Effects of reciprocal mating for horn presence, moon phase and natural light-dark cycle on reproductive and growth traits in Saanen goats

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SUMMARY

This study investigated the effects of mating type, lunar cycle, natural light-dark cycle, and environmental factors on reproductive performance and growth traits of semi-intensively reared Saanen goats. Data were obtained by mating horned bucks with polled does, and polled bucks with horned does during the two-year study period. Mating type and twin birth rate were significant at conception, whereas only mating type rate was significant at parturition ($P<0.05$). Birth frequency was highest around the new moon and lowest around the first quarter of the lunar phase, with most births occurring during daylight hours. Mating type, lunar phase, year, parity, and birth type were found to have a significant effect on gestation length in goats ($P<0.05$). For offspring ratios at birth, the effect of lunar cycle and time of birth on birth type was significant ($P<0.05$). There were also significant differences between mating type and lunar cycle ($P<0.05$). Gestational age, birth weight, weaning weight, average daily gain, and Kleiber ratio (KR) were significantly affected by parental mating type, lunar phase, time of birth, maternal parity, birth type, and offspring sex ($P<0.05$). The study showed that mating type, lunar cycle, and natural light-dark cycle significantly affected the productivity of Saanen goats. In addition, this study reports evidence that the lunar cycle is an external timer for the synchronization of mating and parturition.

KEY WORDS

Horn presence; Kleiber ratio; lunar cycle; natural light-dark cycle; reproduction.

INTRODUCTION

Goat rearing plays an important socio-cultural and economic role in meat and milk production in many countries around the world (1-4). Saanen is one of the most common and productive dairy goat breeds in the world (5). Goat production systems and mating practices affect productivity in many ways (6-8). For example, inadequate maternal and neonatal care and nutrition during pregnancy, parturition, and the postnatal period contribute significantly to the annual goat kid mortality rate, which ranges from about 3% to 45% worldwide (4, 9, 10). In addition, differences in kid loss rates are due to factors such as breed, genotype, offspring sex, birth type, parity, production system, circadian rhythm, lunar cycle and horn presence (5, 7, 11).

In goats, a member of the biological family of ruminants, the horn plays an important role in social behavior and protection (12). Polled goats are easy to manage with high fertility compared to horned goats, making them an attractive option for many breeders (13). However, inherited polledness in goats is mainly associated with recessive intersexuality and is an important cause of infertility in goats, with incidence ranging from about 2.0% to 24.0% in flocks (7, 12). The phenomenon of polled intersex syndrome is an important problem that threatens the potential development of goat populations as well as reproductive disorders (12). For example, it directly affects phenotypic traits by altering the sex ratio in favor of males. In goats, it may be possible to avoid the negative effects of the naturally occurring polled variant with intersexuality by using reciprocal mating methods for horn presence. However, previous studies have generally focused on the genetic effects, fertility, and social behavior of horn presence in ruminants (6, 7, 12, 13).

All living organisms, including ruminants such as sheep, cattle, and goats, have an internal biological clock known as the circadian rhythm (5). Primarily regulated by the natural light-dark cycle, these rhythms influence various physiological processes such as sleep-wake patterns, hormone secretion, and metabolic events (5, 14). There is evidence that another natural light phenomenon, lunar cycle, interacts with circadian rhythms to regulate reproductive events in terrestrial and marine organisms (15). On the other hand, little is known about how lunar cycles affect reproduction in ruminants. In this context, El-Darawany et al. (15) reported that different phases of the lunar cycle had significant effects on body weight and mor-

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phological structure, as well as progesterone levels and age at puberty in Nubian goats.

Feed efficiency is recognised as an economically important indicator in pasture-based small ruminant production systems, especially in semi-arid and continental regions (1, 5, 16). There is also a need to improve growth performance to maximize the benefits of selection programs. One solution could be the inclusion of a trait such as Kleiber Ratio (KR) as an alternative indirect selection criterion indicating metabolic rate and feed conversion efficiency (17, 18). KR is defined as growth rate divided by metabolic weight.

To my knowledge, this study is the first approach to potentially predicting reproductive efficiency, growth performance, and parturition behavior in Saanen goats based on a wide range of environmental factors, including horn presence, the lunar cycle, and the natural light-dark cycle. Therefore, the objectives of this study were to evaluate the effect of reciprocal mating for horn presence on productivity and reproductive efficiency, growth, morphological and KR traits in Saanen goats.

MATERIAL AND METHODS

Animal, feeding and pasture area

This study analysed data from 217 Saanen goats reared under semi-intensive conditions on a private farm in Konya province, Türkiye. The goats grazed on about 50 hectares of pasture in an area with a continental climate that was almost completely dry between July and October. The pasture area is about 1015 m above sea level. In 2012 and 2013, the annual rainfall was 248 mm and 204 mm, the average temperature was 12.4 °C and 12.2 °C, and the average relative humidity was 59.8% and 56.3%, respectively. After birth, date and time of birth, offspring sex, birth type and doe tag number of the kids were recorded. The kids were fed colostrum milk from their does for 3 days. They were then separated from their does and bottle-fed until weaning after about two months. Bottle feeding of kids was started with 250 g of milk at each meal in the morning and evening and then gradually increased to 600 g until weaning. Kids were allowed to drink about 51 kg of milk until weaning. Additionally, an average of 500 g of concentrate feed and ad libitum alfalfa and wheat straw were given from the second week onwards throughout the weaning period.

The goats were kept indoors during the winter months when heavy snow and blizzards made grazing impossible. The goats were fed a diet consisting of approximately 1200 g of roughage, including 800 g of alfalfa, 400 g of wheat mixture, and 1000 g of concentrate with 2450 kcal/kg ME and 15% crude protein during the last three months of gestation. During the lactation period, the goats were provided with 800 g of concentrate feed (17.1% CP, 2600 kcal ME kg-1) and 400 g of dry alfalfa hay in addition to foraging on pasture.

The vegetation is mainly composed by 21.7% *Juncus maritimus*, 16.7% *Juncus gerardi*, 12.2% *Inula aucherana*, 7.8% *Allium sp*., 2.8% *Bromus tectorum*, 1.8% *Centaurea depressa*, 1.0% *Consolida orientalis*, 1.0% *Aegilops ovata*, 0.8% *Anthemis tinctoria*, 0.8% Phleum exaratum 0.5% *Agropyron repens*, 0.5% *Apera intermedia*, 0.3 % *Briza humilis* and 30.8 % of bare area. The annual production of dry matter from the natural pasture is about 400 kg KM ha^{-1} y^{-1}, with the main production period from May to July. Mineral supplements were given to the goats during feeding periods. In addition, the flocks were routinely treated for internal and external parasites and regularly vaccinated against the major epidemic diseases in Türkiye.

Data collection

Hand mating method was used to improve reproductive performance in goat flocks. Hand mating involves placing an oestrus doe in a small pen where she is mated to a single buck under supervision. In the study, 4 horned bucks were mated with 95 polled does and 5 polled bucks were mated with 122 horned does. The males were 3-4-year-old bucks that had previously been used for hand mating and had proven fertility. Search bucks were used to detect oestrus in goats during the mating season, which lasted from mid-September to mid-October, in the cool morning and evening hours. Goats showing signs of oestrus were mated with bucks in separate pens.

Data on reproductive characteristics of Saanen goats were calculated as follows;

Pregnancy rate: (number of does giving birth/number of mated does) * 100

Birth rate: (number of does giving birth/number of mated does) * 100

Twinning rate: (number of does giving birth to twins/number of does giving birth) * 100

Survival rate: (number of kids weaned/number of kids born) * 100

Abortion rate: (number of pregnant does with abortion/number of pregnant does) * 100

The length of daylight ranged from 11:01 to 12:13 hours during the birthing period between 15 February and 16 March. The time of birth was divided into the daylight phase (mean 11:35 h) and the dark phase (mean 12:25 h). The phases of the lunar cycle were analyzed following the methodology of (17). The length of the synodic lunar cycle is approximately 29.54 days, divided into eight periods (~3.7 days) according to the percentage of illumination. For statistical analyses, the 8 lunar phases were coded to correspond to 4 phases: bright nights, dark nights, first quarter (first quarter to waxing gibbous), and last quarter (third quarter to a waning crescent). Days around the full moon, waning gibbous and waxing gibbous, were defined as relatively 'bright nights' (11. 1 days); similarly, days around the new moon, waning crescent and waxing crescent, were defined as relatively 'dark nights' (11. 1 days). Body weights and body measurements (wither height, body length and hearth girth) of the goats were taken after parturition. Birth weight, 2^{nd} month (weaning) weight and average daily gain were calculated for the kids. Kleiber ratio (KR) was calculated according to the principle reported by (17) as follows; (average daily gain / (weaning weight $^{3/4}$).

Statistical analysis

Effects of mating type, parity, year, lunar phase and time of birth on the reproductive traits of Saanen goats were analysed using the chi-squared test. The general linear model analysis of variance (ANOVA) procedure of Minitab 14 was used to analyse the effects of mating type, lunar phase, time of birth, parity, offspring sex, birth type, and year on body weight, gestation length and body measurements. Tukey test was used to confirm statistically significant differences between factors (19). The following model was used:

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

where $y_{ijklmno}$ is the observation, μ the overall mean, a_i the mating type effect (i= horned × polled, polled × horned) b_j the lu-

Table 1 - Frequency distribution of lunar phases at conception and parturition in Saanen goats.

Traits Lunar phase	*Number of births	Frequency distributions	Luminosity rate of lunar	* Mating type Horned × polled / Polled × horned	* Birth time Light / Dark	* Birth type Single / Twin	**Offspring sex Male / (male + female)
	n	%	%	n	n	n	n
At conception							
Dark nights	93	46.5	9.6	32/61 [b]	70/23	45/48 [a]	68/141
First quarter	12	6.0	53.9	6/6 [a]	11/1	11/1 [b]	8/13
Bright nights	68	34.0	86.6	40/28 [a]	53/15	36/32 [a]	55/100
Last quarter	27	13.5	50.2	11/16 [a]	21/6	15/12 [a]	19/39
Chi-square				9.785	1.655	8.058	1.729
P				0.020	0.647	0.045	0.631
At parturition							
Dark nights	106	53.0	8.9	32/74 [b]	80/26	58/48	76/154
First quarter	8	4.0	53.0	3/5 [a]	8/0	7/1	5/9
Bright nights	61	30.5	87.9	38/23 [a]	47/14	32/29	48/90
Last quarter	25	12.5	47.2	15/10 [a]	20/5	10/15	21/40
Chi-square				19.227	2.669	5.639	0.470
P				0.000	0.445	0.131	0.925
Overall	200	100		89/111	155/45	107/93	150/293

*: number of does; **: kid ratios.

nar phases effect (j=dark nights, first quarter, bright nights, last quarter), c_k the time of birth effect (k=dark, light), d_l the parity effect (l=1, 2, 3, 4, 5), f_m the offspring sex effect (m=male, female), g_n the birth type effect (n=single, twin), h_o the year effect (o=1, 2), $e_{ijklmno}$ the random error.

RESULTS

In this study, the frequency distribution of lunar phases at conception and parturition in Saanen goats were showed in Table 1. In goats, mating type and twin ratio were important for conception, but only mating type ratio was important for parturition. Offspring sex ratio was not affected by lunar phases, both at conception and at parturition. It was found that mating type, parity and year had no significant effect on the reproductive performance of Saanen goats (Table 2). In addition, time of birth and lunar cycle had no statistically significant effect on twinning rate and survival rate (Figure 1). Gestation length in Saanen goats was affected by mating type, year, lunar phase, parity, offspring sex, and birth type and is presented in Table 3 (P<0.05). In addition, body weight, wither height, and body length were affected by year, parity, and birth type, while chest circumference was affected by mating type, parity, offspring sex, and year (P<0.05). Figure 2 (a-f) shows the percentages of offspring, sex, and birth type according to mating type, lunar cycle and time of birth. Figure 2 (g, h) also shows the relationship between mating type, lunar cycle, and birth time. A consistent excess of males was observed in the sex ratio. Male offspring comprised 51.6% and 50.6% of the offspring of horned × polled and polled × horned mating, respectively, and no intersex was observed in the offspring of reciprocal mating. Birth type was influenced by lunar cycle and time of birth (Figure 2 d, f). Lunar cycle also had a significant effect on mating type (Figure 2g). It was found statistically significant (P<0.05) that gestational age, birth weight, weaning weight, average daily gain, and KR of offspring were influenced by parental mating type, lunar phase, time of birth, maternal parity, birth type, and offspring sex (Table 4).

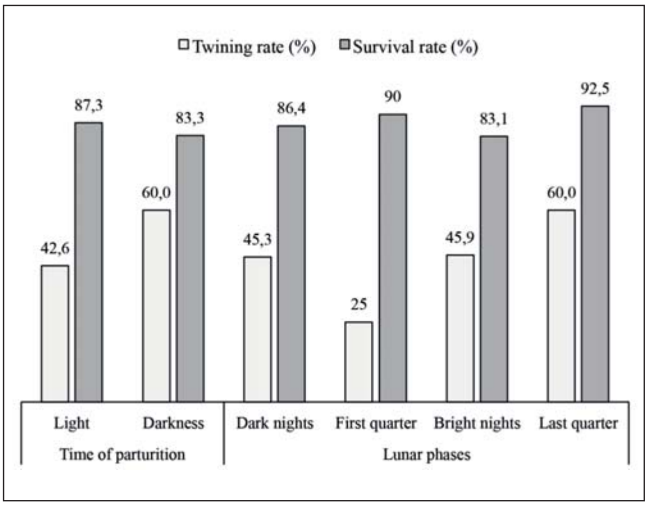

Figure 1 - Effect of time of parturition and lunar phases on twinning rate and survival rate.

DISCUSSION

The aim of this study was to evaluate the potential relationship between mating practices and reproduction and growth in Saanen goats, with a particular focus on horn presence, birth type, offspring sex, natural light-dark cycle, and lunar phases.

The number of goats giving birth increased during the dark lunar nights and decreased during the other phases according to the time of conception. Similarly, the number of goats with single births increased during dark lunar nights compared to conception at parturition. In addition, the rate of twin births at conception was highest on dark lunar nights, while at parturition it was highest in the last quarter. The ratios of polled × horned mating type and horned × polled mating type at conception and at birth were significantly lower during the dark lunar nights than during the bright lunar nights, first quarter and last quarter phases. Dark night phases of the moon at con-

Table 2 - Effects of some environmental factors on reproductive traits of Saanen goats.

Traits	n	Pregnancy rate (%)	Birth rate (%)	Abortion rate (%)	Twining rate (%)	Survival rate (%)
Mating type						
Horned × polled	95	98.9	93.7	5.3	41.6	89.7
Polled × horned	122	98.4	91.0	7.5	50.5	83.8
Chi-square		0.001	0.022	0.348	0.576	0.152
P		0.976	0.882	0.555	0.448	0.697
Lunar phase						
Dark nights	115	98.3	92.2	6.2	45.3	86.4
First quarter	9	100.0	88.9	11.1	12.5	88,9
Bright nights	66	98.5	92.4	6.2	47.5	83.3
Last quarter	27	100.0	92.6	7.4	60.0	92.5
Chi-square		0.004	0.006	4.569	5.639	0.146
P		1.000	1.000	0.206	0.131	0.986
Year						
2012	102	99.0	95.1	4.0	48.5	90.3
2013	115	98.3	89.6	8.8	44.7	82.6
Chi-square		0.002	0.093	1.800	0.105	0.272
P		0.968	0.760	0.180	0.745	0.602
Parity						
1	42	100.0	88.1	11.9	37.8	78.4
2	51	100.0	94.1	5.9	45.8	80.0
3	54	98.1	96.3	1.9	61.5	96.4
4	51	100.0	96.1	3.9	44.9	85.9
5	19	89.5	73.7	17.9	21.4	82.4
Chi-square		0.100	0.551	6.197	3.579	0.908
P		0.999	0.968	0.185	0.466	0.923
Overall	217	98.6	92.2	6.5	46.5	86.3

ception seemed to be associated with a higher number of polled × horned goats at parturition. However, the illumination rate of the lunar phases was higher during the conception period, except for the bright lunar nights. The fact that the conception and parturition in goats almost coincide with the same lunar phases may indicate that goats synchronise their reproductive biology and gestation period according to the lunar cycle. These findings may be evidence that the lunar cycle provides an external temporal and environmental cue to synchronise mating and parturition.

This study showed that the reproductive performance of Saanen goats was not affected by horn presence, parity and year

Table 3 - Effects of some environmental factors on gestation length, body weight and body measurements of Saanen goats.

Traits	n	Gestation length (days)	Body weight (kg)	Wither height (cm)	Body length (cm)	Hearth girth (cm)
Mating type		**				*
Horned × polled	89	149.4±0.29	47.3±0.87	72.7±0.49	70.5±0.47	84.5±0.68
Polled × horned	111	148.4±0.26	46.2±0.78	72.1±0.44	69.9±0.43	83.2±0.62
Lunar phase		**				
Dark nights	106	149.5±0.21^{A}	47.1±0.64	72.8±0.36	70.5±0.35	84.7±0.51
First quarter	8	148.8±0.68^{AB}	45.9±2.02	71.6±1.13	69.5±1.10	82.6±1.59
Bright nights	61	148.3±0.26^{B}	46.5±0.79	72.6±0.44	70.3±0.43	83.4±0.62
Last quarter	25	149.0±0.39^{AB}	47.5±1.17	72.7±0.65	70.5±0.64	84.7±0.92
Time of birth						
Dark	45	148.7±0.34	47.0±1.00	72.4±0.56	70.1±0.55	84.0±0.79
Light	155	149.1±0.23	46.5±0.67	72.4±0.38	70.3±0.37	83.8±0.53
Parity		**	**	*	*	**
1	37	148.0±0.34^{B}	44.1±1.01^{B}	71.2±0.57^{b}	68.9±0.55^{b}	81.4±0.80^{B}
2	48	148.6±0.31^{AB}	45.9±0.93^{AB}	71.6±0.52^{b}	69.7±0.51^{ab}	83.2±0.73^{AB}
3	52	148.9±0.33^{AB}	47.7±0.99^{A}	72.7±0.55^{ab}	70.5±0.54^{a}	84.5±0.78^{AB}
4	49	149.3±0.34^{A}	48.5±1.01^{A}	73.0±0.57^{a}	70.8±0.55^{a}	85.2±0.79^{A}
5	14	149.6±0.54^{A}	47.6±1.61^{AB}	73.6±0.90^{a}	70.9±0.88^{a}	85.2±1.26^{AB}
Offspring sex		*	*			*
Male	106	149.2±0.27	47.5±0.80	72.7±0.45	70.4±0.44	84.5±0.63
Female	94	148.6±0.28	46.0±0.83	72.1±0.46	69.9±0.45	83.2±0.65
Birth type		**	*	*	*	
Single	107	149.8±0.26	45.9±0.79	71.9±0.44	69.7±0.43	83.5±0.62
Twin	93	148.0±0.28	47.6±0.84	73.0±0.47	70.7±0.46	84.2±0.66
Year		*	**	**	**	*
2012	93	149.3±0.32	45.5±0.95	71.6±0.53	69.3±0.52	83.0±0.75
2013	107	148.5±0.25	48.0±0.74	73.3±0.41	71.1±0.40	84.8±0.58
Overall	200	148.9±0.24	46.8±0.72	72.4±0.40	70.2±0.39	83.9±0.56

Dark nights: waning crescent, new moon, waxing crescent; Bright nights: waxing gibbous, full moon, waning gibbous.
[a, b, c] Means within an inside-class of a column with different superscripts differ significantly at small letters – (* P<0.05), capital letters – (** P<0.01).

(Table 2), and time of birth and lunar cycle (Figure 1), although there were obvious differences. However, the twinning rate of horned does was slightly higher than that of pooled does, while the survival rate of the offspring at weaning was slightly lower. In other words, during the breeding season, the twinning rate increased when pooled Saanen bucks were used, whereas fertility and offspring survival were higher when horned Saanen bucks were used. This situation is consistent with Damascus bucks (20). In Saanen goats, birth rate, twinning rate and survival rate increased up to 3rd parity, while abortion rates decreased. In addition, the twinning rate of goats giving birth in the dark was higher than those giving birth in the daytime. Furthermore, the offspring of goats giving birth in the last quarter of the moon had a higher survival rate compared to the offspring of goats giving birth at other phases of the moon (Figure 1). Therefore, selection programmes based on parity, time of birth and lunar cycle, especially in large flocks, can help to improve management practices and increase productivity.

In this study, the survival rate of weaned kids was found to be 86.3%, which can be considered quite high for dairy goat breeds reared under rural conditions (1, 4, 9, 10, 21). A possible explanation for this could be that the bottle-feeding system protects the offspring from pathogens in the maternal udder, and prevents losses due to overfeeding, starvation, hypothermia, etc. In addition, although the difference was not significant, the survival rate of the offspring of the polled × horned mating was almost 6% lower than that of the horned × polled mating and 6% is economically and productively important. On the other hand, polled × horned mating resulted in approximately 9% more twin births than horned × polled mating. This can be explained by the lower live weight of the twin-born offspring, as well as the fact that the offspring receive less nutrients and oxygen in utero, depending on their circadian rhythm, welfare, maternal age, sex and dystocia (22-24). Therefore, to minimise the loss of kids, it is possible to adapt management practices to environmental factors, especially photoperiod, and closely monitor the care and nutritional status of kids from the foetal period to weaning (4, 8, 20). In addition, providing a safe and quiet environment away from environmental stressors such as predators and anthropogenic noise during pregnancy and the postnatal period is likely to increase offspring survival (5, 25).

The gestation length of Saanen goats showed a decreasing trend from dark to bright phase of the moon and an increasing trend from bright to dark phase of the moon. The effect of lunar cycle on gestation length changed gradually. Interestingly, as the parity and body weight of goats and birth weight of kids increased, the gestation length also increased. This can be explained by weaker uterine contractions in elder does and greater uterine space occupied by larger kids, as well as indirect effects of nutrition, hormonal changes, and anthropogenic stressors on gestation length (22, 26). Gestation length and body weight are higher in does giving birth to males than does giving birth to females. However, does giving birth to twins had shorter gestation length and higher body weight than does giving birth to singletons. This may be explained by the fact that, depending on the light and intensity of the lunar phases, including photoperiod, the sex of the offspring and the type of birth during pregnancy affects the level and timing of the release of melatonin and endogenous steroids by altering the maternal physiological and metabolic cycles. Therefore, monitoring pregnancy, which appears to be influenced by environmental factors, can play an important role in facilitating birth, preventing goat and kid losses, and improving animal health and welfare (4, 27). In addition, improving fertility traits in Saanen

Table 4 - Effect of some environmental factors on gestational age, growth traits and Kleiber ratio (KR) in Saanen kids.

Traits	n	Gestational age (days)	Birth weight (kg)	Weaning weight (kg)	Average daily gain (g)	KR
Parental mating type		**	**	**	**	**
Horned × polled	112	149.1±0.23	3.14±0.04	14.1±0.22	183±3.1	25.1±0.15
Polled × horned	140	148.6±0.21	3.02±0.03	13.1±0.20	168±2.9	24.3±0.14
Lunar phase		*	*	**	**	*
Dark nights	133	149.4±0.17^{a}	3.16±0.03^{a}	13.3±0.21^{B}	171±3.0^{B}	24.5±0.15^{b}
First quarter	8	148.7±0.54^{b}	2.98±0.11^{b}	13.3±0.50^{B}	172±7.3^{AB}	24.6±0.35^{ab}
Bright nights	74	148.7±0.22^{b}	3.01±0.04^{ab}	14.2±0.17^{A}	184±2.4^{A}	25.0±0.12^{a}
Last quarter	37	148.8±0.30^{ab}	3.08±0.06^{ab}	13.6±0.27^{AB}	175±3.9^{AB}	24.6±0.19^{ab}
Time of birth		*	*	*	*	*
Light	192	149.0±0.18	3.13±0.03	13.3±0.25	172±3.6	24.5±0.17
Dark	60	148.7±0.26	3.03±0.05	13.9±0.17	179±2.4	24.9±0.12
Maternal parity		**	**	**	**	**
1	40	148.0±0.28^{B}	2.88±0.06^{C}	12.5±0.27^{B}	161±4.0^{B}	24.1±0.19^{B}
2	56	148.6±0.25^{AB}	3.03±0.05^{BC}	13.4±0.23^{A}	172±3.4^{AB}	24.5±0.16^{AB}
3	81	148.8±0.25^{AB}	3.13±0.05^{AB}	13.9±0.23^{A}	180±3.4^{A}	24.9±0.16^{A}
4	61	149.4±0.27^{A}	3.19±0.05^{AB}	14.1±0.25^{A}	182±3.7^{A}	24.9±0.18^{A}
5	14	149.5±0.45^{A}	3.16±0.09^{A}	14.0±0.44^{A}	182±6.3^{A}	25.1±0.31^{A}
Offspring sex		*	**	**	**	**
Male	130	149.1±0.21	3.17±0.04	14.1±0.20	183±2.9	25.0±0.14
Female	122	148.6±0.22	2.99±0.04	13.1±0.20	168±3.0	24.4±0.14
Birth type		**	**	**	**	**
Single	86	149.9±0.23	3.27±0.05	14.4±0.22	185±3.2	25.0±0.16
Twin	166	147.8±0.21	2.89±0.04	12.8±0.19	166±2.7	24.4±0.13
Year		**	**	**	**	*
2012	129	149.1±0.25	3.16±0.05	13.9±0.23	180±3.4	24.9±0.16
2013	123	148.6±0.20	3.00±0.04	13.3±0.19	171±2.7	24.5±0.13
Overall	252	148.8±0.19	3.08±0.03	13.6±0.18	176±2.6	24.7±0.13

Dark nights: waning crescent, new moon, waxing crescent; Bright nights: waxing gibbous, full moon, waning gibbous.
$^{a, b, c.}$ Means within an inside-class of a column with different superscripts differ significantly at small letters – (*P< 0.05), capital letters – (**P< 0.01).

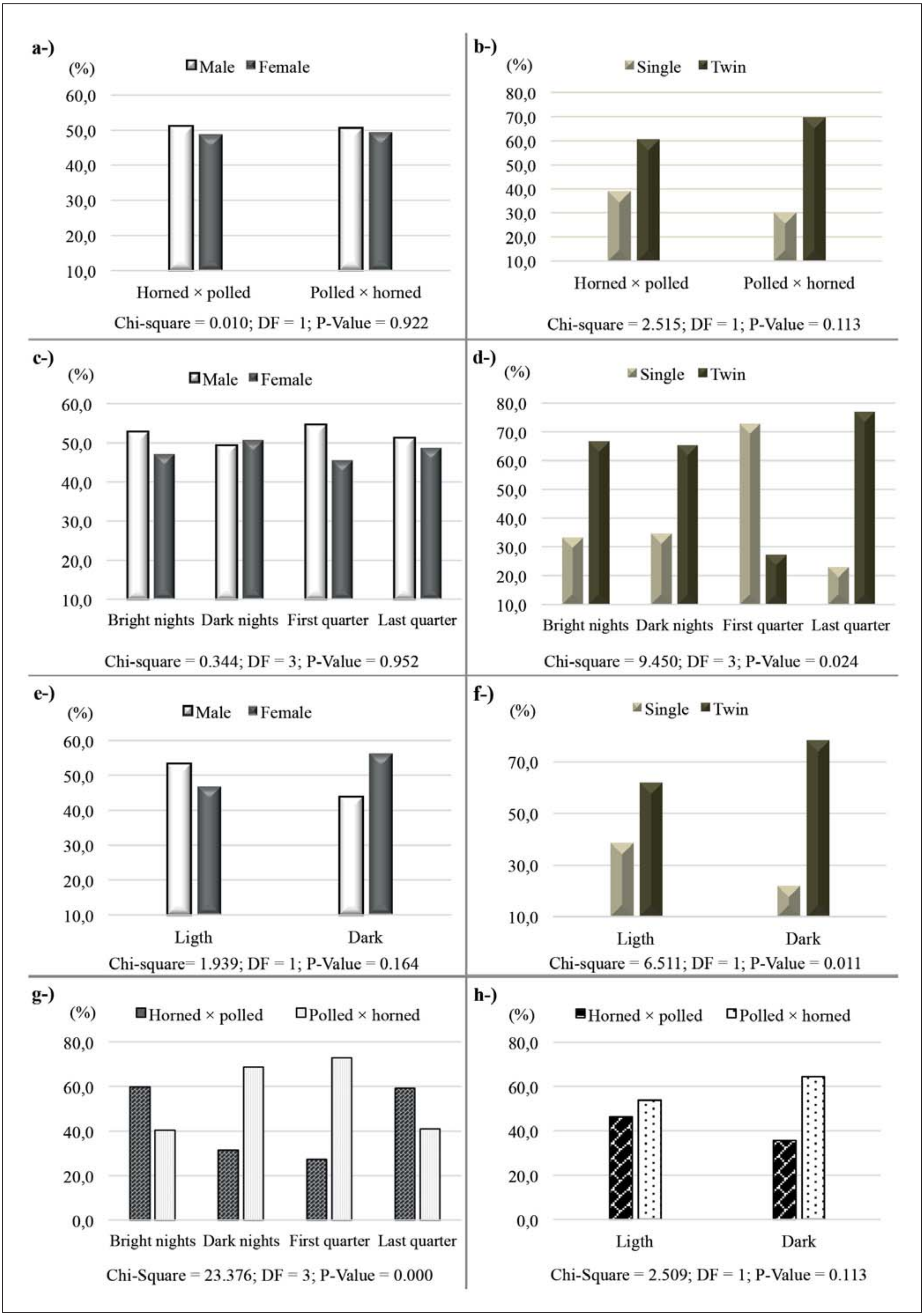

Figure 2 - Effect of mating type, lunar cycle and time of birth on sex and birth type of offspring (a-f), and the effect of mating type on parturition time and lunar cycle on mating type (g, h).

goats will contribute to production, sustainability, and income from goat production. It is important that breeders are aware of these factors and take the necessary steps to improve fertility traits in Saanen goats.

In this study, the highest number of births occurred in the dark phases of the moon with 53% (106 births), while the lowest number of births occurred in the first quarter of the moon with 4% (8 births; Table 1). Parturition, which determines the behaviour and productivity of Saanen goats, varied throughout the lunar cycle and was not randomly distributed. However, in my previous study of the lunar cycle in local and crossbred goats raised on grazing in mountainous and forested areas at an altitude of 1400-1800 metres, the highest births were found in the waning gibbous and full moon phases and the lowest births were found in the new moon phase (28). It therefore seems possible that the synergy of the lunar cycle with genotype, nutrition, photoperiod, geographical structure, altitude and management systems may physiologically affect circadian rhythms and thus birth timing. Furthermore, this finding is both consistent and inconsistent with previous studies in other mammalian species (14, 29-33). A possible explanation for this is the evolutionary change of species depending on production system, climate conditions, light duration, light intensity and social defence behaviour against predation (2, 5). Another reason for more births during the dark phase of the moon could be that the hormone melatonin, which is secreted more in the dark and towards the end of pregnancy, stimulates more uterine contractions and triggers labour on dark nights (5, 27). More importantly, according to the phases of the moon, the average number of kids born per day is highest in the dark phase (154/11.1=13.9 kids/day), moderate in the bright phase and in the last quarter (90/11.1=8.1 kids/day 5.5 and 40/3.7=10.8 kids/day) and significantly lowest in the first quarter (9/3.7=2.4 kids/day). A possible explanation for the increase in births during the dark phase of the moon is that increased melatonin in darkness or low light levels both indirectly regulates foetal ACTH release and stabilises maternal cortisol levels, providing a favourable environment for birth (2, 5, 34). This may suggest that during labour, the internal rhythms that synchronise the physiological readiness of both the mother and the foetus and trigger labour are influenced by the phases of the moon. This evidence suggests that circadian events modulated by the lunar cycle may be the mechanisms by which goats adjust their biological rhythms to optimise their adaptation, survival and reproductive success. Although goats are active during the day, birth is predominantly diurnal and is influenced by photoperiod, management, climate, and geographical conditions (5). In addition, births tended to occur during the resting period or before and after the milking and feeding periods, which is consistent with previous studies (4, 5). 155 of the goats were born in daylight and 45 of them were born in darkness. In other words, the number of goats giving birth in daylight is 3.44 more than the number of goats giving birth in darkness. This can be explained by the fact that increasing environmental stressors such as noise, activity, and farm routine increase the likelihood of goats to postpone giving birth in the near future (2, 5, 22). In addition, the negative association between birth and farm routine suggests that high stress and internal hormonal rhythms during pregnancy and lactation preparation regulate birth in goats (5, 27). These findings suggest that improving birth control during day and lunar cycle periods, when more births are expected and more dystocia or perinatal deaths may occur, may have a positive effect on the productivity of dairy goats.

Offspring birth rates were influenced by the remarkable relationship between lunar cycle and mating type, and birth type (Figure. 2 d, g). This relationship can be included in the selection index of breeding programs to prevent economic losses due to fertility in dairy goats and, in particular, to increase the survival rate of twin offspring.

In the current study, gestational age, birth weight, weaning weight, daily weight gain, and KR of the offspring increased with increasing maternal parity. This study also showed that the gestational age, birth weight and weaning weight of the offspring from the horned × polled mating grew heavier and faster than those from the polled × horned mating. This difference in body weight was evident at birth (120 g) and increased further at weaning (1000 g) and daily weight gain (15 g/d). This could be due to a number of factors, such as better pregnancy and postnatal period, higher nutrient intake, better development due to lower twin ratio and the genetic make-up of the offspring of horned × polled mating (13). However, some studies show that horned goats are less stressed and have better welfare than polled goats (6, 35). Therefore, it can be said that it is more advantageous to use the horned × polled mating model to improve growth traits in Saanen goat breeding.

In this study, on the one hand, offspring exposed to daylight hours or dark moon phase days at birth had a longer gestational age than offspring exposed to dark hours or light moon phase days. On the other hand, birth weight, weaning weight, average daily gain, and KRs were found to increase more in offspring exposed to daylight hours and dark moon phase days at birth. The differences in the frequency of births in the natural light-dark cycle may be due to the adaptation of the offspring to the environmental conditions.

In this study, the between-group variation in kid's KR for body weight ranged from 24.1 to 25.1, with a mean of 24.7. KR increased with increasing body weight of the kids. This KR value is higher than that reported in previous studies in purebred and crossbred goat populations (18, 36, 37). These population differences are probably due to nutrition, horn presence, genotype, and production purpose and selection power. The KR of horned × polled progeny was higher than that of polled × horned progeny. However, our results were shown to be lower than KR values of other sheep and cattle species (38, 39). This suggests that goats can more easily maintain body temperature balance, require less energy due to their shorter digestive system, and can be more efficient with less feed (2, 18). On the other hand, according to sex, the KR of female kids was lower than that of male kids. With regard to birth type, the KR of kids born as singletons was higher than that of kids born as twins. This may indicate that body weight and environmental factors varied the metabolic rate of the kids. Therefore, KR can be used as an indirect selection criterion to improve feed efficiency and growth traits and thus contribute to increase productivity.

CONCLUSION

This study showed that offspring from horned × polled mating, as well as those born during periods of bright lunar days grew faster and attained higher body weights. Mating type, lunar cycle, offspring sex, birth type, parity and year were found to be important factors in determining the gestation period of Saanen goats. It was also found that Saanen goats gave birth more during dark moon phases and daylight hours compared to light moon phases and dark hours. The results of this study showed that the horn presence, lunar cycles and birth timing significantly affect the productivity and management of the Saanen goat. With a better understanding of these factors, including circadian rhythms, more efficient and sustainable ruminant production systems can be developed. Although these results contribute significantly to the current knowledge of goat, further studies are needed to confirm the importance of these factors in flock management and elucidate the mechanisms involved.

Ethical Approval

The study was conducted in accordance with both Directive 2010/63/EU and Article 9 of Law No. 5996 on Animal Welfare in Türkiye. This study did not involve the use of animal for laboratory studies. No animal rights were violated.

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Author Contributions

HE: Conceptualisation, methodology, writing of the original draft, visualization and originality review & editing, project administration

Conflict of Interest Statement

The author declared that there is no conflict of interest.

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