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Original article

Effect of Breed and Non-genetic Factors on Body Weight and Average Daily Gains of Goats in Tunisia

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Abstract

The present study was carried out to evaluate growth performance of three goat breeds in Tunisia (Alpine, Boer and Damascus) from birth to 90 days and to investigate the effect of non- genetic factors on birth weight (BW), weight at 10 days (W10), weight at 30 days (W30), weight at 70 days (W70), weight at 90 days (W90) and average daily weight gains from birth to 30 days (ADG0-30), from 10 to 30 days (ADG10-30), from 30 to 70 days (ADG30-70), from 30 to 90 days (ADG30-90), from 70 to 90 days (ADG7090). A total of 3198 goats including Alpine (n=1030), Boer (n=2084) and Damascene (n=84), born during the period 2004-2016 were used. Data analysis showed non-significant effect of breed on growth traits. However Damascus goats had the heaviest overall live weight at birth (3.99±0.05kg) followed by Alpine (3.94±0.02kg) and Boer (3.90±0.02kg) until 90 days (13.25±0.66, 12.13±0.35, 12.07±0.35kg respectively).Average daily weight gains followed the same trend as weights. Overall, sex-type of birth, season and the combined year of birth-farm-herd influenced growth traits. Higher performances were recorded in males born as singles, during the rainy season (November to March), in 2007 and 2008, belonging to herd"1"of Chenchou experimental station and herd" 5" belonging to a private farm respectively. In conclusion, our study confirms that non-genetic factors affect these three goat breeds. Adjustments for those factors are necessary to provide standard comparisons among breeds under challenging Tunisian conditions.

Keywords: Breed, Goats, Growth, Meat.

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INTRODUCTION

Tunisia has about 742,000 female goats raised in different regions of the country (OEP, 2021). Due to its characteristics such as adaptability to harsh environmental conditions, tolerance to diseases, good digestibility of cellulosic feed and high prolificacy, goat breeding contributes significantly to food security and farmers' incomes in rural areas of Tunisia, in particular in mountain and arid regions (Djemali and Bedhiaf-Romdhani, 2005). Goats are chiefly kept for meat while milk is dedicated to family consumption. The "Arbi" is the local and the main reared goat in Tunisia. Nevertheless, its productivity is low (Najari, 2005; Atoui et al., 2020). To overcome this shortage, genetic improvement by crossbreeding was suggested. Therefore, exotic goats were introduced and hierarchically crossed with local Tunisian goats such as the Alpine, Damascus and Boer (Djemali et al., 2004). In order to design genetic programs to enhance meat production, it is imperative to have a good understanding of the growth dynamics of young animals as they are considered an indicator for assessing the level of adaptation to the conditions of a given production system (Kume and Hajno, 2010). Birth to weaning weights and growth rate are key determinants of meat production efficiency in livestock (Assan, 2020). Nevertheless, these quantitative traits are influenced by the animal's own genetic makeup and environmental factors such as type of birth, sex of birth, year of birth and kidding season...

To increase the productivity of animals, it is necessary to simultaneously enhance the genetic make-up of flocks and provide an appropriate environment for an efficient genetic expression of the trait (Ali et al., 2020). Hence, for sustainable livestock production, efforts should be made to determine the effects of environmental factors on growth. These values are important for the standardization of performance values by elimination of the effects of the environmental factors in question and for the identification of the animals to be selected in a subsequent step (Gül et al., 2020). Even though some studies (Atoui et al., 2017; Atoui et al., 2018; Mabrouk et al., 2010; Najari et al., 2013) on the effect of genetic and non-genetic factors affecting growth performance of Arbi goats have been done, little work has been on the exotic goats in Tunisia (Ben Said, 2003; Gaddour and Najari,2009) . In view of the above problems, this study was aimed to 1) compare growth performances of the three goat breeds. 2) evaluate the effect of non-genetic factors on weights at different ages and average daily gains of goats in Tunisia.

MATERIALS and METHODS

Data collection

The study was undertaken on 3198 Tunisian goats including Alpine (n=1030), Boer (n=2084) and Damascus (n=84). Goat kids were born in the period 2004-2016 and belonged to 5 herds from both private and public farms. Data including farm name, herd number, government, sector, breed, animal ID, dam ID, date of birth, sex of kid and type of birth were recorded. The studied traits were birth weight

(BW), weight at 10 days of age, weight at 30 days of age (W30), weight at 70 days of age (W70), weight at 90 days of age (W90), as well as average daily gain between 10 and 30 days of age (ADG 10-30), average daily gain between 30 and 70 days of age (ADG 30-70), average daily gain between 30 and 90 days of age (ADG 30-90) and average daily gain between 70 and 90 days of age (ADG 70-90).

Statistical analysis

The data were edited and only weights falling in the range of the corresponding mean ± 2 SD were considered. Analysis of variance ANOVA was applied using the GLM procedure of SAS. Different least-square means between levels were tested using by the Tukey method. The statistical model used was:

$$\boldsymbol{y}_{\mathrm{ijklmn}} = \mu + \boldsymbol{B}_{\mathrm{i}} + \boldsymbol{ST}_{\mathrm{j}} + \boldsymbol{M}_{\mathrm{k}} + \boldsymbol{YFH}_{\mathrm{l}} + \boldsymbol{e}_{\mathrm{ijklm}}$$

Where y_{ijklmn}= live weights at birth, 10, 30, 70, 90 days as well as average daily gains, ADG0-30, ADG10-30, ADG30-70, ADG30-90 and ADG70-90, μ= overall mean, B_i= the effect of breed(i=Alpine, Boer, Damascus), ST_j= the combined effect of sex-Type of birth (j= male single, female single, male multiple, female multiple), M_k= the effect of season of kidding (l= season1: November--January; season2: February –April), YFH_l= the combined effect of year of kidding-farm-herd , e_{ijklm}: the random residual error.

RESULTS and DISCUSSION

Growth performances of the genetic groups

Average growth weights at birth, 10, 30, 70 and 90 days were 4.06kg, 5.80 kg, 7.53kg, 12.82kg and 15.52 kg respectively for Damascus, 3.96kg, 4.98kg, 6.50 kg, 10.18 kg and 12.93 kg, respectively for Alpine and 3.92kg, 4.82kg, 6.32kg, 10.12kg and 12.88kg respectively for the Boer breed.

Average daily weight gains ADG0-30, ADG10-30, ADG30-70, ADG30-90, ADG70-90 were 15.52g/d, 112.37g/d, 114.39g/d, 114.39g/d, 116.96g/d, 123.86g/d and 129.76g/d, respectively for Damascus, 87.72g/d, 89.74g/d, 90.39g/d, 94,85g/d, 96.94g/d for the Alpine and 80.25g/d, 86.30g/d, 99.04g/d, 108.5g/d and 131.06g/d, respectively for the Boer.

Sources of variation

Sources of variation are in table (1) showed that Year-Farm-Flock, sex-type, and month of birth were significant sources of variation for growth weight and weight gains of the three breeds. These results translated that weights and weight gains are influenced, beside the animal genetic makeup, by

non-genetic and environmental factors. For these latter reasons, adjusted weights are used to compare young animals for culling and selection purposes.

Table 1. Sources of variation and F values of growth traits of Damascus, Boer and Alpine goat breeds

Source of variation	BW	W10	W30	W70	W90	ADG030	ADG1030	ADG3070	ADG3090	ADG7090
Breed	2.51	2.51	1.30	0.64	1.22	1.43	0.04	0.25	0.13	2.33
	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Sex-type	153.52***	204.64***	153.57***	109.99***	82.53***	152.13***	86.66***	57.73***	45.34***	18.95***
	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Season of kidding	10.65***	29.05***	9.62***	3.05	4.19	6.38**	1.36	37.87***	6.74**	2.19
	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Year-Farm-Flock	70.54***	79.76***	89.63***	100***	76.36***	90.76***	82.58***	95.70***	74.13***	56.82***
	(30)	(31)	(30)	(27)	(25)	(30)	(31)	(28)	(26)	(26)
R^2	0.54	0.50	0.52	0.61	0.59	0.52	0.50	0.60	0.58	0.53

Bw: birth weight; W10:weight at 10 days of age; W30: weight at 30 days of age; W70: weight at 70 days of age; W90: weight at 90 days of age; ADG030: average daily gain between birth and 30 days of age; ADG1030: average daily gain between 10 and 30 days of age; ADG 30-70: average daily gain between 30 and 70 days of age; ADG7090: average daily gain between 30 and 90 days of age. R2: regression coefficient; (df) between brackets: degree of freedom; **: significant effect (P<0, 01); ***: significant effect (P<0, 001).

Effect of breed

Damascus goats had the heaviest growth Lsmeans, followed by Alpine (Table 2). Gaddour and Najari (2009) reported similar results. In overall, Damascus goats tended to have heavier weights at 90d (13.25 ±0.66 kg) and better weight gains between 70-90d (120 ± 13 g/d) (Table 2).

Table 2. Lsmeans of growth weights and weight daily gains of Alpine, Boer and Damascus goats.

	Alpine		Boer		Damascus	
	Nb	**LSmeans**	**Nb**	**LSmeans**	**Nb**	**LSmeans**
BW	931	3.94±0.02	2029	3.90±0.02	60	3.99±0.05
w10	1002	4.80±0.05	2083	4.76±0.04	83	5.06±0.12
w30	825	6.35±0.08	1925	6.28±0.08	63	6.65±0.22
w70	551	10.02±0.22	1437	9.99±0.22	51	10.63±0.50
w90	459	12.13±0.35	1281	12.07±0.35	54	13.25±0.66
ADG030	831	89.37±2.20	1926	87.99±2.09	62	89.58±6.05
ADG1030	858	87.49±2.21	1908	85.61±2.12	71	87.80±5.80
ADG3070	597	80.91±3.12	1413	80.69±3.12	54	85.76±6.94
ADG3090	491	89.93±3.96	1260	89.62±4.06	55	93.86±7.52
ADG7090	495	95.50±6.57	1324	92.00±6.72	56	121.23±12.46

Bw, birth weight; W10, weight at 10 days of age; W30, weight at 30 days of age; W70, weight at 70 days of age; W90, weight at 90 days of age; ADG030, average daily gain between birth and 30 days of age; ADG1030, average daily gain between 10 and 30 days of age; ADG 30-70, average daily gain between 30 and 70 days of age; ADG7090, average daily gain between 30 and 90 days of age.

Effect of sex-type of birth

Results revealed a significant effect of the Sex-Type of birth (P<0.01) on all growth traits. Male kids born as singles weighed more than others up to 90 days and had the heaviest average daily weight gains, while females born as singles were heavier and displayed better average daily weight gains than females born as multiple (Table 3). The outcome of the current study is quite natural and the higher body weight observed in males can be explained by the influence of the male sex hormone (androgen) which is involved in the development of male body characteristics (Nkungu et al., 1995). Furthermore, the benefit of single-born kids over twins and triplets in growth traits may be explained by the reduction of caruncles attached to each foetus in the uterus in cases of multiple kids, resulting in reduced foetal feeding (Robinson et al., 1977, Zhang et al., 2006) and competition for milk between multiple-born kids from birth to weaning (Al-Shorepy et al., 2002). These results agree with the study of Atoui et al. (2017) on local Tunisian goats , who reported a significant effect of the interaction between sex and type of birth on birth weight (P<0.01) with male kids born as singles were heavier at birth as compared to multiples at a difference of 0.47 kg. A further study conducted by the same author (2018) indicated a significant effect of sex-type on ADG1 (from birth to 30 days), ADG2 (from 30 to 60 days), ADG3 (from 60 to 90 days), ADG4 (from 90 to 120 days) and ADG5 (from 120 to 150days). Similar results were found by Kuthu et al. (2013). They reported a significant effect of the interaction between sex and type of birth on weaning weight of Teddy goats in Pakistan, with male kids born as singles were heavier at weaning (1.80±0.06 kg) as compared to the others and females born as quadruplets and triplets were lighter in weight (1.38±0.06 kg). Several similar results on small ruminants were also reported in the literature confirming the superiority of males born as single over the twin and triplet ones in average daily weight gains (Djemali et al., 1994; Chalh et al., 2007; Ben Abdallah et al., 2018).

Table 3. Least square means and standard errors of growth traits by sex-type of birth.

	BW	**W10**	**W30**	**W70**	**W90**	**ADG030**	**ADG1030**	**ADG3070**	**ADG3090**	**ADG7090**
M-S	4.04^{b}±0.02	5.34^{b}±0.05	7.18^{b}±0.09	11.32^{b}±0.23	13.85^{b}±0.33	103.16^{b}±2.59	100.15^{b}±2.53	89.98^{b}±3.22	102.38^{b}±3.83	114.35^{b} ±6.32
M-M	3.86^{d}±0.02	4.73^{d}±0.05	6.3^{d} ±0.09	9.99^{d}±0.22	12.3^{d} ±0.32	80.91^{d}±2.59	81.57^{d}±2.54	77.90^{c}±3.14	90.66^{c} ±3.73	106.08^{bc}±6.17
F-S	3.96^{c}±0.02	5.03^{c}±0.05	6.80^{c}±0.09	10.60^{c}±0.22	12.86^{c}±0.33	93.35^{c}±2.56	94.57^{c}±2.51	82.91^{c}±3.18	93.91^{c} ±3.80	102.11^{c}±6.28
F-M	3.76^{a}±0.02	4.38^{a}±0.05	5.77^{a}±0.09	8.92^{a}±0.22	10.87^{a}±0.32	65.07^{a}±2.56	71.55^{a}±2.51	65.20^{a}±3.14	77.29^{a} ±3.72	88.77^{a}±6.15

M, male; F, female; S, single; M, multiple; Bw, birth weight; W10, weight at 10 days of age; W30, weight at 30 days of age; W70, weight at 70 days of age; W90, weight at 90 days of age; ADG030, average daily gain between birth and 30 days of age; ADG1030, average daily gain between 10 and 30 days of age; ADG 30-70, average daily gain between 30 and 70 days of age; ADG7090, average daily gain between 30 and 90 days of age. Least squares means with different superscripts (a, b, c, d) are significantly different at P<0.01.

Effect of season of birth

Season of birth influenced the growth traits significantly (p<0.01) except for the W70, ADG10-30 and ADG70-90. Kids born during the rainy season (from November to March) weighed more and had the highest average daily gain (Table 4). The higher growth performances for wet season-born kids observed might be attributed to the abundance of feed for the doe during rainy season to produce

sufficient milk. The outcomes of the current study are in agreement with Ofori et al. (2020), who reported a significant seasonal effect on birth, weaning, 6 month, 9 month, and yearling weight in West African Dwarf goats as kids born in major rainy season had higher ($p < 0.001$) means than those born in the minor rainy season. Likewise, Mustafa et al. (2019) found that the season of birth influenced ($P<0.0001$) most of the growth traits with kids born in the wet season had the heaviest weaning weight. Atoui et al. (2017) cited that Tunisian local goats born from November to December had heavier birth weight than kids born from February to April. Tesema et al. (2021) noted that the BW of Boer x Central Highland goats born during the short rainy season was greater and the weight at 9 Months of kids born during the main rainy season was higher than dry season. Nevertheless, Birteeb et al. (2015) found no significant effect of season of birth on birth weight, weaning weight, and pre-weaning growth performance in West African Dwarf goats reared in the transitional zone of Ghana.

Table 4. Least square means and standard errors of growth traits by season.

	BW	W10	W30	W70	W90	ADG030	ADG1030	ADG3070	ADG3090	ADG7090
S1	3.94^{a}±0.03	5.06^{a}±0.07	6.72^{a}±0.13	9.85^{a}±0.37	11.72^{a}±0.62	90.10^{a}±3.61	89.02^{a}±3.52	61.06^{a}±5.28	79.98^{a}±7.18	92.37^{a}±11.90
S2	3.86^{b}±0.02	4.68^{b}±0.04	6.32^{b}±0.07	10.57^{b}±0.18	13.24^{b}±0.29	81.19^{b}±2.04	84.91^{b}±2.02	97.19^{b}±2.61	102.29^{b}±3.27	113.46^{b}±5.42

Bw, birth weight; W10, weight at 10 days of age; W30, weight at 30 days of age; W70, weight at 70 days of age; W90, weight at 90 days of age; ADG030, average daily gain between birth and 30 days of age; ADG1030, average daily gain between 10 and 30 days of age; ADG 30-70, average daily gain between 30 and 70 days of age; ADG7090, average daily gain between 30 and 90 days of age. S1, November to March; S2, April to October. Least squares means with different superscripts (a, b) are significantly different at $P<0.01$.

Effect of year of birth-farm-herd

Year-farm-herd (YFH) had a significant ($P<0.001$) effect on all studied growth traits. The highest BW, W30, ADG0-30, ADG10-30 and W10, W70, W90 were recorded in flock"1" belonging to Chenchou experimental station during 2007 and 2008 respectively , while the highest ADG30-70, ADG30-90, ADG70-90 were recorded during 2007 in flock 5 belonging to a private farm respectively (Table 5). It is expected that the different herds across farms and years have different levels of production because of variations in the level of management and changes in climatic conditions. For instance, herds with good management including nutrition, vaccination, disease prevention, hygienic practice, the performances are expected to be high. Similarly the climatic conditions that determine the availability of feed resources and disease distribution thereby influences the performances of goats. The results of the current study agree with the findings from Anggraeni et al. (2020) who found a significant effect of year of kidding on body weight at 120 days old kid. Tesema et al. (2021) revealed a significant effect of year of kidding on the live weight at 6, 9 and 12 months with kids born in 2016 and 2017 had the highest values. This is in line with the findings from Gül et al. (2021) who reported a significant effect of year of kidding on the birth weight, weaning weight and daily weight gains in Kilis goat. Similarly significant effects have also been reported by Atoui et al. (2017), Mabrouk et al. (2010) in

Tunisian goats, Gupta et al. (2014) in Mehsana goat of India and Alemu et al. (2020) in Ethiopian goats. Inversely, some studies stated non-significant effect of year of kidding on growth performances such as Gül et al. (2016) in Kilis goats.

Table 4. Least square means and standard errors of growth traits by year-farm-herd.

YFH	P0	w10	w30	w70	w90	ADG030	ADG1030	ADG3070	ADG3090	ADG7090
2004-3-5	3.55±0.03	3.91±0.09	4.72±0.15	8.01±0.38	9.61±0.61	39.03±4.12	47.19±4.19	70.97±5.43	65.92±6.97	67.16±11.54
2005-4-1	4.19±0.03	5.58±0.07	8.09±0.14	13.13±0.29	15.61±0.45	128.51±3.72	139.42±3.74	110.41±4.09	118.13±5.13	124.36±8.50
2006-3-5	3.70±0.03	4.58±0.08	5.71±0.14	11.19±0.31	14.39±0.48	64.19±3.90	68.08±3.88	121.68±4.44	141.84±5.56	162.43±9.19
2006-4-1	4.06±0.14	5.31±0.43	7.22±0.70	13.12±1.21	16.35±1.66	103.52±19.14	103.83±19.70	133.42±17.51	150.27±19.06	174.71±31.60
2007-1-2	3.72±0.03	4.03±0.09	5.34±0.15	9.55±0.43	11.37±0.65	52.18±4.13	69.91±4.19	97.13±6.15	87.10±7.52	81.80±12.46
2007-2-3	4.04±0.07	4.82±0.20	6.83±0.34	11.51±0.66	14.33±0.89	95.13±9.42	94.02±9.31	133.34±9.30	123.68±10.23	113.62±16.95
2007-3-5	4.11±0.03	5.39±0.08	7.85±0.15	13.89±0.32	17.46±0.49	121.93±4.00	131.79±4.01	135.15±4.66	152.40±5.73	223.81±9.02
2007-4-1	4.28±0.04	6.32±0.10	8.54±0.19	13.90±0.33	16.20±0.48	141.40±5.16	144.99±4.77	117.14±4.61	124.21±5.50	115.16±9.11
2008-1-2	3.71±0.03	4.29±0.10	5.51±0.17	6.16±2.06	6.27±2.81	57.48±4.68	64.52±4.72	12.02±29.93	18.03±32.38	17.77±53.67
2008-3-5	3.88±0.03	5.07±0.08	6.30±0.15	9.60±0.31	13.53±0.48	78.29±4.00	78.57±4.03	73.17±4.50	119.38±5.52	206.39±9.11
2008-4-1	4.08±0.07	6.52±0.19	8.13±0.34	15.37±1.06	17.48±1.45	123.95±8.93	99.44±9.15	107.42±15.28	114.04±16.69	116.23±27.66
2009-1-2	3.67±0.03	4.22±0.08	4.89±0.16	6.63±0.32	7.38±0.48	39.89±4.26	43.33±4.25	28.29±4.62	38.53±5.57	47.87±9.23
2009-3-5	4.02±0.03	4.92±0.09	7.37±0.15	12.86±0.35	15.74±0.51	111.76±4.16	130.12±4.19	120.85±4.93	133.34±5.91	145.90±9.74
2009-4-1	4.15±0.04	5.79±0.13	7.86±0.22	11.88±0.71	13.37±1.02	121.37±5.95	110.49±6.01	103.31±10.23	108.19±11.51	99.74±18.77
2009-4-4	4.10±0.05	6.72±0.16	7.98±0.33	12.37±1.02	13.38±1.50	119.98±8.97	94.54±9.10	106.42±14.26	110.04±14.70	113.23±25.86
2010-1-2	3.63±0.03	4.09±0.09	4.97±0.15	7.23±0.32	8.44±0.48	43.69±4.08	51.73±4.09	40.81±4.61	55.22±5.57	68.82±9.23
2010-3-5	3.93±0.03	4.96±0.08	6.54±0.14	10.35±0.33	12.88±0.50	85.07±3.95	91.31±3.93	89.00±4.68	108.03±5.72	133.48±9.47
2010-4-1	4.25±0.04	5.90±0.11	8.48±0.20	14.24±0.55	16.84±0.77	140.48±5.53	126.32±5.98	134.89±7.76	138.24±8.86	123.45±14.69
2010-4-4	3.60±0.02	3.99±0.08	4.92±0.15	7.19±0.30	8.54±0.46	44.18±4.08	52.63±4.06	41.80±4.52	56.32±5.67	69.74±9.30
2011-1-2	3.60±0.03	4.00±0.09	5.04±0.15	6.67±0.37	7.36±0.55	45.04±4.12	59.85±4.10	29.46±5.34	38.98±6.32	42.77±10.42
2011-3-5	4.10±0.03	5.90±0.09	7.89±0.16	11.95±0.32	14.14±0.49	124.13±4.23	113.88±4.20	87.30±4.60	100.67±5.62	114.91±9.31
2012-1-2	3.69±0.04	4.24±0.10	5.47±0.17	10.41±0.39	11.94±1.11	57.31±4.73	68.88±4.78	103.79±5.56	78.64±12.77	67.51±21.17
2012-3-5	4.01±0.03	5.41±0.10	7.29±0.16	10.95±0.33	12.26±0.51	107.00±4.46	105.30±4.47	75.85±4.69	79.00±5.91	70.60±9.80
2013-1-2	3.69±0.03	4.27±0.08	4.56±0.15	5.93±0.34	7.24±0.58	30.49±4.19	31.62±4.20	18.58±4.80	38.13±6.65	60.14±11.02
2013-3-5	4.09±0.03	5.44±0.09	7.53±0.16	12.40±0.32	15.11±0.49	112.09±4.32	113.65±4.31	108.23±4.64	124.44±5.64	142.73±9.33
2014-1-2	3.58±0.03	4.10±0.10	4.88±0.16	7.70±0.34	9.16±0.48	42.71±4.48	47.70±4.50	56.48±4.89	67.18±5.53	80.97±9.17
2015-1-2	3.75±0.03	4.48±0.08	5.66±0.14	8.02±0.33	9.50±0.67	61.36±3.95	66.68±3.93	51.69±4.76	59.24±7.72	58.80±12.80
2016-1-2	3.87±0.04	5.00±0.11	6.37±0.19	8.76±0.38	10.54±0.55	80.25±5.24	79.31±5.29	46.12±5.44	67.59±6.37	99.06±10.56

Bw, birth weight; W10, weight at 10 days of age; W30, weight at 30 days of age; W70, weight at 70 days of age; W90, weight at 90 days of age; ADG030, average daily gain between birth and 30 days of age; ADG1030, average daily gain between 10 and 30 days of age; ADG 30-70, average daily gain between 30 and 70 days of age; ADG7090, average daily gain between 30 and 90 days of age.

Conclusion

The current study indicated that Damascus goats proved higher growth performance compared to Alpine and Boer. In addition, in overall, body weight from birth up to 90 days and average daily gains were influenced by the sex-type of birth, season, and year-farm-herd. The provided information will be useful to design appropriate genetic improvement programs to maximize the profitability of each animal. Accordingly, environmental factors must be adjusted in order to achieve the required level of profitability.

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Conflicts of interest

The authors declare no conflicts of interest.

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