.77±0.51	8.89±0.49	8.23±0.47	-	***	***	8.46±0.57

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

birth weights of male and female Angora kids in goats were 2.45 kg and 2.32 kg, respectively (Şenyüz 2021), the average birth weights were 2.9 kg in Saanen goats (Ceyhan and Karadağ 2009), 2.01 kg in Sekota goats (Deribe and Taye 2013) and 3.02 kg in Hair goat kids (Tekin and Öğeç 2017). Similarly, recent studies on Hair goats raised under breeder conditions in Türkiye reported birth weights between 2.7 and 3.2 kg, supporting the range observed in our study (Erdoğan et al. 2023; Güngör et al. 2021). The birth weights determined in our study were generally compatible with the values reported in previous studies, falling within the mid-range of these published values.

It should not be forgotten that genetic factors are important for growth performance and productivity of kids. The growth performance of different goat breeds varies significantly accordingly. Depending on the genotype, both birth and weaning weights may vary in kids (Yıldırır et al. 2019). Similarly, crossbreeding of Hair goats with Boer goats has led to significant differences in growth rates, which are largely influenced by breed type (Bolacali et al. 2017). In our previous study, the average live weights of Gurcu kids at day 30 and day 270 of age were 6.4 kg and 31.6 kg, respectively. Sex at day 210 and day 270 and type of birth at day 90 and day 150 were effective on live weight (Boğa Kuru et al. 2024). The present study showed that birth weight in Gurcu kids was consistent with values reported for many local goat breeds. Moreover, similar to our findings regarding the effect of sex, studies on Hair goat populations in Türkiye have demonstrated a clear sex-linked growth pattern, with males showing a significant growth advantage (Ceyhan et al. 2022; Gul et al. 2023). However, in our case, live weight at day 270 was considerably higher than the

Table 8 Effect of dam age, sex, and birth type on testis diameter, testis length, and scrotum volume

Days	Dam age (year)		Birth type		Significance		Overall ($n=40$)
	3 ($n=12$)	4 ($n=10$)	Single ($n=8$)	Twin ($n=14$)	Dam age	Birth type	
Testis diameter (cm)							
15	1.43±0.16	1.33±0.13	1.46±0.15	1.34±0.14	-	-	1.38±0.15
30	1.92±0.28	1.82±0.30	2.06±0.16	1.76±0.29	-	-	1.87±0.29
45	2.40±0.32	2.42±0.47	2.45±0.36	2.39±0.41	-	-	2.41±0.39
60	2.64±0.36	2.78±0.40	2.71±0.43	2.70±0.36	-	-	2.70±0.38
75	2.82±0.45	3.08±0.51	2.89±0.49	2.96±0.50	-	-	2.94±0.48
90	3.04±0.43	3.52±0.21	3.19±0.42	3.30±0.43	*	-	3.26±0.42
105	3.36±0.44	3.75±0.26	3.66±0.39	3.46±0.42	**	*	3.54±0.41
120	3.53±0.44	3.87±0.26	3.79±0.36	3.62±0.42	*	-	3.68±0.40
135	3.64±0.54	3.94±0.26	3.96±0.43	3.67±0.45	-	-	3.78±0.46
150	3.79±0.51	4.20±0.35	4.08±0.49	3.92±0.48	*	-	3.98±0.48
165	4.07±0.57	4.34±0.24	4.35±0.48	4.10±0.44	-	-	4.19±0.46
180	4.39±0.53	4.50±0.24	4.65±0.43	4.32±0.37	-	-	4.44±0.42
210	4.66±0.58	4.71±0.20	5.01±0.45	4.49±0.32	-	**	4.68±0.44
240	5.03±0.64	4.96±0.28	5.44±0.34	4.75±0.40	-	**	5.00±0.50
270	5.22±0.70	5.14±0.42	5.71±0.24	4.88±0.48	-	***	5.18±0.58
Testis length (cm)							
15	3.33±0.21	3.23±0.27	3.36±0.23	3.24±0.23	-	-	3.28±0.23
30	3.61±0.24	3.40±0.29	3.63±0.28	3.45±0.27	-	-	3.51±0.28
45	3.75±0.26	3.50±0.24	3.88±0.23	3.50±0.20	-	-	3.64±0.28
60	4.03±0.51	3.63±0.22	4.21±0.51	3.64±0.21	*	-	3.85±0.44
75	4.28±0.96	3.86±0.25	4.56±1.07	3.82±0.24	-	-	4.09±0.74
90	4.63±1.06	4.23±0.34	5.06±0.96	4.09±0.48	-	-	4.45±0.82
105	5.13±1.03	5.05±0.60	5.50±0.80	4.86±0.79	-	-	5.09±0.84
120	5.15±0.73	5.35±0.67	5.48±0.44	5.11±0.79	-	-	5.24±0.69
135	5.41±0.86	5.65±0.94	5.80±0.42	5.36±1.05	-	-	5.52±0.89
150	5.88±1.09	6.10±0.88	6.31±0.65	5.79±1.10	-	-	5.98±0.98
165	6.63±1.15	6.90±0.81	7.19±0.65	6.50±1.09	-	-	6.75±1.00
180	7.29±1.37	7.65±0.82	7.94±0.42	7.18±1.34	-	-	7.45±1.14
210	8.17±1.09	8.20±0.95	8.81±0.46	7.82±1.07	-	*	8.18±1.01
240	8.79±1.10	8.45±0.93	9.50±0.46	8.14±0.91	-	**	8.64±1.01
270	9.79±1.27	8.95±0.98	10.69±0.59	8.68±0.75	-	***	9.41±1.20
Scrotum volume (cm^3)							
15	19.58±6.20	18.80±3.65	21.88±5.94	17.71±4.03	-	-	19.23±5.10
30	22.08±6.56	23.00±3.50	25.00±6.55	21.07±4.01	-	*	22.50±5.29
45	24.75±8.41	26.00±5.68	30.00±5.35	22.64±6.80	*	**	25.32±7.16
60	30.00±7.98	29.00±8.43	35.63±9.43	26.07±4.46	*	***	29.55±8.00
75	34.17±11.45	32.00±10.85	40.63±10.84	28.93±8.81	-	*	33.18±10.97
90	44.17±21.93	40.30±16.23	55.63±20.95	34.86±13.81	-	*	42.41±19.20
105	57.08±33.20	54.00±22.71	73.13±29.87	45.71±22.77	-	*	55.68±28.30
120	73.33±43.97	63.50±28.87	95.00±38.17	53.93±28.43	-	*	68.86±37.35
135	88.33±53.82	84.50±32.10	118.13±39.55	68.57±36.57	-	*	86.59±44.30
150	110.00±45.53	106.00±30.62	133.75±38.15	93.57±31.53	-	-	108.18±38.62
165	145.83±45.02	126.50±34.32	175.63±33.53	115.00±25.34	-	**	137.05±40.79
180	165.00±36.80	154.00±35.65	188.75±20.31	143.57±32.49	-	**	160.00±35.86
210	204.17±35.79	197.00±34.33	223.75±25.60	187.86±32.62	-	**	200.91±34.49
240	236.67±23.48	236.00±38.64	247.50±31.96	230.00±28.82	-	*	236.36±30.48
270	267.08±42.02	246.00±43.00	292.50±17.53	237.50±40.13	-	**	257.50±42.81

n denotes the number of kids, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$, -: None significance

Table 9 Summary of significant effects ($P<0.05$) of dam age, sex, and birth type on growth and morphological traits in Gurcu goat kids, including overall means and coefficients of variation (CV%)

Trait	Dam age effect ($P<0.05$)	Sex effect ($P<0.05$)	Birth type effect ($P<0.05$)	Overall (Mean ± SD)	CV (%)
Live weight	Birth	150–270 d	15–270 d	32.85 ± 4.55	13.8
Daily live weight gain	—	90–270 d	All periods	0.095 ± 0.014	14.7
Body length	—	165–270 d	45–270 d	63.86 ± 4.13	6.5
Withers height	Birth, 60 d	30–270 d (except 15, 45)	30–270 d (except Birth, 15)	63.34 ± 3.51	5.5
Rump height	Birth	30, 60–90, ≥165 d	75 d	64.90 ± 3.52	5.4
Chest depth	Birth–30 d	270 d	30–270 d	28.39 ± 2.18	7.7
Chest circumference	15, 30, 60, 75, 180, 210 d	≥180 d	60–270 d	70.42 ± 5.12	7.3
Head length	—	≥60 d	75–270 d	18.76 ± 1.41	7.5
Forehead length	30, 60–90 d	≥60 d	≥60 d	11.72 ± 0.89	7.6
Front shin circumference	240 d	≥165 d	Birth, 75, 135, ≥165 d	9.77 ± 0.52	5.3
Rear shin circumference	—	≥165 d	30–270 d (except 75 d)	9.89 ± 0.49	5.0
Testicular diameter	90–150 d (except 135)	—	105, 210–270 d	3.87 ± 0.48	12.4
Testicular length	60 d	—	210–270 d	6.37 ± 0.58	9.1
Scrotal volume	45, 60 d	—	All ages except 15 & 150 d	64.95 ± 11.22	17.3

d: day

upper range reported for several other breeds, which may reflect favorable adaptation of Gurcu goats to regional conditions or effective herd management practices.

Sex-related differences in growth became apparent from day 90, with males showing higher performance thereafter. Birth type affected live weight from day 15 onward, consistent with the notion that single-born kids have physiological and nutritional advantages over twins. Comparable results have also been reported in Cyprus Native Hair goats, where males and singletons showed consistently higher growth rates throughout the pre-weaning and post-weaning periods (Arsoy et al. 2024). Taken together, these results confirm the strong influence of sex and birth type on postnatal growth and highlight the importance of early-life management in optimizing kid development.

In the present study, the effect of dam age was limited to birth weight, which is in line with reports showing that maternal age mainly influences intrauterine development, whereas postnatal growth is more strongly shaped by milk yield, kid vigor, and management conditions (Ramaroka et al. 2024; Sarma et al. 2019). The early and persistent effect of birth type on growth traits is also consistent with studies indicating that twins receive less uterine nutrient supply and share maternal milk, resulting in reduced early growth compared with singletons (Elmaz et al. 2020; Gül et al. 2022). Overall, these findings support the view that early developmental constraints—particularly those related to litter size—can have long-lasting impacts on growth trajectories in local goat breeds.

Daily live weight gain

In Kilis (Gül et al. 2022), Mehsana (Patel and Pandey 2013), and Hair goat kids (Yılmaz et al. 2023), the highest daily live weight gain was also in males and singles. In addition, as dam age increased, daily live weight gain in kids could increase (Koluman et al. 2024). Similarly, in Ethiopian goats (Deribe and Taye 2013) and in Bangladeshi Black Bengal goats (Husain et al. 1996), similarly, male and single kids grew faster, and daily live weight gain increased as parity increased. In Saanen × Hair goat crossbreds, daily gain was lower in the offspring of younger dams and in twins (Yıldırır et al. 2019). Comparable patterns were reported in Turkish Hair goats, where males consistently showed higher pre-weaning daily gains than females, and single-born kids outperformed twins (Ceyhan et al. 2022). Similarly, Kilis goats demonstrated significantly higher daily gains in males and singles, supporting the sex- and litter-size–dependent pattern observed in our study (Gul et al. 2023).

For comparison, in our study, the effect of dam age on daily live weight gain in Gurcu goat kids was not significant, whereas differences in sex and birth type became evident starting from days 90 and 15, respectively. After this stage, male kids had higher daily live weight gain values than females, and singles had higher daily live weight gain values than twins. These findings are consistent with the general pattern reported for many local goat breeds, where sex and birth type play decisive roles in postnatal growth dynamics. In light of these results, it shows that daily live weight gain is mainly affected by sex and birth type, while dam age, although significant in some studies, is not always a determining factor. Perhaps if a wider dam age scale could have been studied, the effect of dam age could have been better revealed. Nevertheless, a broader range of dam ages might have clarified whether age-related maternal factors exert a more subtle influence on early growth performance.

Table 10 Pearson correlation coefficients between live weight and morphological traits in female, male, single, twin, and all kids

Variables	Live weight	Head length	Forehead length	CC	Front shin	Rear shin	Body length	Withers height	Chest depth
Female kids									
Head length	0.873**								
Forehead length	0.677**	0.731**							
CC	0.913**	0.878**	0.710**						
Front shin	0.762**	0.730**	0.688**	0.792**					
Rear shin	0.790**	0.760**	0.676**	0.817**	0.838**				
Body length	0.909**	0.879**	0.732**	0.947**	0.811**	0.804**			
Withers height	0.895**	0.878**	0.708**	0.924**	0.807**	0.861**	0.928**		
Chest depth	0.887**	0.883**	0.727**	0.943**	0.810**	0.864**	0.927**	0.963**	
Height at rump	0.900**	0.857**	0.741**	0.908**	0.833**	0.825**	0.949**	0.947**	0.931**
Male kids									
Head length	0.872**								
Forehead length	0.824**	0.894**							
CC	0.922**	0.921**	0.851**						
Front shin	0.824**	0.821**	0.742**	0.909**					
Rear shin	0.800**	0.837**	0.765**	0.899**	0.925**				
Body length	0.902**	0.918**	0.863**	0.958**	0.876**	0.873**			
Withers height	0.914**	0.914**	0.857**	0.961**	0.875**	0.876**	0.960**		
Chest depth	0.924**	0.925**	0.860**	0.967**	0.880**	0.867**	0.963**	0.967**	
Height at rump	0.932**	0.917**	0.869**	0.970**	0.881**	0.877**	0.963**	0.982**	0.970**
Single kids									
Head length	0.883**								
Forehead length	0.803**	0.907**							
CC	0.931**	0.889**	0.794**						
Front shin	0.857**	0.838**	0.766**	0.928**					
Rear shin	0.809**	0.816**	0.759**	0.884**	0.934**				
Body length	0.911**	0.902**	0.817**	0.956**	0.896**	0.859**			
Withers height	0.904**	0.920**	0.856**	0.931**	0.880**	0.884**	0.937**		
Chest depth	0.925**	0.918**	0.829**	0.944**	0.891**	0.884**	0.956**	0.965**	
Height at rump	0.931**	0.913**	0.840**	0.957**	0.895**	0.880**	0.961**	0.970**	0.970**
Twin kids									
Head length	0.854**								
Forehead length	0.719**	0.804**							
CC	0.908**	0.903**	0.787**						
Front shin	0.766**	0.766**	0.729**	0.818**					
Rear shin	0.791**	0.812**	0.743**	0.853**	0.871**				
Body length	0.894**	0.890**	0.784**	0.952**	0.818**	0.838**			
Withers height	0.914**	0.889**	0.788**	0.954**	0.833**	0.862**	0.956**		
Chest depth	0.899**	0.886**	0.778**	0.966**	0.818**	0.845**	0.945**	0.959**	
Height at rump	0.909**	0.874**	0.794**	0.937**	0.842**	0.843**	0.953**	0.969**	0.942**
All kids									
Head length	0.871**								
Forehead length	0.765**	0.848**							
CC	0.918**	0.898**	0.777**						
Front shin	0.804**	0.797**	0.727**	0.863**					
Rear shin	0.799**	0.814**	0.731**	0.867**	0.897**				
Body length	0.904**	0.898**	0.794**	0.954**	0.850**	0.847**			
Withers height	0.908**	0.902**	0.799**	0.945**	0.854**	0.872**	0.947**		
Chest depth	0.909**	0.899**	0.782**	0.957**	0.849**	0.862**	0.949**	0.962**	
Height at rump	0.921**	0.894**	0.808**	0.946**	0.864**	0.859**	0.957**	0.969**	0.954**

**: Correlation is significant at the 0.01 level (2-tailed). CC: Chest circumference

Body length

In our study, the effect of dam age on body length in Gurcu goat kids was not significant, and the effects of sex and birth type appeared after days 150 and 45, respectively. After this period, male kids were superior to females, and singles were superior to twins in terms of body length. For comparison, in Manavlı goat kids, males were superior to females in terms of body length (Akbaş et al. 2023). Similarly, in Cyprus Native Hair goats, males exhibited larger body dimensions than female (Arsoy et al. 2024). In Saanen goat kids, singles had longer body length than (Ceyhan and Karadağ 2009). In Hair and Saanen × Hair crossbreds, birth type especially affected body length during the weaning period, but dam age was not a determining factor (Tozlu Çelik and Olfaz 2018). Taken together, both in our study and in the literature, body length is mainly affected by sex and birth type, while dam age is not a determining factor.

Body length is influenced mainly by sex and birth type, which aligns with the biological expectations of postnatal growth. Male kids generally exhibit greater musculoskeletal development due to higher androgen sensitivity after birth, leading to longer body measurements compared to females (Idamokoro et al. 2017). Single-born kids also tend to have larger body dimensions because they benefit from greater uterine space and nutrient availability, resulting in superior early growth compared with twins (Gül et al. 2022). In contrast, dam age typically has only a limited effect on postnatal linear growth; its influence is more evident on birth weight rather than subsequent morphometric traits, which become increasingly shaped by nutrition, genetic potential, and environmental factors after birth. These biological explanations further support our findings, where sex and birth type affected body length at later stages, whereas dam age did not demonstrate a significant impact.

Withers height

Dam age, sex, and birth type may affect growth and withers height in kids. In Manavlı goat kids, sex is the most decisive factor in terms of withers height, with males having higher values than females in growth periods. In the same goat breed, the effect of birth type is insignificant, while the effect of dam age (3–4 years) is limited (Akbaş et al. 2023). In Aleppo and Hair goats, males were superior to females in withers height. However, birth type and dam age had no significant effect on withers height (Erdem et al. 2022). In our previous study on Gurcu goat kids, sex and birth type could affect withers height in some growth periods (Boğa Kuru et al. 2024). In this study, however, dam ages were not significantly effective on withers height. But sex and birth type were effective on withers height starting from the first month. Similarly, in Cyprus Native Hair goats, males showed greater withers height than females (Arsoy et al. 2024). In addition, strong positive correlations were obtained between body weight and withers height, and withers height may be a reliable parameter in evaluating growth performance in Gurcu goat kids. These correlations indicate that withers height may serve as a practical field indicator to estimate overall body development without requiring detailed measurements.

These findings are biologically expected. Male kids generally show greater musculoskeletal development, which explains their higher withers height compared with females. This difference is supported by detailed study on Gurcu goat kids, which found that males exhibited wider growth plates in long bones, indicating superior skeletal development (Boğa Kuru et al. 2024). Single-born kids also tend to grow taller because they benefit from greater uterine space and nutrient availability during gestation (Mellado et al. 2011). In contrast, the limited effect of dam age is consistent with previous reports, as maternal age influences birth weight more than postnatal linear growth, which is largely shaped by genetic potential and nutrition. Therefore, the pattern observed in Gurcu goats follows the expected biological trajectory reported across various local breeds, further supporting the robustness of these results.

Chest depth and circumference

In our study, dam age and sex were effective on chest depth and circumference in Gurcu goat kids during certain growth periods. However, the situation was somewhat different for birth type, and in almost all growth stages, birth type was effective on chest depth and length. Males had higher values than females, and singles had higher values than twins, which is similar to Damascus × Hair kids, where sex was effective starting from day 90 and birth type created differences in some periods (Erdem et al. 2022). In Boer × Hair and Hair kids, chest measurements at weaning and at day 150 were affected by sex and birth type, but dam age was not a determining factor (Bolacali et al. 2017). In Saanen × Hair crossbreds, chest circumference was affected by birth type and chest depth was affected by sex (Tozlu Çelik and Olfaz 2018). A similar pattern was also observed in Cyprus Native Hair goats, where chest circumference was significantly higher in males across age groups (Arsoy et al. 2024). In our study, in parallel with the literature, chest depth and chest circumference were affected by sex and birth type, while dam age was not a determining factor. Taken together, in our study, high positive correlations were also determined between body weight and chest circumference and chest depth. This finding is consistent with the literature, which shows that chest measurements and many other measured

parameters are reliable indicators in the estimation of body weight (Pesmen and Yardimci 2008; Waheed et al. 2020). Therefore, chest-related measurements may serve as practical and easily obtainable indicators for evaluating growth performance in field conditions. The pronounced effects of sex and birth type on chest depth and chest circumference observed in this study are biologically expected. Male kids possess greater skeletal growth capacity—as demonstrated in Gurcu goats by wider epiphyseal plates and longer humerus length—while single-born kids benefit from more favorable intrauterine conditions and enhanced early postnatal nutrition, collectively explaining their superior thoracic development (Boğa Kuru et al. 2024). In contrast, the limited influence of dam age is consistent with literature indicating that maternal age primarily affects general growth traits such as birth and weaning weights rather than specific morphometric characteristics (Güngör et al. 2021). Thus, thoracic development is driven primarily by intrinsic physiological and nutritional factors. Overall, our findings align with the literature and confirm that chest depth and circumference are primarily shaped by sex and birth type rather than maternal age.

Head length and circumference

Head length and circumference in kids may vary between sexes at different stages of growth. In Damascus × Hair goats, males have longer head measurements than females at certain growth stages (Erdem et al. 2022). In Boer × Hair crossbreds, head length at weaning and at day 150 was affected by sex and birth type (Bolacali et al. 2017). In Shami goats, however, the differences between sexes in terms of head length were statistically insignificant (Abd-Allah et al. 2019). In addition, in Beetal goats, forehead length was shown to be weakly but positively correlated with body weight (Iqbal et al. 2013). Taken together, these findings show that head-related traits can differ meaningfully depending on breed structure, sex, and birth type.

In this study, the effect of dam age on head length in Gurcu goat kids was insignificant, while the effects of sex and birth type became evident starting from day 60 and day 75, respectively. After this growth stage (days 60–75), males and singles had higher values compared to females and twins in terms of head length. In forehead length, dam age had no significant effect except in some periods, but differences depending on sex and birth type were especially evident after day 60. It can be said that measurements related to head structure in kids are more affected by sex and birth type than by dam age. This pattern is consistent with the biological expectation that cranial growth is closely linked to overall skeletal development, which progresses more rapidly in males and single-born kids. In addition, strong correlations were obtained between body weight and head length and forehead length, and it was understood that these measurements could be used for the indirect estimation of body weight. Therefore, head-related measurements may serve as practical morphometric indicators to support early selection and body weight prediction in field evaluations.

Front and rear shin circumference

Front and rear shin circumference may vary depending on sex and birth type during growth periods. In Damascus × Hair goats, males are superior to females in shin measurements, while birth type may create differences in some periods (Erdem et al. 2022). Supporting this, in Boer × Hair goat crossbreds, birth type and sex were effective on shin circumference at weaning and at day 150 measurements (Bolacali et al. 2017). In different goat breeds in China, front and rear shin length and circumference varied depending on sex (Saleh et al. 2022). Taken together, these findings emphasize that shin morphology is a trait strongly shaped by sex and litter size across different goat breeds.

In our study, the effect of dam age on front and rear shin circumference in Gurcu goat kids was found to be insignificant, while differences related to sex and birth type became clearer especially in later growth periods. After this growth stage, males and singles were determined to be superior to females and twins in terms of shin circumference. The stronger body structure of males or singles was also reflected in front and rear shin circumference. This is biologically reasonable, as limb robustness generally parallels overall musculoskeletal development, which progresses more rapidly in males and single-born kids due to greater nutrient allocation and postnatal growth potential. Therefore, shin circumference may serve as an additional supportive parameter in evaluating structural development and growth symmetry in Gurcu goat kids.

Testicles and scrotum

Testicular development in kids varies depending on the growth period, and scrotal biometry can be a reliable indicator in determining breeding value. In Afar male goat kids, age had an effect on testicular measurements and was highly correlated with scrotal circumference (Husain et al. 1996). In Indian indigenous goats, testicular length and volume increased depending on age (Kerketta et al. 2015). In addition, even among different breeds, testicular length, scrotal circumference, and volume may show significant differences (Saleh et al. 2021). These findings indicate that testicular traits are highly responsive to growth dynamics and may differ considerably between breeds. In our previous studies, we examined the effects of season (spring, summer,

autumn, and winter) (Kulaksiz et al. 2020) or breeding season (Kulaksız et al. 2019) on testicular and scrotal measurements in Gurcu bucks, but we did not determine the effects of growth, dam age, and birth type. In our study, in Gurcu goat kids, testicular diameter and length were affected by birth type starting from day 210, and scrotal volume from day 30. Single-born kids had higher measurements compared to twins. This shows that singles may perhaps be more advantageous for selection as breeding males, but such a decision should still be made together with positive results from other tests. In addition, strong positive correlations were obtained between body weight and testicular diameter, testicular length, and scrotal volume in Gurcu goat kids, and these measurements may be indirect indicators of growth performance and future reproductive capacity. Such correlations strengthen the potential use of testicular traits as early selection criteria for evaluating reproductive capability in young males.

The birth-type differences found in our study appear to be linked mainly to early postnatal growth. Single-born kids are heavier at birth in Black Bengal goats (Husain et al. 1996), and testicular and scrotal measurements increase closely with body weight during male development (Agga et al. 2011; Kerketta et al. 2015). Birth type has also been shown to influence testicular dimensions in ram lambs (Koyuncu et al. 2005), while better early-life nutritional conditions accelerate scrotal growth and pubertal development in Boer goats (Bezerra et al. 2009). These findings suggest that the greater testicular development observed in single-born Gurcu goat kids is largely a reflection of superior early growth rather than intrinsic reproductive differences.

Survival rate

The future of a farm can be safeguarded through the optimal housing of newborns, the implementation of strict management strategies, and achieving high survival rates (Groenevelt 2025; Robertson et al. 2020). Accordingly, many factors affect the survival of newborns, and various studies have been conducted on this subject (Dwyer et al. 2015; Groenevelt 2025). According to previous research, survival rates up to day 60–90 of age were reported as 92.7–99.0% in Hair goat kids (Koluman et al. 2024), over 97% in Honamlı goats (Elmaz et al. 2012), and 90–95% in Saanen crossbreds (Yıldırır et al. 2019). Up to day 180 of age, survival was 92.31% in Saanen goats (Bolacali et al. 2011) and 88.5% in Angora goats (Snyman 2010). At day 360, survival rates were 85–90% in Ethiopian goats (Deribe and Taye 2013) and 80–85% in Black Bengal goats (Husain et al. 1996). In our previous studies, survival rates in Gurcu goat kids were 93.75% up to day 120 of age (Kuru et al. 2017) and 87–100% in the neonatal period (Kuru et al. 2024). In the present study, survival rates were determined as 91.1% at day 30, 97.6% at day 180, and 88.9% at day 270. Similar to our previous findings, mortalities were mostly concentrated during the neonatal period and among twin-born kids. Therefore, it can be stated that the neonatal period is a critical and challenging stage for Gurcu goat kids, requiring closer monitoring and more intensive care. These findings reinforce the widely accepted notion that early-life management practices (colostrum intake, hygiene, thermal regulation, and dam–kid bonding) play a decisive role in determining kid survival. Thus, targeted interventions during the first weeks of life may substantially improve overall herd productivity and long-term breeding success.

Study limitations

This study has several limitations. It was conducted on a single institutional farm with a relatively small and homogeneous herd, which may limit the generalizability of the findings. Although management practices were standardized, seasonal grazing activity could not be fully controlled and may have introduced variation in growth performance. No additional nutritional supplementation beyond the routine feeding program was used, restricting the evaluation of dietary effects on kid development. The high-altitude environment (1751 m) may also have influenced growth patterns differently than low-altitude systems. Moreover, the study did not include genetic or sire-based evaluations, nor detailed hematological or metabolic profiling, which could have provided deeper insight into the physiological mechanisms behind growth variation. Finally, the reproductive implications of testicular development at 9 months were not assessed, limiting the ability to directly link morphological traits with breeding decisions. Future studies involving multi-farm populations, wider environmental conditions, and reproductive performance data are needed to validate and expand these findings.

Practical implications

The present findings offer several actionable points for breeders. The consistent advantage of single-born kids indicates that twins require closer nutritional and health monitoring, especially early in life. Sex-based growth differences suggest that males and females should be managed and marketed with separate strategies. Because dam age affected only birth weight, management should prioritize postnatal care rather than maternal age. Strong correlations between body weight and simple morphometric traits also show that field-friendly measurements can reliably estimate growth. Importantly, the superior growth and testicular traits of single-born males suggest that 9-month testicular

measurements may serve as a practical criterion for early buck selection in conservation-oriented programs. Likewise, targeted nutritional support for twin-born kids may help reduce early disadvantages under traditional management conditions. These insights may enhance productivity, early decision-making, and the long-term conservation of the Gurcu goat.

Conclusion

Kars has harsh geographical conditions and a severe climate, being located in the easternmost part of Türkiye. The Gurcu goat is one of the rare local breeds that has adapted to this region. To the best of our knowledge, no study has monitored the long-term growth performance, morphological characteristics, and survival rate of Gurcu goat kids. For this reason, we conducted this study to fill the gap in the literature and provide findings that could also benefit local breeders. Overall, the effect of dam age on the monitored parameters of Gurcu goat kids was limited, being mainly restricted to birth weight while having no meaningful influence on postnatal growth or morphometric traits. Male and single kids were superior in growth and in many morphological traits, which was further supported by testicular measurements, particularly the greater testicular diameter, length, and scrotal volume observed in single-born males. In addition, the morphological traits measured for growth monitoring showed strong correlations with body weight. Furthermore, the survival rate of 88.9% determined at the end of the nine-month monitoring period demonstrates the adaptability of Gurcu goat kids to harsh environmental conditions. However, it also indicates that mortality was concentrated mainly in the neonatal period and among twin kids, with most losses occurring within the first weeks of life and predominantly affecting twin-born kids. Therefore, more intensive management practices and closer monitoring are recommended during this critical stage, including targeted nutritional support and early-life care protocols for twin-born kids. With this study, we also provided original data on long-term survival in Gurcu goats, whereas previous studies in the literature have mostly reported short- and medium-term observations, without providing extended follow-up through later growth stages. In this context, the findings highlight the adaptive capacity and genetic importance of the Gurcu goat, offering valuable data that may guide breeding, selection, and management strategies. Future studies focusing on genetic evaluations, follow-up to the first reproductive cycle, or testing management interventions for twin-born kids would further enhance the applicability of these results.

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Author contributions BBK, FB, MK, and MÖ designed the study and supervised the experiments. Data were analyzed by BBK, MK, and SAI. The manuscript was prepared and edited by BBK and TK. All authors contributed to the article and approved the submitted version.

Data availability The data can be obtained from the corresponding author upon reasonable request.

Declarations

Ethical approval This study was conducted following approval from the Ethics Committee for Animal Experiments of Kafkas University (KAÜ-HADYEK/2020−178), Kars, Türkiye. Additionally, permission for the study implementation was obtained from the Kafkas University Faculty of Veterinary Medicine, A.R. AKSOY Education-Research and Application Farm (Session no: 2020/2021-07, Decision no: 16).

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References

Abd-Allah S, Abd-El Rahman HH, Shoukry MM, Mohamed MI, Salman FM, Abedo AA (2019) Some body measurements as a management tool for Shami goats raised in subtropical areas in Egypt. Bull Natl Res Centre 43(1):17. https://doi.org/10.1186/s42269-019-0042-9

Agga GE, Udala U, Regassa F, Wudie A (2011) Body measurements of bucks of three goat breeds in Ethiopia and their correlation to breed, age and testicular measurements. Small Ruminant Res 95(2–3):133–138. https://doi.org/10.1016/J.SMALLRUMRES.2010.09.011

Akbaş AA, Saatcı M, Elmaz Ö, Yazıcı CM (2023) The first data of a newly recorded native goat genotype called Manavlı in Türkiye: growth traits of kids. Turk J Vet Anim Sci 47(4):413–424. https://doi.org/10.55730/1300-0128.4309

Arsoy D, Abdourhamane IM, İsfendiyaroğlu M (2024) Phenotypic characterization of Indigenous Cyprus native hair goat breed using quantitative and qualitative trait analysis. Rev Cient-Fac Cien V 34(1):1–10. https://doi.org/10.52973/rcfcv-e34314

Atta M, Ali AS, Mohamed MB, Al-Dosari HM, Al-Shamari HS (2024) Prediction of body weight using body measurements in some sheep and goats in Qatar. J Appl Anim Res 52(1):2288917. https://doi.org/10.1080/09712119.2023.2288917

Batu S (1951) Türkiye Keçi Irkları. Ankara Üniversitesi Veteriner Fakültesi Yayınları, Ankara, Türkiye

Bezerra FQG, Filho CRA, Neto LMF, Santos Junior ER, Chaves RM, Azevedo EMP, Santos MHB, Lima PF, Oliveira MAL (2009) Body weight, scrotal circumference and testosterone concentration in young Boer goat males born during the dry or rainy seasons. South Afr J Anim Sci 39(4):301–306. http://www.sasas.co.za/sajas.asp

Boğa Kuru B, Akyüz E, Aydın U, Kuru M, Bektaşoğlu F, Sezer M, Yıldız U, Kırmızıbayrak T (2024) Effect of birth type and sex on

growth performance, wither height, humerus-radius bone dimensions, humerus–ulna growth plate width and selected hormone profile in growing Gurcu goat kids. Vet Med Sci 10(5):e70013. https://doi.org/10.1002/vms3.70013

Bolacali M, Küçük M, (2011) Muş bölgesinde yetiştirilen Saanen oğlaklarının büyüme performansı ve yaşama gücü. Iğdır Üni Fen Bilimleri Enst Der 1(2):125–131.

Bolacali M, Öztürk Y, Yilmaz O, Küçük M, Karsli MA (2017) Effect of genotype and non-genetic factors on growth traits and survival rates in Turkish indigenous hair goats and their first cross with Boer bucks. Indian J Anim Res 51(6):975–981. https://doi.org/10.18805/ijar.B-716

Ceyhan A, Karadağ O (2009) Marmara Hayvancılık Araştırma Enstitüsünde yetiştirilen Saanen keçilerin bazı tanımlayıcı özellikleri. J Agric Sci 15(02):196–203. https://doi.org/10.1501/Tarimbil_0000001091

Ceyhan A, Çınar M, Serbester U (2022) Kid growth performance and reproductive characteristics of hair goats raised under breeder conditions. Turk J Vet Anim Sci 46(4):592–598. https://doi.org/10.55730/1300-0128.4230

Daskiran I, Savas T, Koyuncu M, Koluman N, Keskin M, Esenbuga N, Konyali A, Cemal İ, Gül S, Elmaz O, Kosum N, Dellal G, Bingöl M (2018) Goat production systems of Turkey: nomadic to industrial. Small Ruminant Res 163:15–20. https://doi.org/10.1016/j.smallrumres.2017.10.001

Deribe B, Taye M (2013) Growth performance and carcass characteristics of central Highland goats in Sekota District, Ethiopia. Agric Adv 2(2):250–258. https://doi.org/10.5555/20133313743

Din Iud, Khan A, Rizwan M, Haq Rul, Wazir MA (2019) Study of birth weight and post weaning growth rate in lambs and kids of Damani sheep and Damani goat for fattening purpose. Open Acad J Adv Sci Technol 3(1):1–5. https://doi.org/10.33094/5.2017.2019.31.1.5

Dwyer CM, Conington J, Corbiere F, Holmoy IH, Muri K, Nowak R, Rooke J, Vipond J, Gautier JM (2015) Invited review: improving neonatal survival in small ruminants: science into practice. Animal 10(3):449–459. https://doi.org/10.1017/S1751731115001974

Elmaz Ö, Saatcı M, Dağ B, Aktaş AH, Ata A, Gülay MŞ, Mamak N, Gök B (2012) Some descriptive characteristics of a new goat breed called Honamli in Turkey. Trop Anim Health Prod 44(8):1913–1920. https://doi.org/10.1007/s11250-012-0156-7

Elmaz Ö, Saatcı M, Ağaoğlu ÖK, Akbaş AA, Metin MÖ, Gezer G, Gökçay Y (2020) Reproductive performance and kid growth until weaning in hair goat reared on-farm conditions in Turkey. Turk J Vet Anim Sci 44(2):370–376. https://doi.org/10.3906/vet-1909-18

Erdem E, Özbaşer FT, Erat S (2022) Comparison of growth and development characteristics of hair and Damascus kids reared under extensive conditions. Kocatepe Vet J 15(1):84–93. https://doi.org/10.30607/kvj.995521

Erdoğan İE, Karaman R, Hızlı H, Gül S (2023) Reproductive performance and kid growth in hair goats Raised under farmer conditions in Adana Province of Türkiye. MKU Tar Bil Derg 28(2):446–453. https://doi.org/10.37908/mkutbd.1283298

Groenevelt M (2025) Neonatal mortality in goats. In J. Simões (Ed.), Encyclopedia of livestock medicine for large animal and poultry production. Springer Nature Switzerland, pp. 1–5. https://doi.org/10.1007/978-3-031-52133-1_189-1

Gul S, Arzik Y, Kizilaslan M, Behrem S, Keskin M (2023) Heritability and environmental influence on pre-weaning traits in Kilis goats. Trop Anim Health Prod 55(2):85. https://doi.org/10.1007/s11250-023-03509-3

Gül S, Keskin M, Kaya Ş (2022) Effects of environmental factors on growth performance of Kilis goat in Gaziantep Province. Livest Stud 62(1):16–20. https://doi.org/10.46897/livestockstudies.1077855

Gundemir MG, Yildiz AE, Buyukunal SK, Murataglu K, Ozkan E, Demircioglu A, Choudhary OP, Guzel BC (2023) Evaluation of cold carcasses of Kıvırcık and Romanov lambs by geometric morphometric method. Kafkas Univ Vet Fak Derg 30(1):87–94. https://doi.org/10.9775/kvfd.2023.30539

Güngör İ, Alkoyak K, Öz S, Koncagül S (2021) Growth, survival rate, and some reproductive characteristics of hair goat under breeder conditions in Kahramanmaraş Province. Turk J Vet Anim Sci 45(6):1022–1029. https://doi.org/10.3906/vet-2104-51

Hegde NG, Deo AD (2020) Monitoring body weight gain of goat kids for improving productivity. Asian J Res Zool 3(2):14–22. https://doi.org/10.9734/ajriz/2020/v3i230087

Husain SS, Horst P, Islam ABMM (1996) Study on the growth performance of black Bengal goats in different periods. Small Ruminant Res 21(3):165–171. https://doi.org/10.1016/0921-4488(95)00832-2

Idamokoro EM, Muchenje V, Masika PJ (2017) Peri- and post-parturient consequences of maternal undernutrition of free ranging does: a review. Livest Res Rural Dev 29(10):202. https://www.lrrd.cipav.org.co/lrrd29/10/mond29202.html?utm_source=chatgpt.com

Iqbal M, Javed K, Ahmad N, Javed K (2013) Prediction of body weight through body measurements in beetal goats. Pak J Sci 65(4):458–461. https://doi.org/10.57041/VOL65ISS4PP

Kaymakçı M (2013) İleri Keçi Yetiştiriciliği. Meta Basım Matbaacılık, İzmir, Türkiye

Kerketta S, Singh M, Patel BHM, Dutt T, Upadhyay D, Bharti PK, Sahu S, Kamal R (2015) Relationships between age, body measurements, testicular measurements and total ejaculation of semen in local goat of Rohilkhand region. Small Ruminant Res 130:193–196. https://doi.org/10.1016/J.SMALLRUMRES.2015.07.006

Kheirabadi K, Rashidi A (2019) Modelling and genetic evaluation of Markhoz goat growth curve parameters. Small Ruminant Res 170:43–50. https://doi.org/10.1016/J.SMALLRUMRES.2018.11.017

Koluman N, Durmuş M, Güngör İ (2024) Improving reproduction and growth characteristics of indegenous goats in smallholding farming system. Ciênc Rural 54(5):e20230028. https://doi.org/10.1590/0103-8478CR20230028

Koyuncu M, Uzun SK, Ozis S, Duru S (2005) Development of testicular dimensions and size, and their relationship to age and body weight in growing Kivircik (Western Thrace) ram lambs. Czech J Anim Sci 50(6):243–248

Kulaksiz R, Arı UÇ, Kuru M, Yıldız S, Lehimcioğlu NC, Öztürkler Y (2020) Seasonal variations of testicular measurements, fresh sperm quality and post-thaw sperm motility in Gurcu bucks. Slovak J Anim Sci 53(4):161–167

Kulaksız R, Arı UÇ, Kuru M, Yıldız S, Lehimcioğlu NC, Öztürkler Y, Atakişi E (2019) Seasonal changes in testes size, fresh and post-thawing semen characteristics, serum testosterone level, and phospholipase A2 activity in Gurcu male goats. J Anim Plant Sci 29(2):353–358

Kuru M, Boğa Kuru B (2020) Kars ve yöresinde kaybolmaya yüz tutan lokal bir ırk: Gürcü keçisi. In: Ayvazoğlu P, Demir (eds.). Kuzey Doğu Anadolu Bölgesinde Hayvancılık. Iksad Publishing House, pp. 75–111

Kuru M, Boğa Kuru B (2024) The effect of different durations of progesterone based estrus synchronization on pregnancy rates in Gurcu goats during the breeding season: a review of studies from 2016 to 2024. 8th International Congress on Advances in Bioscience and Biotechnology (ICABB), p. 91–100

Kuru M, Boğa Kuru B, Kulaksız R, Çağın Arı U, Oral H (2017) Gürcü keçilerinin bazı reprodüktif özellikleri. Harran Üniv Vet Fak Derg 6(2):119–125. https://doi.org/10.31196/huvfd.383632

Kuru M, Oral H, Kulaksiz R (2018) Determination of gestational age by measuring defined embryonic and foetal indices with

ultrasonography in Abaza and Gurcu goats. Acta Vet Brno 87(4):357–362. https://doi.org/10.2754/avb201887040357
Kuru M, Makav M, Boğa Kuru B, Bektaşoğlu F, Demir MC, Bulut M, Alwazeer D (2024) Hydrogen-rich water supplementation improves metabolic profile during peripartum period in Gurcu goats and enhances the health and survival of kids. Res Vet Sci 171:105208. https://doi.org/10.1016/J.RVSC.2024.105208
Kuthu ZH, Javed K, Babar ME, Sattar A, Abdullah M (2013) Environmental effects on growth traits of teddy goats. J Anim Plant Sci 23(3):692–698
Mellado M, Meza-Herrera CA, Arévalo JR, De Santiago-Miramontes MA, Rodríguez A, Luna-Orozco JR, Veliz-Deras FG (2011) Relationship between litter birthweight and litter size in five goat genotypes. Anim Prod Sci 51(2):144–149. https://doi.org/10.1071/AN10112
Ölmez M, Akyüz E, Öğün M, Şahin T, Makav M, Yörük M, Gökçe G, Boğa Kuru B (2020) Gürcü keçilerinde metabolik profilin Beslenme dönemlerine göre karşılaştırılması. Atatürk Üniversitesi Vet Bil Derg 15(3):287–293. https://doi.org/10.17094/ataunivbd.710999
Özdemir FH, Keskin M (2018) Kilis ve Gaziantep illerinde yetiştirilen Kilis keçilerinin bazı morfolojik ve fizyolojik özellikler bakımından karşılaştırılması. MKU Ziraat Fakültesi Dergisi 23(1):115–123
Patel AC, Pandey DP (2013) Growth, production and reproduction performance of Mehsana goat. J Livestock Sci 4:17–21
Pesmen G, Yardimci M (2008) Estimating the live weight using some body measurements in Saanen goats. Arch Zootech 11(4):30–40
Ramaroka MP, Tada O, Banga CB (2024) Evaluation of non-genetic factors affecting birth weight of Kalahari red goats in South Africa. S Afr Jnl Agric Ext 52(4):1–16. https://doi.org/10.17159/2413-3221/2024/v52n4a16077
Robertson SM, Atkinson T, Friend MA, Allworth MB, Refshauge G (2020) Reproductive performance in goats and causes of perinatal mortality: a review. Anim Prod Sci 60(14):1669–1680. https://doi.org/10.1071/AN20161
Saleh AA, Rashad AMA, Hassanine NNAM, Sharaby MA, Zhao Y (2021) Evaluation of morphological traits and physiological variables of several Chinese goat breeds and their crosses. Trop Anim Health Prod 53(1):1–15. https://doi.org/10.1007/S11250-020-02549-3
Saleh AA, Rashad AMA, Hassanine NNAM, Sharaby MA, Zhao Y (2022) Morphological body measurements, body indices, and their genetic background for several Chinese goat breeds. Trop Anim Health Prod 54(4):204. https://doi.org/10.1007/s11250-022-03203-w
Sarma L, Nahardeka N, Goswami RN, Aziz A, Zaman G, Das A, Akhtar F (2019) Non-genetic factors affecting pre-weaning growth and morphometric traits in Assam hill goat. Vet World 12(8):1327–1331. https://doi.org/10.14202/vetworld.2019.1327-1331
Şenyüz HH (2021) Fertility, live weight, survival rate, greasy fleece weight, and quality traits of Angora goats in Turkey. Small Ruminant Res 197:106332. https://doi.org/10.1016/J.SMALLRUMRES.2021.106332
Sezgin E, Kopuzlu S, Yüksel S (2010) Gürcü keçisi. Ulusal Keçicilik Kongresi, p. 237–240
Snyman MA (2010) Factors affecting pre-weaning kid mortality in South African Angora goats. South Afr J Anim Sci 40(1):54–64. http://www.sasas.co.za/sajas.asp
Tekin ME, Arlı M (2019) The growth and survival rate of Hair goat kids raised by public in Karaman region. Vet Hekim Der Derg 90(2):152–157. https://doi.org/10.33188/vetheder.539444
Tekin ME, Öğeç M (2017) Konya bölgesinde Halk Elinde yetiştirilen Kıl keçisi oğlaklarının büyüme ve yaşama gücü. Lalahan Hay Araşt Enst Derg 57(2):93–98. https://dergipark.org.tr/tr/pub/lahaed/issue/39469/465423
Tozlu Çelik H, Olfaz M (2018) Investigation on survival rate and growth characteristics of pure Hair goat and Saanen x Hair goat (F1, B1, B2) crossbreds in breeder conditions. Mediterr Agric Sci 31(1):77–85. https://doi.org/10.29136/mediterranean.408097
TÜİK. (2024) Turkish Statistical Institute, Livestock Statistics. https://www.tuik.gov.tr
Waheed HM, Moaeen-ud-Din M, Khan MS, Saif-ur-Rehman M, Nawaz-ul-Rehman MS (2020) Prediction of monthly body weight from body measurements in beetal goats reared under field and farm conditions. J Anim Plant Sci 30(1):25–31. https://doi.org/10.4314/bajopas.v1i1.57511
Yahia A, Hammami N, Saidani K, Hamrat K, Mimoune N (2024) Estrous cycle length in the Algerian arbia goat: exfoliative vaginal cytology and serum progesterone levels. Kafkas Univ Vet Fak Derg 30(3):311–317. https://doi.org/10.9775/kvfd.2023.30898
Yilmaz O, Kor A, Ertugrul M, Wilson RT (2012) The domestic livestock resources of Turkey: goat breeds and types and their conservation status. Anim Genetic Resour 51:105–116. https://doi.org/10.1017/S2078633612000331
Yıldırır M, Karadağ O, Yilmaz M, Yüksel MA, Sezenler T, Ceyhan A (2019) The comparison of milk and reproductive performance of Saanen and Saanen × Hair goat crossbreds (F1, B1 & B2) and growth performance of their kids in semi-intensive production system. Turkish J Agric - Food Sci Technol 7(6):871–876. https://doi.org/10.24925/turjaf.v7i6.871-876.2450
Yılmaz A, Deniz D, Vural ME (2023) Birth and various period live weights of Hair goat kids. BEÜ Fen Bilimleri Dergisi 12(3):863–870. https://doi.org/10.17798/bitlisfen.1330206

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