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ORIGINAL ARTICLE

Genetic and environmental factors influenced the birth and weaning weight of lambs

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This paper's main goal was to determine the most important factors affecting meat production in the semi-arid region of Ukraine and derive adjustment factors for known non-genetic sources of variation. The study's object was the influence of genetic and non-genetic factors on the birth and weaning weight of lambs. Data from 2,603 ewes were included in the analysis, where 3,961 lambs were obtained during the five years of the research. Their mating evaluated the growth traits of lamb in the Ascanian Fine-Fleece ewes with the sires of the following genotypes, which are the Ascanian Fine-Fleece, the Australian Merino, and the half-bred rams. The influence of the year of lambing, ram genotype, age of dam, type of birth, sex of lamb on the birth, and weaning weight of lamb was also studied. A significant effect on the birth and weaning weight of lambs was established for all genetic and non-genetic factors used in the study (the year of lambing, ram genotype, age of dam, type of birth, and sex of lamb). The interaction year of lambing × ram genotype was significant only for the weaning weight of lambs (P = 0.005), the interaction year of lambing × age of dam was significant only for the birth weight of lambs (P = 0.044), the interaction year of lambing × type of birth was significant both for the birth weight of lambs (P < 0.001), and also for the weaning weight of lambs (P = 0.007). The interaction year of lambing × sex of lamb was significant only for lambs' weaning weight (P = 0.035). In addition to environmental effects, we also noted that the interaction between the ram genotype × type of birth was significant for the weight of lambs both at birth (P < 0.001) and at weaning (P = 0.004). Finally, the significant interaction of three factors (year of lambing × ram genotype × type of birth and ram genotype × age of dam × type of birth) on the birth weight of lamb was also noted. We registered that two-way factor interactions of the year of lambing × age of dam, year of lambing × type of birth, ram genotype × type of birth and three-way factor interactions of the year of lambing × ram genotype × type of birth and age of dam × ram genotype × type of birth had significant effects (P < 0.001…0.044) on birth weight in the Ascanian Fine-Fleece and crossbreed lambs. Effects of the year of lambing × ram genotype, year of lambing × type of birth, year of lambing × sex, and ram genotype × type of birth interaction had significant effects (P < 0.004…0.035) on the weaning weight of lambs.

Keywords: the genetics and non-genetic factors, birth and weaning weight of lambs, the two- and three-factor interactions, the Ascanian Fine-Fleece, the Australian Merino, sheep

Introduction

The growth rate is an economic trait of interest in domestic animals as the growth of the lambs, piglets is a reflection of the adaptability and economic viability of an animal and hence, may be used as criteria for the selection among breeds and the individual within breeds (Kramarenko et al., 2020). The fast growth rate ultimately determines their meat-producing capability up to the marketing age. The study of body weights also helps or even guides the breeders to determine optimum management practices to maintain the gain at an optimum level (Lalit et al., 2016).

Annual lamb production measured for each ewe as the weight of lamb weaned was included in a selection index, the weaning weights of individual lambs being adjusted for environmental sources of variation (Jury et al., 1979). Many factors contribute to the variation in the weaning weight of lambs. Factors such as the lamb's age at weaning, its sex, and whether it was born as a twin or a single tend to obscure genetic differences between lambs. If the information on these factors' effects is available, it can be used to adjust records to achieve maximum improvement (Ch'Ang & Rae, 1961).

In order to improve breeding value, selection must be based on genotypic rather than environmental superiority. Thus, variation due to definable environmental effects must be removed by the use of suitable adjustment factors. Ideally, these adjustments would be developed individually for each management unit (i.e., flock), but only rarely is sufficient data available to allow this (Notter et al., 1975).

In Ukraine, sheep breeding is represented by the most significant number of breeds and breed types, although this species is characterized by a significant reduction in the number of ewes, and it was most noticeable during 2011-2019 (Voitenko et al., 2019).
The Ascanian Fine-Fleece sheep breed is a fine-wool breed developed at Askania Nova in the period from 1925 through 1934. The breed was developed by crossing American Rambouillet with Merinos (Mason, 1996). According to the yield clip and wool quality, the Askanian herd ranked the first among all merino herds. The scientists of the Askania Nova Institute, using the intra-breed method, began work on creating a new type of Ascanian Fine-Fleece sheep with the involvement of the Australian merino gene pool. The use of these breeds has given positive results. The wool clip of pure wool in herds of breeding farms increased by 0.87-1.20 kg and amounted to 3.3-3.6 kg on average, the yield of pure fiber, respectively, was 10-12% and 50-55%, the length of the wool increased by 1.5-2.0 cm, qualitative characteristics of wool has improved (Vdovychenko et al., 2018).
Through the last years, a problem arose concerning preserving the herds of the Ascanian fine fleece breed. One of the conditions for its solution was the formation and maintenance of scientifically based genetic structure in the separate herds. If this condition is not fulfilled, the total inbreeding coefficient will increase, which will lead to a decrease in the productivity and the reproductive abilities of sheep (Boikovski et al., 2006).
Successful sheep breeding requires a perfect breeding program, which should consider the influence of various factors at all technological processes. Simultaneously, the birth and weaning weight of lambs has a significant role in achieving profitability in the sheep breeds raised for meat and wool (Petrović et al., 2015; Kramarenko et al., 2020).
This study's objectives were to determine the most important factors affecting meat production in the semi-arid region of Ukraine and derive adjustment factors for known non-genetic sources of variation.

Materials and methods

The study was carried out based on the Institute of Animal Husbandry of Steppe Regions named by M. F. Ivanov "Askania-Nova" – the National Scientific Agricultural Center in Sheep Breeding of NAAS. The study's object was genetic and non-genetic factors on the birth and weaning weight of lambs. Data from 2,603 ewes were included in the analysis, where 3,961 lambs were obtained during the five years of the research.
Their mating evaluated the growth traits of lambs in the Ascanian Fine-Fleece ewes (AC) with the sires of the following genotypes, which are the Ascanian Fine-Fleece, the Australian Merino (AM), and the half-bred rams (1/2AC + 1/2AM). The influence of the year of lambing, ram genotype, age of dam, type of birth, sex of lamb on the birth (WB), and weaning weight (WW) of lambs was also studied. Ewes were divided into three groups based on their age: 2 years old (AG1), 3-6 years old (AG2), and seven years and older (AG3). Only ewes with single and twin lambs were included in the analysis.
All calculations and statistical analyses were processed by a statistical package STATISTICA v.7 for Windows Software (Stat Soft Inc.)

Results

The results of the influence of the year of lambing, ram genotype, age of dam, type of birth, sex of lamb, and the two and three factors of interactions on the birth and weaning weight of lambs are presented in Table 1 and Table 2, respectively. A significant effect on the birth and weaning weight of lambs was established for all genetic and non-genetic factors used in the study (the year of lambing, ram genotype, age of dam, type of birth, and sex of lamb) (Kramarenko et al., 2020).
The year of lambing effects was significant on the birth and weaning weight of lambs ($P < 0.001$). The average birth weight of lambs was 4.17 ± 0.01 kg, and the weaning weight of lambs was 27.06 ± 0.09 kg. However, the means for different years varied between 3.62... 4.52 kg and 25.35... 30.02 kg, respectively. The interaction year of lambing × ram genotype was significant only for lambs' weaning weight ($P = 0.005$). The ram genotype's significant influence was noted only during the 1st year of lambing (Table 3).

Table 1. The effect of the year of lambing, ram genotype, age of dam, type of birth, sex of lamb, and the two- and three-factor interactions on birth weight of lambs

Source	*df*	*MS*	*F*	*P*
Year of lambing	4	92.151	428.34	< 0.001
Ram genotype	2	0.942	4.38	0.013
Age of dam	2	0.771	3.58	0.028
Type of birth	1	296.783	1379.53	< 0.001
Sex of lamb	1	24.376	113.31	< 0.001
Year of lambing × ram genotype	6	0.419	1.95	ns
Year of lambing × age of dam	7	0.445	2.07	0.044
Year of lambing × type of birth	4	3.890	18.08	< 0.001
Year of lambing × sex of lamb	4	0.390	1.81	ns
Ram genotype × type of birth	2	1.856	8.63	< 0.001
Year of lambing × ram genotype × type of birth	6	0.487	2.27	0.035
Ram genotype × age of dam × type of birth	4	0.995	4.62	0.001
Error	3722	0.215	-	-

ns: not significant ($P > 0.05$).

Table 2. The effect of the year of lambing, ram genotype, age of dam, type of birth, sex of lamb, and the two-factor interactions on weaning weight of lambs

Source	*df*	*MS*	*F*	*P*
Year of lambing	4	3422.986	131.06	< 0.001
Ram genotype	2	280.481	10.74	< 0.001
Age of dam	2	112.128	4.29	0.014
Type of birth	1	5185.301	198.54	< 0.001
Sex of lamb	1	1542.197	59.05	< 0.001
Year of lambing × ram genotype	6	80.684	3.09	0.005
Year of lambing × age of dam	7	31.620	1.21	ns
Year of lambing × type of birth	4	92.761	3.55	0.007
Year of lambing × sex of lamb	4	67.691	2.59	0.035
Ram genotype × type of birth	2	143.314	5.49	0.004
Error	3381	26.117	-	-

For the weaning weight of lambs, ewes mated to the Ascanian Fine-Fleece rams produce lambs that are heavier than ewes mated to the Australian Merino and the half-bred rams ($P < 0.001$). The differences between the means over the five years of observation of the weaning weight of lamb and the means for the first year of lambing were 0.34, 1.57, and 2.04 kg for ewes which were mated to the Ascanian Fine-Fleece, half-bred and Australian Merino rams, accordingly. Similar estimates for the second year (considering scale adjustments) were 0.34, -0.40, and -0.45 kg, and for the fifth year of lambing, they were 0.34, -0.50, and -0.69, respectively (Table 3).

The interaction year of lambing × age of dam was significant only for lambs' birth weight ($P = 0.044$). Simultaneously, a significant effect of the dam's age was also noted in the first year of lambing (Table 4). Generally, aged ewes produce lambs that were heavier than 2-year-old ewes.

The differences between the weight mean at lamb birth and the first year of lambing were 0.03, -0.02, and 0.04 kg the ewes of the age groups AG1, AG2, and AG3, respectively. Similar estimates for the second year of lambing (considering scale adjustments) were 0.03, 0.12, and 0.14 kg; for the third year, they were 0.03, 0.19, and 0.14, and for the fifth year, they were 0.03, 0.03, and 0.09, respectively (Table 4).

Consequently, there is an unequal variability in the reproductive traits of different ages of ewes against the background of variations in climatic conditions in different years.

The interaction year of lambing × type of birth was significant both for the birth weight of lambs ($P < 0.001$) and also for the weaning weight of lambs ($P = 0.007$). The significant differences between the weight of single and twin lambs occurred throughout the five-year observation period.

As can be expected, single lambs were characterized by higher weight both at birth and at weaning (Table 5). However, the extent of these differences was largely dependent on the year of lambing. The differences between the mean weight for single and twin lambs at birth during 1-5 years of lambing were 0.79, 0.50, 0.65, 0.68, and 0.43 kg, and at weaning, it was 2.22, 2.88, 1.46, 4.01, and 2.58 kg, respectively.

Table 3. Means and standard errors for the birth weight and weaning weight of lambs for different year of lambing × ram genotype interactions, kg

YoL	Birth weight of lamb				Weaning weight of lamb			
	AC	1/2AC + 1/2AM	AM	*F (P)*	AC	1/2AC + 1/2AM	AM	*F (P)*
1	4.29±0.10 (*n*=61)	4.14±0.04 (*n*=305)	4.15±0.04 (*n*=354)	ns	27.90±0.63 (*n*=52)	25.89±0.30 (*n*=262)	24.50±0.25 (*n*=325)	15.15 (<0.001)
2	4.63±0.06 (*n*=95)	4.52±0.02 (*n*=552)	4.49±0.02 (*n*=413)	3.28 (0.038)	30.40±0.66 (*n*=84)	30.36±0.26 (*n*=500)	29.49±0.29 (*n*=378)	ns
3	-	3.57±0.03 (*n*=302)	3.65±0.03 (*n*=498)	ns	-	25.45±0.25 (*n*=292)	25.94±0.20 (*n*=477)	ns
4	-	4.14±0.05 (*n*=256)	4.23±0.04 (*n*=271)	ns	-	28.50±0.42 (*n*=237)	27.75±0.38 (*n*=247)	ns
5	4.22±0.06 (*n*=72)	4.23±0.02 (*n*=450)	4.26±0.03 (*n*=332)	ns	25.63±0.65 (*n*=63)	25.69±0.26 (*n*=401)	24.96±0.32 (*n*=296)	ns
		$F(6; 3722) = 1.95$ (ns)				$F(6; 3381) = 3.09$, $P = 0.005$		

YoL: Year of lambing.

Table 4. Means and standard errors for the birth weight and weaning weight of lambs for different year of lambing × age of dam interactions, kg

YoL	Birth weight of lamb				Weaning weight of lamb			
	AG1	AG2	AG3	*F (P)*	AG1	AG2	AG3	*F (P)*
1	4.03±0.06 (*n*=133)	4.19±0.03 (*n*=537)	4.17±0.10 (*n*=50)	2.51 (0.050)	24.42±0.41 (*n*=113)	25.62±0.22 (*n*=480)	24.83±0.62 (*n*=46)	3.24 (0.040)
2	4.50±0.04 (*n*=113)	4.52±0.02 (*n*=824)	4.54±0.06 (*n*=123)	ns	30.66±0.59 (*n*=105)	30.03±0.21 (*n*=753)	29.34±0.59 (*n*=104)	ns
3	3.65±0.06 (*n*=110)	3.60±0.02 (*n*=591)	3.69±0.05 (*n*=99)	ns	25.31±0.39 (*n*=108)	25.86±0.18 (*n*=568)	25.61±0.40 (*n*=93)	ns
4	-	4.16±0.03 (*n*=416)	4.29±0.06 (*n*=111)	ns	-	28.32±0.32 (*n*=380)	27.38±0.60 (*n*=104)	ns
5	4.13±0.16 (*n*=9)	4.24±0.02 (*n*=733)	4.22±0.05 (*n*=112)	ns	22.00±0.69 (*n*=8)	25.57±0.21 (*n*=655)	24.56±0.56 (*n*=97)	3.13 (0.044)
	$F(7; 3722) = 2.07, P = 0.044$				$F(7; 3381) = 1.21$ (ns)			

Thus, the variability of climatic conditions is unequally manifested in the weight of single and twin lambs, and, also, these conditions are manifested in different degrees on the birth/weaning weight of lambs.

Table 5. Means and standard errors for the birth weight and weaning weight of lambs for different year of lambing × type of birth interactions, kg

YoL	Birth weight of lamb			Weaning weight of lamb		
	single lambs	twin lambs	*F (P)*	single lambs	twin lambs	*F (P)*
1	4.67±0.04 (*n*=259)	3.88±0.02 (*n*=453)	315.52 (< 0.001)	26.78±0.32 (*n*=228)	24.56±0.22 (*n*=400)	33.16 (< 0.001)
2	4.90±0.03 (*n*=299)	4.40±0.01 (*n*=734)	323.78 (< 0.001)	32.05±0.36 (*n*=274)	29.17±0.22 (*n*=667)	49.27 (< 0.001)
3	4.12±0.04 (*n*=209)	3.47±0.02 (*n*=563)	291.72 (< 0.001)	26.90±0.30 (*n*=191)	25.44±0.18 (*n*=547)	17.23 (< 0.001)
4	4.70±0.06 (*n*=149)	4.02±0.03 (*n*=364)	147.28 (< 0.001)	31.01±0.55 (*n*=141)	26.99±0.31 (*n*=329)	45.36 (< 0.001)
5	4.55±0.03 (*n*=281)	4.12±0.02 (*n*=544)	212.91 (< 0.001)	27.14±0.37 (*n*=249)	24.56±0.22 (*n*=487)	39.58 (< 0.001)
	$F(4; 3722) = 18.08, P < 0.001$			$F(7; 3381) = 3.55, P = 0.007$		

The interaction year of lambing × sex of lamb was significant only for lambs' weaning weight (P = 0.035). The significant differences between the mean weight in male and female lambs occurred three times during the five-year observation period (the first, second, and fifth-year lambing). As it might be expected, male lambs had a higher weaning weight in these years (Fig. 1).

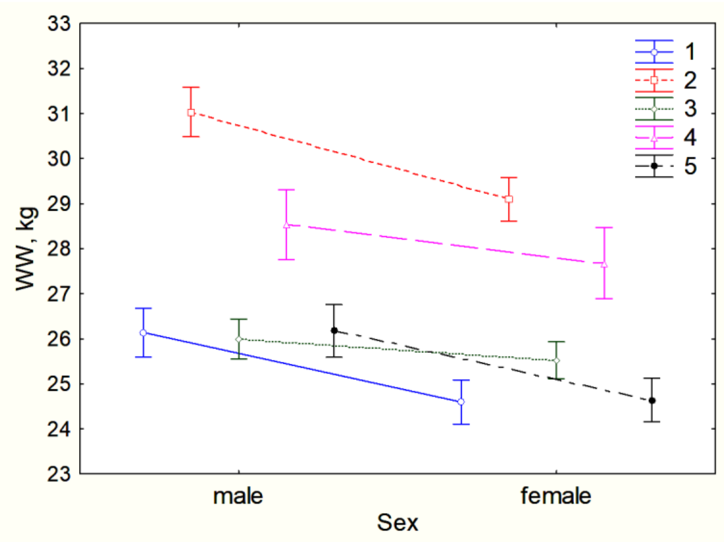

Fig. 1. Means and standard errors for the weaning weight of lambs for different year of lambing × sex of lamb interactions

However, if in the first and fifth year of lambing, the mean differences between the weaning weight of male and female lambs were 1.53-1.54 kg, then in the second year, this difference was higher (1.94 kg).

Thus, the variability of climatic conditions is manifested in different degrees in the weaning weight of different sexes of lamb, although, in general, there is a tendency that the weight of male lambs prevails over female lambs.

In addition to environmental effects, we also noted that the interaction between the ram genotype × type of birth was significant for the weight of lambs both at birth ($P < 0.001$) and at weaning ($P = 0.004$). For both single and twin lambs, the lamb weight at birth and weaning was significantly different among ewes that were mated to rams of different genotypes (in both cases: $P < 0.001$). Concerning the lamb weight at birth, both singles and twins were ranked as follows: the Ascanian Fine-Fleece rams > half-bred rams > Australian Merino rams, according to the genotype of the sire. In terms of the lamb weight at weaning, this order was: the Ascanian Fine-Fleece rams = half-bred rams > Australian Merino rams (Fig. 2).

The differences between the mean birth weight of single and twin lambs were 0.72, 0.61, and 0.59 kg, and the differences between the mean weaning weight of single and twin lambs were 1.44, 3.23, and 1.79 kg for ewes that were mated to the Ascanian Fine-Fleece rams, half-bred rams, and Australian Merino rams, respectively.

Thus, the most significant effect of type of birth with birth weight occurred among lambs born from ewes that were mated to the Ascanian Fine-Fleece rams. In contrast, the most significant effect of type of birth with weaning weight occurred among lambs born from ewes that were mated to the half-bred rams.

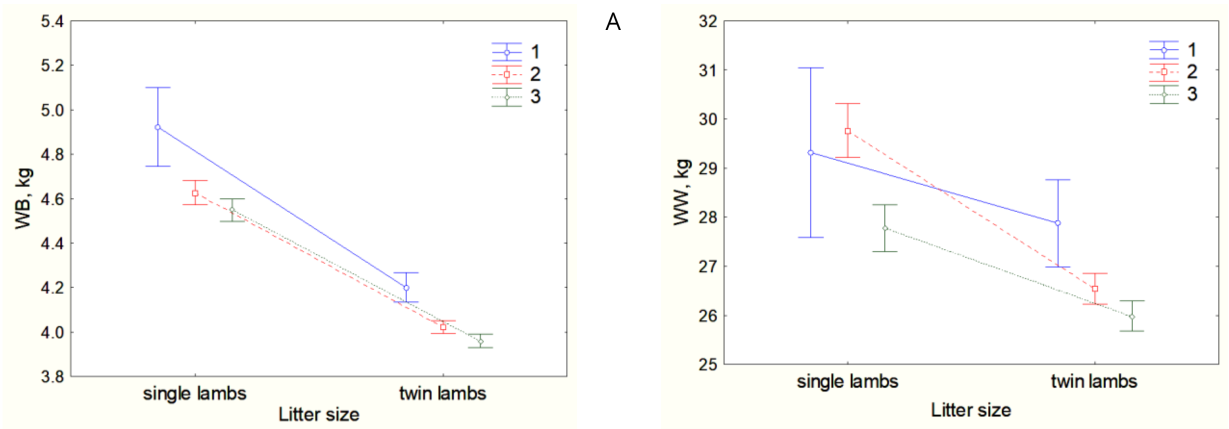

Fig. 2. Means and standard errors for the birth weight (A) and weaning weight of lambs (B) for different ram genotype × type of birth interactions: 1 – the Ascanian Fine-Fleece rams; 2 – half-bred rams; 3 – Australian Merino rams

Finally, three factors' significant interaction on lambs' birth weight was also noted (Table 1). Means and standard errors for the birth weight of lambs for different years of lambing × ram genotype × type of birth interactions are presented in Fig. 3. The differences between the mean birth weight of single and twin lambs were the biggest for ewes that were mated to the Ascanian Fine-Fleece rams in the first (1.12 kg) and second (0.81 kg) years of lambing, as well as for ewes that were mated to the half-bred rams in the fourth year of lambing (0.85 kg). On the other hand, the differences between the mean birth weight of single and twin lambs were the least for ewes that were mated to the Australian Merino rams (0.43 kg) and the half-bred rams (0.43 kg) in the fifth year, as well as for ewes that were mated to the Australian Merino rams in the second year of lambing (0.44 kg).

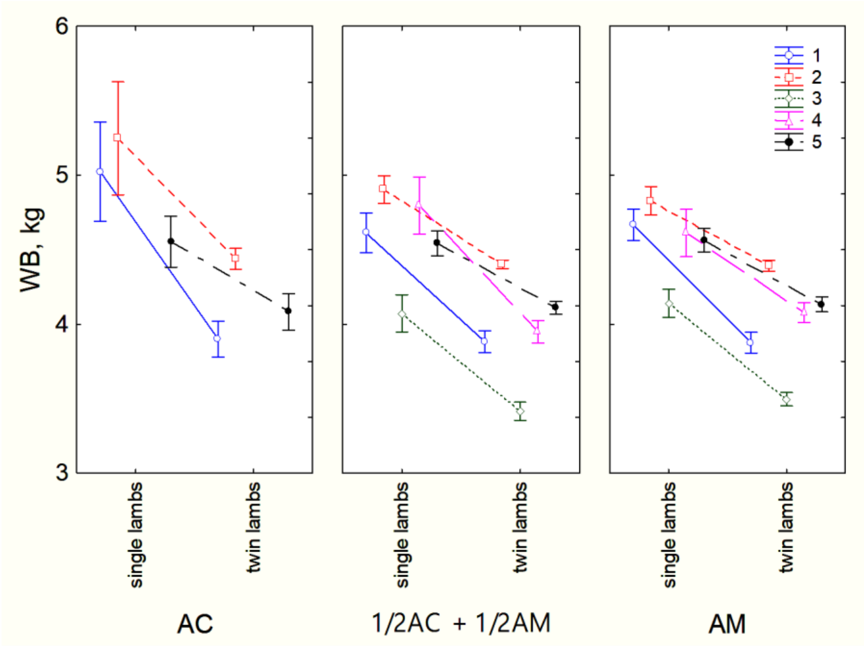

Fig. 3. Means and standard errors for the birth weight of lambs for different year of lambing × ram genotype × type of birth interactions

Means and standard errors for the birth weight of lambs for different ram genotype × age of dam × type of birth interactions are presented in Fig. 4. The differences between the mean weight of single and twin lambs at birth were the biggest for AG2 ewes mated to the Ascanian Fine-Fleece (0.88 kg), and AG1 ewes mated to the Australian Merino rams (0.81 kg). On the other hand, the differences between single and twin lambs' birth weight were the smallest for the age groups AG1 and AG3 of ewes, which were mated to the Ascanian Fine-Fleece rams (0.29 and 0.36 kg, respectively).

Discussion

The information given in the publications regarding genetic and non-genetic factors on the birth and weaning weight of lambs is contradictory. In several publications, the results of the studies did not reveal such an effect. For example, in Ch'Ang & Rae (1961), it was noted that in a dual-purpose breed of sheep such as the Romney Marsh, the first-order interactions between year, age of dam, type of birth, and sex on the birth and weaning weight of lambs were statistically not significant. According to Bathaei & Leroy (1994), the factors affecting birth weight, weaning weight (90 days of age), and daily gain from birth to weaning of 973 lambs in Mehraban sheep in Iran, it was noted that the first-order interactions between type of birth, sex of lamb, age of dam, year of lambing and month of birth were statistically not significant.

Similar results were obtained for the survival rate from birth to weaning. Fogarty et al. (1984) found no breed × season of birth interaction for the survival rate in a study that included three seasons of birth (September, January, and May) and three breeds (Dorset, Rambouillet, and Suffolk). No breed of the sire or genetic group of the dam × environmental category interactions were ($P > 0.05$) observed for the survival rate of the crossbreed lambs obtained in Central Mexico (Osorio-Avalos et al., 2012).

However, more numerous studies have confirmed the presence of such interactions between genetic and non-genetic origin factors when analyzing the variability of the birth and weaning weight of lambs, consistent with our obtained results.

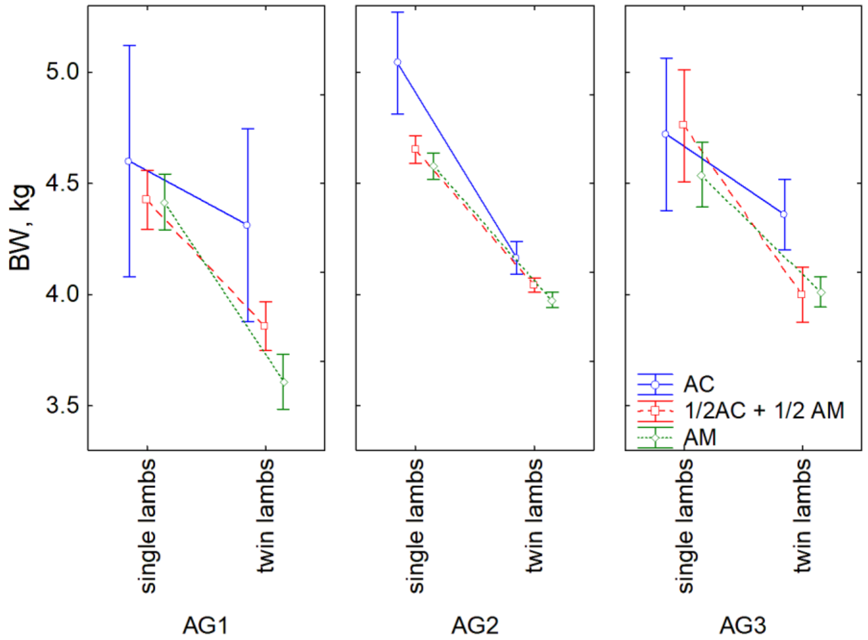

Fig. 4. Means and standard errors for the birth weight of lambs for different ram genotype × age of dam × type of birth interactions

In Notter et al. (1975), field data on 7,166 purebred lambs of seven breeds were used to determine the effects of age of ewe, type of birth, sex, and season of birth 90-day, age-corrected weight, both within and among breeds. Least-squares analyses showed that the breed's interactions with a type of birth and season of birth were significant ($P < 0.05$). Notter et al. (1975) observed a marked increase in Hampshire and Suffolk breeds' superiority for birth and weaning weights in autumn. The breed × season interaction is essentially due to the breed differences in response to stress or differences in management.

In Djemali et al. (1994), it was shown that sex of lamb, type of birth, age of dam, year of lambing, sires within groups, month × year interaction, and type of birth × month × year interaction were highly significant for the growth traits from birth to three months of age of Barbarine lambs in Tunisia ($P < 0.01$). The sex × type of birth interaction was significant ($P < 0.05$) for W30 and highly significant for W70, W90, and ADG10-30.

Assan & Makuza (2005) registered the sex × year interaction had significant effects ($P < 0.001$) on the weaning weight in Dorper and Mutton Merino. Thus two-factor interaction of sire with year suggests that sire performance would depend on the year effect, which encompasses factors such as management, climate, temperature, and disease control, and the main effects of sire and year are meaningless because the performance of the sire will depend on the year and vice versa (Assan & Makuza, 2005). Gbangboche et al. (2006) shown that lambing interval in Djallonke sheep was affected ($P < 0.001$) by the year of lambing, sex of the lamb, type of birth, age of ewe, and type of birth × age of ewe interaction, while the bodyweight of 90-days-lambs per breeding female/year was affected ($P < 0.01$) by the year of lambing, age of ewes, sex of lambs, and age of ewe × sex interaction. Osorio-Avalos et al. (2012) noted that the sire breed × environmental category interaction effect was significant for birth weight ($P < 0.01$) and weaning weight ($P < 0.05$), but relatively minor changes on the ranking of sire breeds were observed between environmental categories for weaning weight for the crossbred lambs obtained by artificial insemination from 114 flocks in

Central Mexico. The genetic group of the dam × environmental category interaction effect was significant for birth and weaning weights ($P < 0.01$). Notter & Brown (2015) registered that effects of flock × age of dam and flock × sex of lamb interaction on the birth weight of lamb from 123 flocks (the Australian Sheep Genetics LAMBPLAN database) were significant (in both cases: $P < 0.05$). Besides that, effects of birth × age of dam and flock × type of birth interaction on the weaning weight were also significant ($P < 0.05$). Simultaneously, the effects of flock × age of dam interaction were most significant ($P = 0.001$) in the data that included yearling dams. Among the non-genetic origin factors that form synergies with first-order interactions and significantly affect the birth weight and weaning weight of lambs, such as the year of lambing and the type of birth, can be noted. Among two-way factor interactions, ram genotype × type of birth interaction was noted more often.

Conclusion

The two-way factor interactions of the year of lambing × age of dam, year of lambing × type of birth, ram genotype × type of birth, and three-way factor interactions of the year of lambing × ram genotype × type of birth and age of dam × ram genotype × type of birth had significant effects ($P < 0.001...0.044$) on birth weight in the Ascanian Fine-Fleece and crossbred lambs. Effects of the year of lambing × ram genotype, year of lambing × type of birth, year of lambing × sex, and ram genotype × type of birth interaction had significant effects ($P < 0.004...0.035$) on the weaning weight of lambs.

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