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The reproductive traits of purebred and crossbred (F1) goats and growth traits of their kids: effects of parturition time and lunar cycle

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ABSTRACT

This study investigated the effects of supplementary feeding at different physiological stages in a crossbreeding programme on the reproductive performance of goats, and the growth and performance of their offspring (purebred, F_1, F_2 and B_1). Hair, Saanen × Hair F_1 (SHF_1) and Alpine × Hair F_1 (AHF_1) crossbred goats were studied in four pasture-based flocks considering the effects of the lunar cycle, parturition time and some environmental factors. Crossbreeding both increased the twinning rate and shortened the gestation period (P<0.05). The distribution of births over the day was mostly between 06:01 and 09:00 (P<0.05; 38.4%). The distribution of births in eight different moon phases showed statistical differences (P<0.05). The lowest number of births (7.6%) occurred during the new moon phase and the highest number of births (20.9%) during the last quarter moon phase (P<0.05). In addition, a much higher birth rate in goats was observed on nights with a bright moon phase than on nights with a dark moon phase (P<0.05). Environmental factors had a significant effect on gestation age at birth and on time from birth to yearling weight of purebred, F_1, F_2, and B_1 generation crossbred kids (P<0.01 to P<0.05). The estimated Kleiber ratio of genotypes was important for weight gain from birth to 12 months of age (P<0.05). This study shows that innovative sustainable goat production systems can be developed through better modelling of environmental changes in mountain areas, and that the reproductive and growth traits of local goats can be improved through crossbreeding.

Key words: crossbreeding; growth traits; Kleiber ratio; lunar cycle; parturition time; reproduction

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Introduction

Animals have different physiological responses to production systems, agro-climatic conditions, and management and feeding practices, resulting in continuous changes in productivity and growth traits (ERDURAN, 2021). However, due to global climate change, it is unlikely that sustainable dairy production based solely on pasture or intensive systems will be economically, socially, and agro-ecologically viable in the future (DUBEUF et al., 2018; ERDURAN, 2023). On the other hand, the negative impact of overgrazing on both rangeland sustainability and greenhouse gas emissions is a significant problem in livestock production, es-

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pecially in mountainous regions where goats are often the main livestock species (ÇELIK and OLFAZ, 2018; AGUIRRE et al., 2021; ERDURAN, 2024). Therefore, alternative models, compatible with ecological and sustainable agricultural systems, are being developed to meet the global demand for livestock (ERDURAN, 2021).

Improving crossbreeding practices and production systems is the fastest way to increase the productivity, growth and production economics of local goat breeds in mountainous areas (CASTILLO-ZUÑIGA et al., 2022; ERDURAN and DAG, 2022; PAKPAHAN and FURQON, 2023). The practice of supplementing goats grazing on natural mountain pastures with additional feed during critical periods has proven to be a promising solution, with a number of potential benefits (ERDURAN, 2021).

The fact that dystocia is observed in goats at a significant rate of about 5% to 20% is an indicator of how important it is to know the time of birth (BATISTA et al., 2009; POLLOCK et al., 2021). Furthermore, newborns should consume at least 10% of their birth weight in colostrum as soon as possible after birth (TAŞKIN et al., 2018). Moreover, knowing the time of birth is a very important advantage for the survival, productivity and longevity of the new-born offspring. Although the timing of birth in mammals is influenced by many factors, including genotype, sex, birth type, maternal age and year, there is strong evidence that it is most closely related to circadian events and is strongly influenced by the production system, behaviour, the light-dark cycle, and the phase of the moon.

Offspring is an economically important factor in sustainable dairy production systems, and the cornerstone of flock productivity. The Kleiber ratio (KR), characterised as the ratio of growth rate to metabolic weight, has been proposed as a beneficial indicator of livestock growth productivity, and an indirect selection criterion for feed conversion (KLEIBER, 1947).

Hair goats account for about 90% of the total goat population, estimated at 10.709 million in Türkiye and distributed throughout the country (TURKSTAT, 2023). Hair goats are highly adaptable to climatic and grazing conditions and have a high stress tolerance (DASKIRAN et al., 2018; ERDURAN, 2021). Despite these advantages, the contribution of goat production to producers and the economy in Türkiye is low. This has led to the crossbreeding of Hair goats with Alpine and Saanen breeds to meet the increasing demand for goat products (ERDURAN and DAG, 2021).

The aim of this study was to compare the reproductive traits of Hair, Saanen × Hair F_1 (SHF_1) and Alpine × Hair F_1 (AHF_1) crossbred goats, grazed under natural pasture conditions and fed supplementary feed, in different physiological periods, as well as the growth traits and KR of purebred, F_1, F_2 and B_1 kids.

Materials and methods

The Animal Ethics Committee of the Bahri Dağdaş International Agricultural Research Institute approved the study protocol.

Animal, location and climate data. Data were used from a crossbreeding programme conducted over two breeding seasons on four goat farms in Konya province, in the central southern part of Türkiye. In order to increase the fertility and milk yield of local Hair goats, crossbreeding with Alpine and Saanen bucks was performed. The study farms were located in two different mountain villages in the northwest of the city centre. Farm-1 was located in the village of Selahattin (37˚ 59´ N, 32˚ 08´ E) with an altitude of 1662 m. Farms 2, 3 and 4 were located in different parts of Sızma village (38˚ 04´ N to 38˚ 06´ N, 32˚ 24´ E to 32˚ 27´ E) with altitudes of 1404 m, 1524 m and 1400 m above sea level, respectively. The average annu- al precipitation, temperature and relative humidity values in the study area were 375 mm, 12.3°C and 56.1% in 2012 and 238 mm, 12.3°C and 52.2% in 2013.

The study was conducted with a total of 585 Hair, SHF_1 and AHF_1 does, mated with Hair (n=5), Saanen (n=8), Saanen F_1 (n=5), Alpine (n=9) and Alpine F_1 (n=4) bucks. A total of 634 purebred and crossbred progeny of the Hair, SHF_1, (Saanen × Hair F_1) buck × (Saanen × Hair F_1) doe (SHF_2) and Saanen buck × (Saanen × Hair F_1) doe (SHB_1),

AHF_1, (Alpine × Hair F_1) buck × (Alpine × Hair F_1) doe (AHF_2), Alpine buck × (Alpine × Hair F_1) doe (AHB_1) generations were obtained from the crossbreeding programme.

Feeding and management system. The region where the study was conducted has a continental climate and is almost completely dry from late June to October. The goats were kept on the pas- ture during the day and in barns at night. During the kidding season, the goats that were expected to give birth according to the insemination date were not taken out to pasture, but kept in the barns. In this way, it was ensured that almost all of the births took place in the barns. The daily grazing time of the goats was between 6 and 8 hours. The goats were grazed at a rate of about 1 goat ha^{-1} y^{-1}. The main production period of the pastures is from May to July, and the average annual dry matter production is 500 kg dry matter ha^{-1} y^{-1}. The pastures consisted of steep grassland, scrub, woodland, herbaceous vegetation, and rocky out-crops. In addition to grazing in the barns, the goats were fed a mixture of 300 g concentrate per day, 500 g alfalfa hay per day, and 500 g wheat straw per day, according to their body condition during the pre-mating (14.8% CP 2680 kcal ME kg^{-1} dry matter), prepartum (15.9% CP 2780 kcal ME kg^{-1} dry matter), and post-parturient (15.1% CP 2710 kcal ME kg^{-1} dry matter) periods (45 days each). The kids were born between mid-February and the end of March and were weaned at around 90 days of age. In addition, the kids were fed an average of 250 g d^{-1} kid growth feed during the suckling period and adlibitum dry alfalfa grass from the age of 14 days.

Reproduction and body weight. The bucks were mated with does at a ratio of 20–30:1 using single mating methods (hand matings) as part of a controlled breeding programme. The light duration of the photoperiod during the parturition period varied between 11.1 and 12.5 hours. Percentage il-lumination data for the lunar phases were obtained from the Astronomical Applications Department of the US Naval Observatory (https://aa.usno.navy.mil/data/MoonFraction). Parturition time and the influence of the lunar cycle on gestation length were analysed in three periods: early (143-146 days), normal (147-150 days), and late (151-154 days). In addition, the method described by HOP-PER et al. (2019) was used to analyse the lunar cycle. The traits calculated for the kids were live weight, average daily gain (ADG) and Kleiber ra-tio (KR) every three months from birth to one year of age, and pre-mating weights in goats. The KR was as proposed by Kleiber (KLEIBER, 1947) and calculated as follows: KR_{0-3} from birth to weaning ($ADG_{0-3}/(0\text{-}3\ MW)^{3/4}$), KR_{3-6} from weaning to 6 months of age ($ADG_{3-6}/(3\text{-}6\ MW)^{3/4}$), KR_{6-9} from 6 months to 9 months of age ($ADG_{6-9}/(6\text{-}9\ MW)^{3/4}$), KR_{9-12} from 9 months to one year of age ($ADG_{9-12}/(9\text{-}12\ MW)^{3/4}$) and KR_{0-12} from birth to one year of age ($ADG_{0-12}/(0\text{-}12\ MW)^{3/4}$).

Statistical analysis. The Chi-square statistic test was used to assess the effects of environmen- tal factors on reproductive traits (KESKIN et al., 2023). Data on growth, body weight and KR traits were determined using least squares analysis of variance. The Tukey multiple comparison method was used to investigate the differences between the factor levels. All statistical calculations were performed using the Minitab 14 software program. The statistical models for goats and kids are pre-sented below.

The statistical model for gestation length and live weight traits of goats is as follows:

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

where y_{ijklm} is the observation, μ the overall mean, A_i the effect of buck genotype (i=Hair, Saa-nen, Alpin, SHF_1, AHF_1), B_j the effect of maternal genotype (j= Hair, SHF_1, AHF_1), C_k the effect of parity (k=1, 2), D_l the effect of year (l= 1, 2), E_m the effect of flock (m=1, 2, 3, 4) e_{ijklm} the random error.

The statistical model for growth traits and KR of kids is as follows:

$$y_{ijklmn} = \mu + a_i + b_j + c_k + d_l + f_m + g_n + e_{ijklmn}$$

where y_{ijklmn} is the observation, μ the overall mean, a_i the effect of kid genotype (i=Hair, SHF_1, SHF_2, SHG_1, AHF_1, AHF_2, AHG_1), b_j the effect of birth type (j= single, twin), c_k the effect of offspring sex (k=female, male), d_l the effect of maternal parity (l= 1, 2), f_m the effect of year (m=1, 2,) g_n the effect of flock (n=1, 2, 3, 4) e_{ijklmn} the random error.

Results

The environmental influences on reproduc- tive traits and body weight are shown in Table 1. SHF_1 and AHF_1 goats had a higher twinning rate compared to Hair goats (P<0.05). Gestation length varied significantly in relation to environmental factors (P<0.05). The study found a significant effect of parturition time and lunar cycle on gestation length (P<0.05; Table 2). The distribution of eight different lunar phases according to the timing of parturition in goats is shown in Fig. 1. In addition, the distribution of lunar light/dark night

Table 1. The **e**ffect of genotype, parity, year and flock on reproductive, gestation length (days), and body weight (kg) traits in goats

Traits	n	Pregnancy rate (%)	Birth rate (%)	Litter size (%)	Twinning rate (%)	Gestation length±SE	Body weight ±SE
Buck genotype						*	
Hair	65	97.0	89.2	1.10	10.3	148.9±0.38^{a}	48.3±1.08
Saanen	190	98.9	93.0	1.21	21.3	148.2±0.30^{b}	48.7±0.88
Alpin	215	99.5	94.9	1.17	16.8	147.9±0.28^{b}	49.3±0.79
SHF_1	65	98.5	90.6	1.22	22.4	148.6±0.43^{ab}	48.0±1.24
AHF_1	50	98.0	89.8	1.18	18.2	148.4±0.44^{ab}	51.3±1.25
Maternal genotype					**	*	
Hair	186	98.9	94.6	1.11	11.5^{B}	149.0±0.24^{a}	49.8±0.68
SHF_1	201	98.5	90.9	1.26	23.9^{A}	147.9±0.34^{b}	48.4±0.99
AHF_1	198	99.0	92.9	1.19	19.2^{A}	148.4±0.33^{b}	49.0±0.95
Parity						**	*
1	337	98.5	91.3	1.17	17.2	148.1±0.15	46.6±0.42
2	248	99.2	94.7	1.20	19.7	148.7±0.22	51.6±0.63
Year						**	
2012	202	98.5	90.5	1.19	19.4	148.2±0.24	48.6±0.68
2013	383	99.0	93.9	1.18	17.7	148.7±0.13	49.7±038
Flock						*	*
1	213	98.6	92.9	1.17	17.4	149.0±0.20^{a}	56.3±0.58^{a}
2	113	99.1	94.6	1.24	23.6	148.5±0.22^{ab}	49.50.64^{b}
3	131	99.2	92.3	1.21	20.8	148.2±0.24^{b}	47.8±0.69^{b}
4	128	98.4	91.3	1.12	12.2	148.1±0.25^{b}	42.8±0.73^{c}
Overall	585	98.8±0.19	91.6±0.69	1.19±0.03	18.3±2.45	148.4±0.14	48.3±0.40

n-number of goats during the mating period; SHF_1-Saanen × Hair $F_{1;}$ AHF_1-Alpine × Hair $F_{1;}$
SE-standard errors
$^{a, b, c}$ Means within an inside-class of a column with different superscripts differ significantly; small letters – (*P<0.01); capital letters – (**P<0.05)

phases according to the time of parturition in goats is given in Fig. 2. The timing of parturition in goats varied significantly (P<0.05) in relation to both lunar phases and light/dark moon nights. The highest number of births occurred in the last quarter moon phase at 20.9%, followed by the full moon phase with 20.1%, and the lowest in the first quarter moon phase with only 3.6%. In addition, the frequency of parturition was higher on bright moon nights than on dark moon nights. Genotype, birth type, sex, maternal parity, year and flock factors had a significant effect (P<0.01 to P<0.05) on gestational age and body weight of the kids at birth, as well as body weight at 3 (weaning), 6, 9 and 12 months of age (Table 3). However, there was no difference between these factors and the survival rate of the kids at weaning, which ranged from 69.1% to 83.3%. The mean values of ADG and KR of the kids are presented in Table 4. The maximum ADG of the kids was reached in the pre-weaning period (142.6 g/day), while the minimum was reached between 9 months and old age (10.3 g/day).

Table 2. The effect of parturition time and lunar phases on the gestation period in goats

Traits	Gestation period			Total
	143-146 days	147-150 days	151-154 day	
	n (%)	n (%)	n (%)	n (%)
Moon phases				
New moon	3 (7.3)	30 (73.2)	8 (19.5)	41 (7.6)
Waxing crescent	7 (10.4)	53 (79.1)	7 (10.4)	67 (12.5)
First quarter	5 (23.8)	14 (66.7)	2 (9.5)	21 (3.9)
Waxing gibbous	12 (24.0)	33 (66.0)	5 (10.0)	50 (9.3)
Full moon	22 (20.4)	65 (60.2)	21 (19.4)	108 (20.1)
Waning gibbous	7 (9.0)	53 (67.9)	18 (23.1)	78 (14.6)
Last quarter	15 (13.4)	84 (75.0)	13 (11.6)	112 (20.9)
Waning crescent	4 (6.8)	40 (67.8)	15 (25.4)	59 (11.0)
$\chi 2$: 27.297; DF: 14; P-value: 0.018				
Time period				
06:01-09:00	32 (15.5)	151 (73.3)	23 (11.2)	206 (38.4)
09:01-12:00	12 (13.5)	59 (66.3)	18 (20.2)	89 (16.6)
12:01-15:00	7 (13.0)	38 (70.4)	9 (16.7)	54 (10.1)
15:01-18:00	6 (7.7)	57 (73.1)	15 (19.2)	78 (14.6)
18:01-24:00	5 (8.9)	35 (62.5)	16 (28.6)	56 (10.4)
24:01-06:00	13 (24.5)	32 (60.4)	8 (15.1)	53 (9.9)
$\chi 2$: 19.191; DF: 10; P-value: 0.038				
Total	75 (14.0)	372 (69.4)	89 (16.6)	536 (100.0)

$\chi 2$-Chi-square result, DF-degree of freedom; n-number of animals; P-significance level

Table 3. Mean values and standard errors (±SE) for gestation length, survival rate at weaning (3 months of age), birth weight, live weight at 3, 6, 9 and 12 months for kids

Traits (n)	Gestation length±SE (days)	Birth weight±SE (kg)	Weaning weight±SE (kg)	Survival rate at weaning (%)	Six-month weight±SE (kg)	Nine-month weight±SE (kg)	Yearling weight±SE (kg)
Genotype	**	*	*		**	*	*
Hair (54)	148.8±0.25^{A}	3.04±0.04^{ab}	16.2±0.34^{ab}	82.8	22.1±0.42^{ab}	24.0±0.42^{ab}	25.2±0.43^{ab}
SHF_1 (48)	148.2±0.26^{AB}	2.99±0.04^{bc}	15.6±0.36^{ab}	79.7	21.4±0.44^{ab}	22.8±0.45^{ab}	23.4±0.45^{ab}
SHF_2 (51)	148.3±0.22^{AB}	3.14±0.04^{a}	16.5±0.35^{a}	78.9	22.7±0.43^{a}	24.3±0.43^{a}	25.3±0.44^{a}
SHB_1 (111)	147.8±0.17^{B}	2.85±0.03^{c}	15.1±0.25^{b}	77.0	21.1±0.31^{b}	22.7±0.31^{b}	23.6±0.32^{b}
AHF_1 (59)	148.1±0.22^{AB}	3.00±0.04^{ab}	15.4±0.32^{ab}	81.7	21.6±0.39^{ab}	23.2±0.40^{ab}	24.1±0.40^{ab}
AHF_2 (34)	148.4±0.28^{AB}	3.18±0.05^{a}	16.5±0.45^{a}	75.0	22.5±0.55^{ab}	24.3±0.55^{ab}	25.2±0.56^{ab}
AHB_1 (116)	147.8±0.17^{B}	2.86±0.03^{c}	15.4±0.24^{ab}	75.8	21.6±0.30^{ab}	23.1±0.30^{ab}	24.1±0.30^{ab}
Birth type	*	*	*		*	*	*
Single (330)	148.7±0.10	3.18±0.02	16.6±0.16	82.0	22.6±0.19	24.1±0.19	25.1±0.20
Twin (143)	147.7±0.15	2.84±0.03	15.1±0.23	69.1	21.2±0.28	22.8±0.28	23.8±0.28
Sex	*	*	*		*	*	*
Male (237)	148.6±0.13^{a}	3.12±0.02	16.4±0.19	79.9	22.8±0.23	24.3±0.23	25.3±0.24
Female (236)	147.8±0.12^{b}	2.90±0.02	15.2±0.19	76.4	21.0±0.23	22.7±0.23	23.5±0.24
Maternal parity	**	*	**		*	**	
1 (278)	148.0±0.16	2.95±0.02	15.6±0.16	76.3	21.6±0.20	23.2±0.20	24.2±0.20
2 (195)	148.4±0.11	3.07±0.03	16.1±0.23	79.2	22.2±0.28	23.8±0.28	24.7±0.29
Year	*	*	*		*	**	**
2012 (161)	148.0±0.16	2.91±0.03	15.5±0.25	83.3	22.5±0.30	23.9±0.31	24.8±0.31
2013 (312)	148.4±0.11	3.10±0.02	16.2±0.16	75.4	21.3±0.19	23.1±0.19	24.0±0.20
Flock	*	*	*		*	*	**
1 (176)	148.7±0.15^{a}	3.23±0.02^{a}	17.5±0.21^{a}	78.2	24.2±0.26^{a}	25.8±0.26^{a}	27.2±0.27^{a}
2 (98)	148.4±0.17^{ab}	3.05±0.03^{b}	15.9±0.26^{b}	84.0	21.7±0.32^{b}	23.1±0.32^{b}	24.8±0.33^{b}
3 (108)	148.0±0.17^{bc}	2.80±0.03^{b}	14.6±0.28^{bc}	77.2	20.6±0.35^{b}	22.2±0.35^{b}	22.4±0.36^{c}
4 (91)	147.7±0.19^{c}	2.96±0.03^{c}	15.3±0.25^{c}	72.9	20.9±0.30^{b}	22.9±0.30^{b}	23.3±0.31^{c}
Overall (473)	148.2±0.10	3.01±0.02	15.9±0.15	78.1	21.9±0.18	23.5±0.19	24.4±0.19

SHF_1-Saanen × Hair F_1; SHF_2-Saanen × Hair F_1) × (Saanen × Hair F_1); SHB_1- Saanen × (Saanen × Hair F_1); AHF_1-Alpine × Hair F_1, AHF_2-(Alpine × Hair F_1) × (Alpine × Hair F_1); AHB_1-Alpine × (Alpine × Hair F_1)

[a, b, c] Means within an inside-class of a column with different superscripts differ significantly; small letters – (*P<0.01), capital letters – (**P<0.05)

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Table 4. Average daily gain (g) and Kleiber ratio (KR) of different genotypes of kids

Traits (n)	ADG_{0-3}	ADG_{3-6}	ADG_{6-9}	ADG_{9-12}	ADG_{0-6}	ADG_{0-9}	ADG_{0-12}	KR	KR	KR	KR	KR	KR	KR_{0-12}
Genotype	**					**	*							*
Hair (54)	146.6^{a}	64.9	21.7	12.8	105.7	77.7^{a}	61.5^{a}	18.02	6.35	1.99	1.10	10.34	7.14	5.45^{a}
SHF_1 (48)	140.3^{ab}	64.9	15.3	6.5	102.6	73.5^{b}	56.7^{b}	17.77	6.41	1.47	0.61	10.24	7.01	5.31^{b}
SHF_2 (51)	148.6^{a}	69.1	17.9	10.5	108.8	78.5^{ab}	61.5^{ab}	18.02	6.61	1.64	0.87	10.40	7.14	5.42^{ab}
SHB_1 (111)	136.6^{b}	65.9	17.9	10.1	101.3	73.5^{ab}	57.6^{ab}	17.71	6.64	1.72	0.92	10.25	7.05	5.37^{ab}
AHF_1 (59)	138.2^{b}	68.7	17.2	10.8	103.4	74.7^{ab}	58.7^{ab}	17.65	6.79	1.63	0.95	10.27	7.05	5.37^{ab}
AHF_2 (34)	148^{a}	67.1	19.3	10.5	107.6	78.1^{ab}	61.2^{ab}	17.97	6.46	1.78	0.88	10.36	7.13	5.43^{a}
AHB_1 (116)	139.8^{ab}	68.9	16.6	11.0	104.3	75.1^{ab}	59.1^{ab}	17.86	6.78	1.58	1.00	10.36	7.10	5.41^{ab}
Birth type	*				*	*	*	*	**					
Single (330)	148.9	66.5	17.5	10.3	107.7	77.6	60.8	18.01	6.39	1.61	0.88	10.36	7.11	5.41
Twin (143)	136.3	67.6	18.4	10.3	101.9	74.1	58.2	17.70	6.76	1.76	0.92	10.28	7.07	5.38
Sex	*	*		**	*	*	*	*	**	*	**	*	*	*
Male (237)	148.1	70.3	16.9	11.5	109.2	78.5	61.7	18.04	6.72	1.54	1.00	10.44	7.15	5.45
Female(236)	137.0	63.8	19.0	9.1	100.4	73.3	57.2	17.67	6.44	1.84	0.81	10.19	7.02	5.34
Maternal parity														
1 (278)	140.3	66.8	17.7	10.9	103.5	74.9	58.9	17.80	6.62	1.68	0.97	10.30	7.07	5.39
2 (195)	144.9	67.3	18.3	9.7	106.1	76.8	60.1	17.91	6.54	1.70	0.84	10.34	7.10	5.40
Year	**	*	*		*	*	*		*	*		*	*	*
2012 (161)	139.4	78.1	15.8	10.2	108.8	77.8	60.9	17.77	7.53	1.45	0.90	10.49	7.17	5.46
2013 (312)	145.8	56.0	20.2	10.4	100.9	74.0	58.1	17.94	5.62	1.92	0.91	10.15	7.00	5.34
Flock	**	*	*	*	*	*	*	**	*	*	*	*	*	*
1 (176)	158.8^{a}	74.6^{a}	17.2^{b}	16.2^{a}	116.7^{a}	83.6^{a}	66.7^{a}	18.44^{a}	6.81^{a}	1.50^{b}	1.34^{a}	10.65^{a}	7.28^{a}	5.58^{a}
2 (98)	142.7^{b}	64.8^{b}	15.7^{b}	18.0^{a}	103.8^{b}	74.4^{b}	60.3^{b}	17.85^{b}	6.41^{ab}	1.47^{b}	1.62^{a}	10.28^{b}	7.03^{b}	5.42^{b}
3 (108)	137.1^{bc}	62.4^{b}	21.7^{a}	5.0^{b}	99.8^{b}	73.7^{b}	56.6^{c}	17.63^{b}	6.28^{b}	2.09^{a}	0.45^{b}	10.14^{b}	7.03^{b}	5.31^{c}
4 (91)	131.6^{c}	66.3^{b}	17.3^{ab}	2.1^{b}	99.0^{b}	71.8^{b}	54.3^{c}	17.51^{b}	6.80^{ab}	1.69^{ab}	0.20^{b}	10.20^{b}	7.00^{b}	5.27^{c}
Overall (473)	142.6	67.1	18.0	10.3	104.8	75.9	59.5	17.86	6.58	1.69	0.91	10.3	7.09	5.40
SE	1.34	1.01	0.60	0.62	0.86	0.56	0.46	0.06	0.08	0.06	0.05	0.03	0.02	0.01
CV (%)	19.89	34.09	71.21	116.21	17.64	15.98	16.56	6.88	28.21	70.75	114.84	5.84	5.05	5.22

SHF_1-Saanen × Hair F_1, SHF_2: (Saanen × Hair F_1) × (Saanen × Hair F_1); SHB_1-Saanen × (Saanen × Hair F_1), AHF_1: Alpine × Hair F_1, AHF_2-(Alpine × Hair F_1) × (Alpine × Hair F_1); AHB_1-Alpine × (Alpine × Hair F_1); ADG-Average Daily Gain; KR-Kleiber Ratio; ADG_{0-3} or KR_{0-3}: for birth to weaning; ADG_{3-6} or KR_{3-6}: for weaning to 6 months ADG_{6-9} or KR_{6-9}-for 6 months to 9 months; ADG_{9-12} or KR_{9-12}- for 9 months to yearling; ADG_{0-6} or KR_{0-6}-for birth to 6 months; ADG_{0-9} or KR_{0-9}-for birth to 9 months; ADG_{0-12} or KR_{0-12}-for birth to yearling; SE-standard errors, CV-coefficient of variation
[a, b, c]Means within an inside-class of a column with different superscripts differ significantly; small letters - (*P<0.01); capital letters - (**P<0.05)

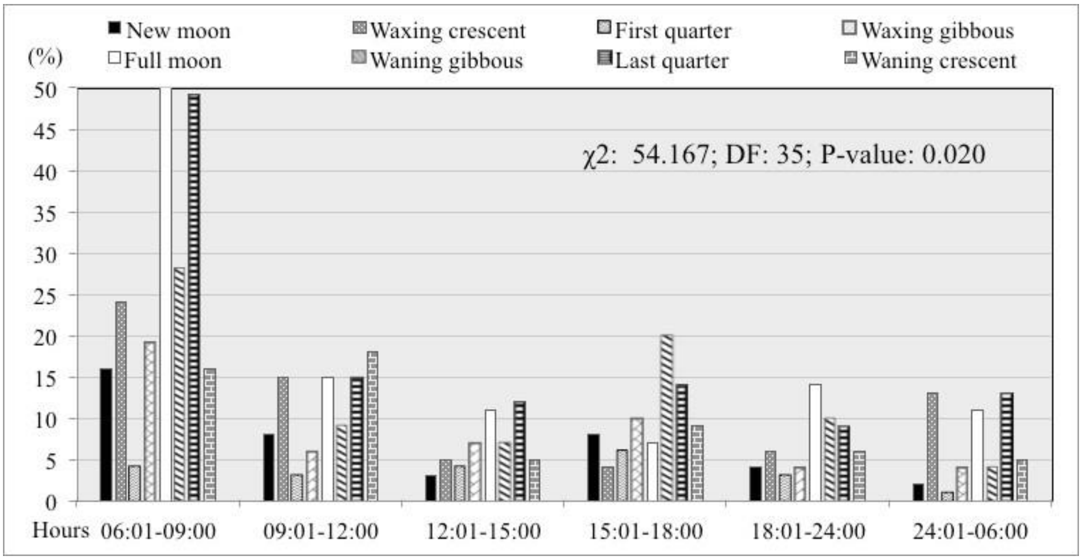

Fig. 1. Distribution of eight different lunar phases according to the timing of parturition in goats
$\chi 2$-Chi-square Result, DF-Degree of Freedom, P-Significance Level

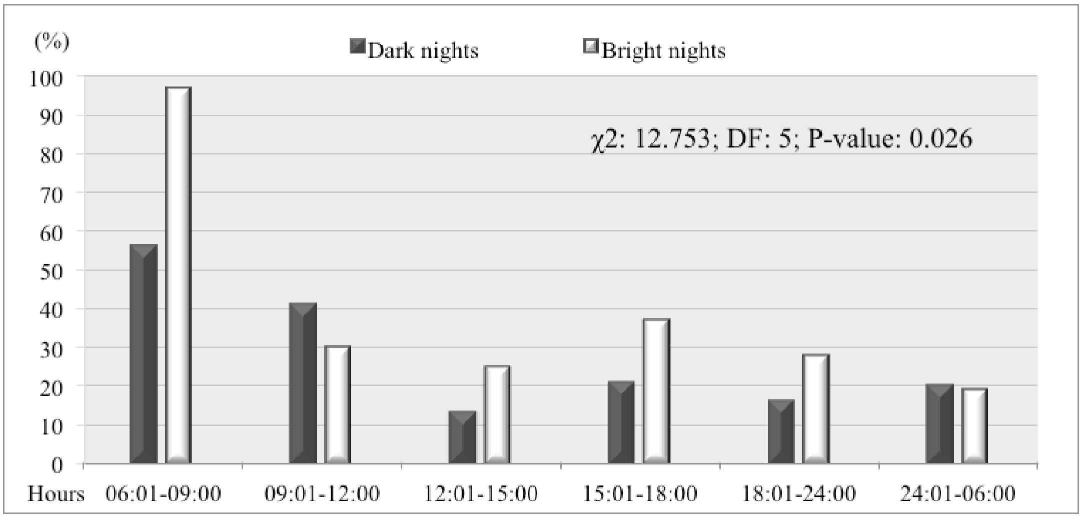

Fig. 2. Distribution of lunar bright and dark phases according to the time of parturition in goats
$\chi 2$-Chi-square Result, DF-Degree of Freedom, P-Significance Level, Dark-(waning crescent, new moon, waxing crescent), Bright-(waxing gibbous, full moon, waning gibbous)

Discussion

Reproductive performances. In the present study, the twinning rate of Hair, SHF_1 and AHF_1 goats was higher than that of purebred and crossbred goats reared in a pasture-based extensive system (ÇELIK and OLFAZ, 2018), and lower than that of purebred and crossbred goats reared in a semi-intensive system (YILDIRIR et al., 2019; TESEMA et al., 2020). This can be explained by differences in selection strategies depending on the production system and rearing conditions, as well as the feed ration given during the flushing period (ÇELIK and OLFAZ, 2018).

The gestation length of the Hair goats was longer by 0.5 and 0.7 days than that of SHF_1 and AHF_1 goats, respectively (P<0.05). Crossbreeding tended to increase the twinning rate and shorten the gestation period. A possible explanation could be that in crossbred goats giving birth to twins, the uterus functions more efficiently and the total fetal weight of the twins is higher, which triggers the physiological response.

The gestation length values for Hair, SHF_1 and AHF_1 genotypes were within the range of values previously reported in the literature for different goat populations (145 to 156 days) (HABEEB et al., 2018; ERDURAN, 2021; TÖLÜ et al., 2022), the variation in gestation length between populations is remarkable. These variations probably indicate that gestation length is directly influenced by gonadal hormones of foetal origin, genotype, parity, geographical structure and management conditions (HABEEB et al., 2018; ERDURAN, 2021).

Gestational age at birth of Hair kids was one day longer than that of B_1 (SHB_1 and AHB_1) crossbred kids (P<0.05). It is also possible that the shortening of gestational age at birth of kids with increasing crossbreeding level may contribute positively to the prolongation of the lactation period, early maturation of the kids, accelerated weaning methods, and practices such as off-season operations.

In the study, the highest number of births was recorded between 24:01 and 06:00 in goats with a gestation length of 143-146 days, between 06:01 and 09:00 in goats with a gestation length of 147-150 days and between 18:01 and 24:00 in goats with a gestation length of 151-154 days. On the other hand, the highest percentage of births in the early gestation period occurred during the waxing gibbous moon phase (24%), the highest percentage of births in the normal gestation period occurred during the waxing crescent moon phase (79.1%), and the highest percentage of births in the late gestation period occurred during the full moon phase (19.4%). The generally accepted average gestation length for goats is 150 days and the fact that most of the goats in this study had a normal gestation length may be an indication of adequate nutrition. However, whether the gestation length is short or long can be influenced by environmental stressors to which the doe is exposed, such as litter size, restricted or excessive feeding, circadian events, changes in the light schedule in late pregnancy, and heat stress during the first third of pregnancy (AMANO et al., 2020; COLOMA-GARCÍA et al., 2020; POLLOCK et al., 2021). This can also affect the optimal health and growth of the offspring during the foetal and postnatal periods, as well as the future productivity and behaviour of the does (COLOMA-GARCÍA et al., 2020; ERDURAN, 2021).

Most births (78.9%) took place between 06:01 am and 18:00 pm, corresponding to daylight hours, and the largest proportion (38.4%) took place between 06:01 am and 09:00 am, corresponding to daylight hours. These findings are broadly consistent with those reported for purebred and crossbred goats (ERDURAN and YAMAN, 2014; ERDURAN, 2021; POLLOCK et al., 2021).

Most births occurred during the last quarter and full moon phases, with a rate of 41%. The temporary increase in the strength of lunar gravitational variations during these two phases is likely to be related to changes in the Earth's terrestrial and electromagnetic fields (BEVINGTON, 2015). This may indicate that the moon regulates the parturition process by affecting melatonin secretion in the plasma and pineal gland of goats exposed to light levels and intensities at night (CHAKRABORTY, 2020). On the other hand, the significant difference of 17.3% in the frequency of births between the last quarter of the moon and the first quarter of the moon may play an important role in the reproductive performance of goat and the profitability of farms. Therefore, monitoring births according to dark/light and lunar cycles can help to prevent dystocia in goats, and reduce losses due to colostrum deficiency in newborns (TAŞKIN et al., 2018; ERDURAN, 2021). These results, which showed that lunar phases influenced the timing of parturition in the goats, also supported previous reports on the effects of the lunar cycle on birthing behaviour in marine and terrestrial species (CHAKRABORTY, 2020; AGUIRRE et al., 2021; IGLESIAS PASTRANA et al., 2023).

Growth traits and Kleiber ratio. Hair, SHF_2, AHF_1 and AHF_2 crossbred kids had higher pre- and post-weaning body weights and survival rates than the B_1 generation crossbred kids. This finding is both consistent and inconsistent with previous studies (MUSTEFA et al., 2019; YILDIRIR et al., 2019; AKBAŞ et al., 2020; PÉREZ-BAENA at al., 2021; SANOGO et al., 2022). A possible explanation for this inconsistency is the differences between studies in genotype, parental influence, crossbreeding level, production system and environmental conditions (ERDURAN, 2021; PÉREZ-BAENA et al., 2021; SANOGO et al., 2022; PAKPAHAN and FURQON, 2023).

In this study, the mean ADGs of kids were estimated for KR_{0-3} (17.86), for KR_{3-6} (6.58), for KR_{6-9} (1.69), for KR_{9-12} (0.91), for KR_{0-6} (10.3), for KR_{0-9} (7.09) and for KR_{0-12} (5.40). The effect of environmental characteristics on growth traits is clear, and this strong relationship is likely to persist for the rest of the kid's life. Therefore, KR can be an extremely sensitive tool that can be used as an indirect selection criterion to pre- dict the growth and development of offspring. For all traits considered, only the difference between 0-12 months of age was significant for KR in kid genotypes. Except for the vegetative growth period, the highest ADG and KR for Hair goat kids were estimated at the ages of 6-9 months (autumn) and 9-12 months (winter), when it is most difficult to find grass on the pasture. The probable reason for this is that Hair goat kids provide higher ADG than other crossbred genotypes due to the fact that Hair goat kids are both a late developing breed and have high adaptability to unfavourable envi- ronmental conditions. In addition, as growth traits have a direct long-term effect on survival, age at first reproduction and regeneration rates, it can be argued that additional management and feeding strategies should be applied to F_1 and B_1 crosses, especially in autumn and winter. Female kids had lower ADG and KR from birth to yearling age than male kids. Possible reasons for the lower performance of female kids could be the mater- nal factor, their different physiological processes and endocrine systems, as well as the quantity and quality of grass in the pasture, which may not be sufficient to provide the nutritional requirements of growing female kids. The type of birth had a significant impact on ADG up to weaning and on KR at 0-3 and 3-6 months of age, but this effect lost significance with increasing age. The differ- ence in growth between singletons and twins can be explained by the fact that the does provide a better environment for singletons during the fetal and postnatal periods, and more breast milk until weaning. Therefore, the development of adaptive diets may be an option to solve the adverse ef- fects of sex and birth type. The effect of year on growth traits was effective in all traits except for ADG and KR ratios in the 9-12-month period of the kids. This can be explained by the variation in pasture vegetation from year to year, depending on the climatic conditions and end of grazing capacity.

The pre-weaning growth stage had the low- est phenotypic coefficient of variation and the highest phenotypic efficiency compared with the post-weaning growth stages for the ADG and KR traits analysed. This difference may be explained by the fact that kids in the pre-weaning period are less exposed to adverse environmental factors and physiologically grow faster. This finding is similar and comparable to previous reports for different goat breeds (JAFARI and RAZZAGZADEH, 2016; BANGAR et al., 2020; TESEMA et al., 2020). In addition, ADG and KR values at 9-12 months of age were the highest phenotypic coefficient of variation compared to the other growth stages. This suggests that after weaning, kids may be exposed to environmental stressors, which may reduce their ability to grow.

Conclusions

The results of this study demonstrated that Crossbreeding shortened the gestation period and increased the twinning rate. Light/dark and lunar cycle appeared to be important factors influenc- ing the timing of parturition in goats. On the other hand, it was observed that B_1 generation crossbred kids were slightly more likely to be affected by environmental factors than Hair, F_1 and F_2 generation crossbred kids. In addition, it may be appropriate to include 0-12 months KR in the selection index, especially to increase the productivity of breeding programmes. These findings can be used to develop production systems and crossbreeding strategies that maximise early life nutritional efficiency and reproductive management for long-term dairy goat performance. In addition, it is important to know the current status of breeds with respect to yield traits, both in terms of sustainability and ecosystems. However, more research is therefore needed to improve different production systems.

Ethics statement

The research protocol was approved by the Animal Ethics Committee of Bahri Dağdaş International Agricultural Research Institute (Approval number: 7).

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Author contributions

Hakan Erduran conceived the idea, supervised the project, analysed and drafted and edited the manuscript. Birol Dag and İsmail Keskin helped to read and edit the manuscript.

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ERDURAN, H., B. DAĞ, İ. KESKIN: Reproduktivna svojstva čistokrvnih i križanih (F1) pasmina koza te svojstva rasta njihove jaradi: utjecaj vremena jarenja i Mjesečevih mijena. Vet. arhiv 95, 423-435, 2025.

SAŽETAK

Istražen je utjecaj doba dana i Mjesečevih mjena pri jarenju na reproduktivna svojstva koza i rast njihove jaradi. Podaci su prikupljeni za životinje držane na pašnjacima u programu križanja pasmina lokalne dlakave koze (H) i njezinih križanaca (F1) sa sanskom kozom (SHF1) odnosno s alpskom kozom (AHF1). Križanjem je povećana stopa višeplodnih legla i skraćeno gestacijsko razdoblje (P<0,05). Raspodjela jarenja s obzirom na doba dana pokazala je predominaciju vremena od 06:01 do 09:00 (P<0,05; 38,4%). Raspodjela jarenja s obzirom na osam različitih Mjesečevih mijena pokazala je statistički znakovite razlike (P<0,05). Najmanji broj ojarenih jedinki (7,6%) bio je u fazi mladog Mjeseca, dok je najveći broj ojanjenih jedinki (20,9%) bio u vrijeme zadnje Mjesečeve četvrti (P<0,05). Uz navedeno, uočena je mnogo veća stopa jarenja koza tijekom noći s jakim Mjesečevim osvjetljenjem negoli za vrijeme noći s tamnim Mjesecom (P<0,05). Čimbenici okoliša znakovito (P<0,01 do 0,05) su utjecali na gestacijsku dob pri jarenju kao i na vrijeme od jarenja do postizanja tjelesne mase čistokrvne i križane jaradi u dobi od jedne godine. Procijenjeni Kleiberov omjer pokazao se znakovitim (P<0,05) za razlike u prirastu tjelesne mase od jarenja do dobi od 12 mjeseci kod čistokrvne jaradi i jaradi različiti križanaca. Ovo istraživanje pokazuje da se inovativni održivi sustavi uzgoja koza mogu razviti boljim modeliranjem promjena u okolišu planinskih područja te da se reproduktivna svojstva i svojstva rasta lokalnih pasmina koza mogu poboljšati križanjem.

Ključne riječi: križanje pasmina; svojstva rasta; Kleiberov omjer; Mjesečeve mijene; vrijeme jarenja; reprodukcija

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