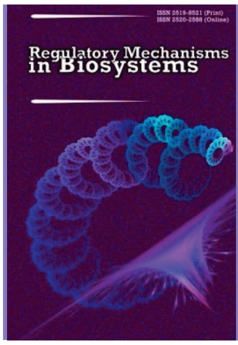

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The impact of environmental temperature on ewe reproduction, adaptive responses during insemination, and productive characteristics of the lambs obtained from them

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The reproductive function of ewes and the development of their offspring are largely influenced by their clinical condition and the temperature of the environment. The maximum temperature values have significantly increased over the last two decades, making climate change a pressing issue for sheep breeding worldwide, including Ukraine. The consequences of exposure to high temperatures of the outside air, above all, in the mating season, can be marked by a significant increase in the heat load on the body of the brood stock, a decrease in clinical indicators and reproductive capacity. On the other hand, the current understanding of how these components interact is insufficient, which conditions the relevance of this work. In order to determine the effective terms of insemination of sheep in the mating season of 2021, taking into account the terms of insemination and the characteristics of the outside air temperature, three technological groups of ewes were formed, which were in the same flock and were artificially inseminated with freshly obtained sperm from the same breeders in August–September: from August 15 to August 27; from August 28 to September 9 and from September 10 to September 21. It was discovered that ewes inseminated between August 28th and September 9th were less adaptable to environmental conditions, experiencing increased daily fluctuations of body temperature, pulse and breathing rates, stillborn lambs, cases of abortion, and decreased preservation of young animals, including ewe lambs, which are highly valuable in breeding – by 15.8% and 10.9% concerning the initial and final phases of the insemination period. However, the young lambs born from ewes inseminated between August 15th and August 27th had the highest survival rate until weaning due to better survival of ewe lambs compared to those inseminated during later phases of the mating season against the background of a lower percentage of output of rams until the moment of weaning against ewes that were inseminated from August 28 to September 9. It has been shown that the growth rate of lambs during early postnatal development varies depending on the timing of their mothers' insemination. Ewes inseminated between August 15th and 27th produced lambs with the highest weight at 90 days, reaching 26.81 and 24.18 kg, respectively; 20.1% and 26.8% more than rams, and 19.1% and 18.8% more than female lambs whose mothers were inseminated in the middle and at the end of the breeding season. A similar picture is characteristic of the average daily growth values. It was determined that the formation of clinical indicators, and above all, the body temperature of young animals born from mothers fertilized at the beginning and in the middle of the mating season, was the most intense. The results of this study made it possible to understand the adaptive mechanisms of the response of sheep to changes in environmental temperature, which will be useful in future investigations to determine its effect on the thermopotential and clinical condition of lambs during the first day after birth, which is the most critical.

Keywords: young animals; air temperature; reproductive capacity; live weight; average daily growth; clinical indicators.

Introduction

The process of formation and development of artificial insemination in countries with developed sheep farming is based on improving the genetic quality of animals, controlling reproductive infectious diseases, and optimizing reproductive function (Gibbons et al., 2019; Putri et al., 2021). On the other hand, the success rate of sheep artificial insemination is only 47.6%, while Rizal et al. (2006) believe that the ideal indicator of its effectiveness should be 70%. It is difficult to disagree with the statement (Tekin et al., 2006; Hashem et al., 2015; Abebe & Alemayehu, 2021) that multiple abiotic and biotic factors can influence the course of the fertilization process: frozen sperm quality, incorrect insemination procedures, wrong timing of estrus and sperm count and timing. They both individually and in combination contribute to a significant decrease in the effectiveness of artificial insemination (Shakhova et al., 2021). In addition, high air temperature is also rightly singled out as a significant negative component of artificial insemination success (Abecia et al., 2016; Arrébola et al., 2016; Van Wettere et al., 2021).

On the other hand, according to a report (Joy et al., 2020), almost 50% of the sheep population is distributed in arid regions of the world, which indicates their versatility and potential adaptability to increased air temperatures. At the same time, as stated (Ozawa et al., 2005; Gharibzadeh et al., 2015), heat stress in ewes directly affects behaviour during estrus, oocyte maturation, embryonic development and, ultimately, the birth of weak lambs. However, this effect is mostly limited to the first 8 days after artificial insemination, which corresponds to the susceptible period of early embryonic development and entry of the embryo into the uterus (Spencer et al., 2004). After this period, the resistance of the embryo to heat stress increases (Dixon et al., 2007). This is consistent with a study that indicates that the reproductive function of sheep is significantly affectted by heat stress in the week before and up to 5 days after oestrus (Van Wettere et al., 2021). A similar opinion is argued that the increased environmental temperature has a negative effect on the biological functions of sheep, which is manifested by a decrease in production and the level of reproduction (Marai et al., 2007). Heat stress occurs when environmental conditions cause the body's core temperature to rise above the normal range and is associated with hyperthermia (Hansen, 2009). However, based on an analysis of literature sources, the scientific community holds contradictory opinions regarding the impact of environmental temperature and artificial insemination timing on the reproductive capacity of ewes. This has led to the need for further research in this area. According to (Dixit et al., 2001), the timing of lambing significantly affects lamb productivity. Zapasnikiene (2002) found that winter-born lambs had higher birth and weaning weights than those born in summer and autumn. Similar conclusions were reached by other researchers. Currently Yilmaz et al. (2007), studying the productive characteristics of lambs of different birth dates, found that winter lambing contributes to an increase in the live weight of lambs compared to young lambs born in spring. The advantages of winter lambing over later lambing are based on the fact that winter lambs are born healthier and stronger than their spring lambing peers, and therefore have higher productivity. Under such circumstances, the position of Yilmaz et al. (2007) seems to be quite justified, according to which he emphasizes that seasonal differences in the live weight of lambs at birth may be a consequence of differences in the temperature of the environment and the course of intrauterine processes in the mother's body during pregnancy. In the context of the above, these positions (Notter et al., 2005; Susic et al., 2005; Magawana et al., 2021) are quite understandable, emphasizing that the live weight of lambs at birth can be influenced by the type of birth and gender. At the same time, this issue is debatable.

Therefore, the reproductive system and formation of ecological tolerance indicators in livestock to adverse environmental factors require further research and evaluation – the key of which is the justification of rational timing of artificial insemination of ewes while simultaneously identifying their adaptability to climate changes, which are accompanied by the growth of both the average annual and in some periods of the year air temperatures and lengthening of dry periods.

In this regard, the research aimed to evaluate the impact of outdoor air temperature on reproductive function parameters, adaptive reactions of ewes during insemination, and lamb productivity before weaning.

Materials and methods

The experiments conducted on the animals did not contradict the current legislation of Ukraine (Article 26 of the Law of Ukraine 5456-VI dated 16.10.2012 "On the Protection of Animals from Cruel Treatment") as amended as of 04.08.2017 and "General ethical principles of experiments on animals", adopted by the First National Congress on Bioethics (Kyiv, 2001) and international bioethical norms (materials of the IV European Convention on the Protection of Vertebrate Animals Used for Experimental and Other Purposes, Strasbourg, 1985) (Simmonds, 2017). The research program was reviewed and approved by the bioethics commission of the Institute of Animal Husbandry of the National Academy of Agrarian Sciences in the current order. Research ethics could be violated for the study of clinical indicators.

The study was carried out at a base farm in Kharkiv region on sheep of the Kharkiv intrabreed type of the Prekos breed. In order to establish the effective terms of insemination of sheep in the mating season of 2021, taking into account the terms of insemination and the characteristics of the outside air temperature, three technological groups of ewes were formed, which were in the same flock and were artificially inseminated with freshly obtained sperm from the same breeders in August–September: the first group (116 head) – from August 15 to August 27; the second group (43 head) – from August 28 to September 9 and the third group (123 head) – from September 10 to September 21. The sexual desire of female sheep was determined through the use of male sheep wearing aprons under their abdomen. A trained technician carried out the artificial insemination process using the visocervical method while adhering to hygiene and sanitary standards. For breeding purposes, three 4-year-old male sheep with an average weight of 115 and 10.4 kg of wool shearing were utilized. The female sheep used were typical animals that met the standards of the elite class based on their primary performance indicators. They were between 6–7 years old with an average weight of 61.7–68.5 kg.

During the spring–summer period of the experiment, the experimental ewes were grazed on natural pastures and provided with concentrated fodder. In the autumn–winter period, the animals were kept using the penbase method and fed with hay made from cereal and leguminous crops, silage, concentrates, and balancing feed additives. Lambing occurred in January–February, and the offspring that were obtained were evaluated. All the young obtained from the experimental ewes were divided into three groups according to their mothers' insemination dates. The lambs were weaned from their mothers at 90 days of age.

Based on official data from the Kharkiv Regional Center of Hydrometeorology for the years 1986–1995 and 2012–2021, the average annual outdoor temperature has increased by 16.0%, from 8.1 to 9.4 ºC. During the months of active fodder crop growth (April–September), the temperature also increased by 15.7%, from 15.9 to 18.4 ºC. Additionally, there has been a decrease in average annual precipitation from 559.9 to 514.5 mm (8.1%), and in summer months from 354.8 to 274.3 mm (19.5%). These changes suggest negative consequences of climate change, which could impact the welfare of sheep and their food supply. The daily amplitude of outdoor air temperature fluctuations during the insemination of ewes and in the room during the growth of lambs until weaning was recorded using two He-173 Loggers – thermal recorders (China), designed for round-the-clock control and recording of air temperature, with measurement accuracy for air temperature ± 0.25 ºC, relative air humidity – ± 2.5%.

The duration of the embryonic period of development of lambs was estimated by the date of artificial insemination of their mothers recorded in the journal and the date of birth. The intensity of growth of lambs during embryogenesis is based on the ratio of their live weight at birth to the duration of embryonic development. Reproductive ability of ewes was evaluated by recording the results of insemination, fertilization, fertility, counting the number of abortions, live and stillborn lambs. Fertility of ewes was studied by the total number of newborn lambs (live and dead) at birth per 100 ewes that lambed; preservation level – according to the output of lambs on the date of weaning to their number at birth; fecundity – by the number of ewes that have lambed as a percentage of their number at the beginning of lambing.

The milk yield of the ewes was determined based on the difference between the live weight of the lambs at the age of 20 days and the weight at birth. The resulting difference was multiplied by 5 (the number of kilograms of breast milk consumed per 1 kg of live weight gain).

To study the physiological state of ewes during mating season and lambs in both winter and summer, their respiratory rate (observed visually through chest movements and counted per minute), pulse rate (measured by heart contractions per minute), and rectal temperature (measured using a medical mercury thermometer with an error margin of 0.2º) were observed during daytime hours. These observations were conducted four times per day, including at 8 am, 12 pm, 4 pm, and 9 pm.

The weight of the newborn animals was measured individually on the first day after birth with a precision of ± 0.1 kg. At ages 20, 60, and 90 days, they were weighed again before morning feeding and watering on scales with a precision of ± 0.5 kg. The weight recorded on each of these dates was considered their weight at 20, 60, and 90 days respectively. Using these data, we calculated the absolute and average daily weight gains of the animals in the study.

Research results were processed using the computer program Statistica 10.0 (StatSoft, USA). Results are presented as mean ± standard error (x ± SE). Tukey's test was used to compare the difference in mean values between groups, where differences were considered statistically significant at $P < 0.05$ for all data.

Results

It has been found that in the period from August 15 to August 27, the insemination of ewes took place at an average daytime temperature of 27.8 ºC, with fluctuations during the daylight hours from 21.0 to 32.0 ºC, at night – 19.8 ºC, with fluctuations from 15.0 to 23.0 ºC; in the period from August 28 to September 9, respectively insemination took place at an average daytime temperature of 28.7 ºC, with fluctuations from 23.0 to 34.0 ºC and average nighttime temperature of 20.4 ºC, with fluctuations from 12.0 to 27.0 ºC; in the period from September 10 to September 21, respectively at an average daytime temperature of 21.9 ºC, with fluctuations from 14.0 to 26.0 ºC and average nighttime temperature of 15.7 ºC, with fluctuations from 10.0 to 21.0 ºC. That is, the difference in average temperatures during the day between groups of ewes was 6.8 ºC, and at night it was 4.7 ºC. During the first period, the average relative humidity during the day was 62%, with fluctuations between 54% and 70%. During the second and third periods, it was 65% with fluctuations between 60% and 70%. The relative humidity increased at night.

Throughout the observations, ewes across all groups maintained a normal body temperature, pulse rate, and respiratory movements. However, animals that were inseminated between August 15 to August 27 and August 28 to September 9 showed a reliable increase in these indicators ($P < 0.05–0.01$), indicating a negative impact on their bodies due to environmental temperatures (Table 1).

It was observed that there were slight changes in the heart rate, respiratory movements, and body temperature of the experimental ewes during the mating season. These changes were influenced by the temperature of the environment. Specifically, the minimum values were noted in the morning, the maximum values were observed at noon, and from 4 p.m. until evening, a moderate decrease was observed. The temperature of female sheep increased by 1.0–1.4 ºC as the air temperature rose from morning to noon, regardless of when they were inseminated. However, the average temperature of sheep inseminated between August 28 and September 9 did not increase as significantly. These sheep had higher temperatures compared to those inseminated at the beginning and end of the mating season, with differences of 0.5 and 0.9 ºC in the morning, 0.1 and 0.6 ºC in the afternoon, and 0.3 and 0.7 ºC in the evening, respectively.

Ewes showed more noticeable changes in their breathing rates throughout the day. In the morning, they breathed more frequently by 1.8 to 2.0 breaths, and at noon when the air temperature as at its peak, by 4.0 to 8.0 breaths. In the evening, they breathed more by 2.0 to 4.0 breaths per minute. The most significant changes occurred in pulse frequency, which was faster in the morning by 9 to 11 beats, in the afternoon by 4 to 20 beats, and in the evening by 10 to 14 beats per minute. These results indicate that ewes have natural protection against increased daytime temperatures, which can cause thermal depression and lead to clinical indicator values increasing from morning to evening. This is especially evident in ewes inseminated between August 28 and September 9.

Table 1
Clinical parameters of the body of ewes ($x \pm SE$, $n = 5$)

Parameter	Time of day, hours	The period of insemination of ewes		
		15.08–27.08*	28.08–9.09**	10.09–21.09***
Body temperature, ºC	8	38.6 ± 0.14^a	39.1 ± 0.45^a	38.2 ± 0.09^a
	12	40.0 ± 0.29^a	40.1 ± 0.17^a	39.5 ± 0.19^a
	16	39.1 ± 0.17^{ab}	39.6 ± 0.18^a	38.9 ± 0.16^b
	21	38.9 ± 0.16^a	39.2 ± 0.13^a	38.5 ± 0.33^a
Breath rate, breaths/min	8	18.2 ± 2.22^a	20.0 ± 1.79^a	18.0 ± 1.14^a
	12	32.0 ± 0.32^a	36.0 ± 1.76^b	28.0 ± 0.32^c
	16	28.6 ± 1.29^a	31.0 ± 1.34^a	22.4 ± 0.81^b
	21	22.0 ± 0.95^a	24.0 ± 1.22^a	20.0 ± 1.14^a
Pulse rate, beats/min	8	81.0 ± 1.58^a	90.0 ± 1.84^b	79.0 ± 0.95^a
	12	98.0 ± 0.32^a	102.0 ± 0.84^b	82.0 ± 1.22^c
	16	91.0 ± 2.35^a	96.0 ± 0.45^a	81.4 ± 1.75^b
	21	84.0 ± 1.00^a	94.0 ± 1.30^b	80.0 ± 1.22^a

Note: * – group of ewes inseminated from August 15 to August 27; ** – group of ewes that were inseminated from August 28 to September 9; *** – group of ewes that were inseminated from September 10 to September 21; different letters indicate significant differences between groups within each row by Tukey's test.

The terms of prenatal development of lambs by groups of ewes did not differ significantly and ranged from 147.6 days to 150.1 days. However, for the use in reproduction of ewes that were inseminated between September 10 and 21, a reliable reduction of 2.1 ($P < 0.05$) and 2.5 ($P < 0.05$) days of fetal development of lambs was found, compared to the early and late stages of the mating season in ewes of six years of age in both cases of comparison. The rate of embryonic growth in the lambs was consistent, ranging from 24.5 to 25.3 grams per day. However, when comparing the weight of ewes that were inseminated between 28th August to 9th September, they were found to be significantly lighter by 4.86 kg or 7.3% ($P < 0.05$) compared to those that were fertilized between 15th August to 27th August, and by 6.83 kg or 10.0% ($P < 0.001$) compared to those inseminated between 10th September to 21st September (Table 2). After analyzing the results, it was discovered that all groups of ewes possessed reproductive qualities that met the target standard for this particular inbred type (Table 3).

Table 2
Embryonic development of lambs and age-weight parameters of experimental ewes

Parameter	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
Duration of prenatal development, days	149.65 ± 13.89^a	150.09 ± 22.89^a	147.57 ± 11.78^b
Average daily growth of lambs during the prenatal period, g	24.78 ± 0.31^a	25.00 ± 0.67^a	24.50 ± 0.27^a
Age of ewes, years	6.03 ± 0.19^a	7.00 ± 0.35^b	5.94 ± 0.16^a
Live weight of ewes, kg	66.51 ± 0.96^a	61.65 ± 1.27^b	68.48 ± 0.83^a

Table 3
Reproductive qualities of ewes

Parameter	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
Fertilized ewes, head	116	43	125
Lambing ewes, head	116	43	125
Fertility, %	100.0	100.0	100.0
Number of aborted ewes, head	–	1	–
Number of stillborn lambs, head	–	2	–
Received live lambs, heads	163	55	185
Yield of lambs per 100 lambing ewes, %	140.5	132.6	148.0

The pregnancy went without significant deviations from the physiological norm. After giving birth, the offspring were grouped into three groups based on the artificial insemination timeline of their mothers. Despite the various temperature factors affecting reproductive qualities, the number of lambs born per 100 ewes was quite high, averaging at 140.4%. Additionally, when comparing the results of artificial insemination during the period from September 10 to September 21 with those at the beginning and middle of the breeding season, there was an increase of 7.5% and 15.4% respectively in the number of lambs born per 100 ewes that gave birth. However, among ewes that were inseminated in the period from August 28 to September 9, two head of lambs were stillborn and one case of abortion was diagnosed during the mating period, which was 4.7% of the total number of those that were inseminated. In inseminated ewes of the other groups, not a single case of abortion or stillbirth in the offspring of lambs was observed. All lambs received the same care, feeding, and maintenance, resulting in most being born healthy and viable. However, there were cases where some individuals were born underdeveloped. In total, 403 viable lambs were born during lambing, including 199 ewe lambs and 204 rams. Among them, 163 were single-born, 234 were twins, and 6 were triplets. The ratio of ewes to rams within the terms of insemination of ewes ranged from 0.81:1 to 1.50:1 (Table 4), with individual values varying. There was also a difference in the level of preservation of lambs during the post-weaning period. Generally, the young lambs born to mothers who were inseminated between August 15 and August 27 had a 7.8% to 4.7% higher viability, due to better survival rates. The survival rate was 91.6%, which was 15.8% to 4.9% higher than the other groups. On the other hand, the maternal qualities of ewes that were fertilized in the period from August 28 to September 9 were characterized by a higher percentage of business yield of rams before weaning by 3.4% and 7.6%, compared to the initial and final phases of the mating season.

Table 4
The level of preservation of lambs before weaning from their mothers

Parameter	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
Received live lambs, head	163	55	185
including: ewe lambs	83	33	83
rams	80	22	102
Correlation ewe lambs : rams	1.03:1	1.50:1	0.81:1
Number of live lambs born, head	163	55	185
Including: single-born	70	31	62
twins	90	24	120
triplets	3	–	3
Number of lambs when weaning, head	146	45	157
including: ewe lambs	76	25	72
rams	70	20	85
Loss of lambs before weaning, head	17	10	28
%	10.4	18.2	15.1
The level of preservation of lambs before weaning, %	89.6	81.8	84.9
including: ewe lambs	91.6	75.8	86.7
rams	87.5	90.9	83.3

Table 5
Milking capacity of ewes inseminated in different periods on the 20th day of suckling rearing of lambs (kg)

Milking capacity of ewes depending on gender and type of birth of lambs	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
Ewes that gave birth to: rams	25.17 ± 0.84^{a}	29.30 ± 2.25^{a}	26.88 ± 1.15^{a}
n	58	19	65
ewe lambs	22.97 ± 0.74^{a}	22.61 ± 2.20^{a}	25.68 ± 1.00^{a}
n	58	24	60
including: single-born	25.59 ± 0.77^{a}	28.97 ± 2.00^{ab}	29.86 ± 1.11^{b}
n	70	31	63
twins	22.35 ± 0.79^{a}	19.79 ± 2.36^{a}	24.07 ± 1.00^{a}
n	45	12	61
triplets	26.00 ± 5.00^{a}	–	23.25 ± 7.25^{a}
n	1	–	1

It is important to note that the highest percentage of lambs lost occurred within the first month of their lives. However, as they continued to grow, there was a decrease in mortality across all groups. In the experimental herd, the highest loss of offspring before weaning (18.2%) occurred in ewes that were inseminated between August 28 and September 9. The lowest loss rate (10.4%) was observed in ewes that were inseminated from August 15 to August 27. Ewes inseminated between September 10 and September 21 had an intermediate loss rate of 15.1%. Quantitative losses among ewe lambs were greater compared to rams, although the percentage was insignificant.

A distinctive feature of the productive characteristics of ewes that were artificially inseminated in the period from September 10 to September 21 was their higher milk yield, due to higher live weight and increased yield of live lambs born as twins (Table 5). On the 20th day of lactation, milking capacity was greater by 1.5 kg or 6.1% on average compared to ewes inseminated between August 15 and August 27. The milk yield of ewes that lambed with rams was greater by 1.7 kg or 6.8%, with ewe lambs – by 2.7 kg or 11.8% ($P < 0.05$) and those that had singletons among their offspring – by 4.3 kg or 16.7% ($P < 0.01$), and twins – by 1.7 kg or 7.7%. The average values of milk yield of ewes inseminated between September 10 and September 21 were also higher compared to ewes inseminated between August 28 and September 9, but no statistically significant relationship between them was observed by this indicator.

Currently, at the level of the trend, the September 10–21 group of ewes prevailed over the 28 August to 9 September group in terms of average milk yield by 0.7 kg or 2.8%. However, ewes that had ewe lambs among their offspring also prevailed by 3.1 kg or 13.6%, single-born by 0.89 kg or 3.1%, twins by 0.89 kg or 3.1% by 4.3 kg or 21.6%, and those individuals that gave birth to rams, on the contrary, had a different character of milk production, in terms of which they were inferior – by 2.4 kg or 8.3%. Changes in growth parameters of lambs in the early postnatal ontogeny demonstrate their relationship with age, are determined by gender and fluctuate depending on the timing of insemination of their mothers (Table 6).

A common feature for both rams and ewe lambs born from mothers inseminated in the periods from August 15 to August 27 and from August 28 to September 9 is a significant increase in live weight at the age of 60 days by 19.6% ($P < 0.01$) and 20.3% ($P < 0.01$) and by 7.7% and 8.0% against peers whose mothers were inseminated at the end of the mating season, but at the age of 90 days, the most noticeable advantage according to this indicator was observed in the young obtained from mothers that were inseminated between August 15 and August 27, where the difference with the rest of the groups was 20.1% ($P < 0.01$) and 26.8% ($P < 0.01$) among rams and 19.1% ($P < 0.01$) and 18.8% ($P < 0.01$) among the ewe lambs. Despite that, the offspring obtained from all ewes did not differ significantly in terms of live weight at birth.

Dominance in terms of live weight of the young born from mothers inseminated in the periods from August 15 to August 27 and from August 28 to September 9 was also confirmed by the indicators of their growth intensity, according to which they reliably surpassed at the age of 60 days their peers from the mothers which were used in reproduction at the end of the mating season by 39.7 ($P < 0.01$) and 63.7% ($P < 0.01$) and by 14.7% ($P < 0.05$) and 44.8% ($P < 0.01$). With increasing age of the young, this advantage decreased and amounted to 42.9% ($P < 0.01$) and 22.3% in rams and 54.9 and 42.9% ($P < 0.01$ in both cases of comparison) in ewe lambs (Table 7).

Table 6
Dynamics of live weight of young animals from birth to weaning depending on the date of insemination of their mothers (kg, x ± SE)

Parameter	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
Live weight of the total population of lambs at birth, kg	3.70 ± 0.04^a	3.78 ± 0.09^a	3.61 ± 0.04^a
n	163	55	185
including: rams	3.90 ± 0.06^a	4.03 ± 0.16^a	3.77 ± 0.06^a
n	80	22	102
ewe lambs	3.51 ± 0.06^a	3.60 ± 0.12^a	3.44 ± 0.05^a
n	83	33	83
Live weight of the total population of lambs at the age of 60 days, kg	17.94 ± 0.31^a	17.87 ± 0.63^a	15.79 ± 0.32^b
n	146	45	157
including: rams	18.91 ± 0.47^a	19.00 ± 0.94^a	15.80 ± 0.46^b
n	70	20	85
ewe lambs	17.01 ± 0.38^a	17.06 ± 0.83^a	15.79 ± 0.45^a
n	76	25	72
Live weight of the total population of lambs at the age of 90 days, kg	25.46 ± 0.43^a	21.15 ± 0.95^b	20.77 ± 0.40^b
n	146	45	157
including: rams	26.81 ± 0.65^a	22.33 ± 1.58^b	21.14 ± 0.60^b
n	70	20	85
ewe lambs	24.18 ± 0.54^a	20.31 ± 1.18^b	20.35 ± 0.52^b
n	76	25	72

Table 7
Intensity of growth of young animals depending on the period of insemination of their mothers (g, x ± SE)

Parameter	The period of insemination of ewes		
	15.08–27.08	28.08–9.09	10.09–21.09
The total number of lambs, head	146	45	157
including: rams	70	20	85
ewe lambs	76	25	72
Average daily growth of the total number of lambs at the age of 60 days, g	235.2 ± 6.3^a	284.8 ± 12.7^b	185.5 ± 5.3^c
including: rams	250.7 ± 9.2^a	293.9 ± 21.6^a	179.5 ± 8.5^b
ewe lambs	220.4 ± 8.4^a	278.4 ± 15.6^b	192.2 ± 6.0^c
Average daily growth of the total number of lambs at the age of 90 days, g	251.8 ± 6.5^a	223.2 ± 11.5^a	170.8 ± 6.1^b
including: rams	265.1 ± 10.3^a	226.9 ± 16.3^{ab}	185.5 ± 9.1^b
ewe lambs	239.2 ± 7.9^a	220.7 ± 16.2^a	154.4 ± 7.6^b

Table 8
Seasonal changes in the clinical indicators of the young animals' bodies (x ± SE, n = 5)

Parameter	Season of the year	Time of day, hours	Outdoor air temperature during observations, ºC	The period of insemination of ewes		
				15.08–27.08	28.08–9.09	10.09–21.09
Body temperature, ºC	winter	8	+2…0	38.2 ± 0.07^a	38.1 ± 0.05^a	37.1 ± 0.14^b
		12	+3…+7	39.4 ± 0.09^a	39.1 ± 0.12^a	38.4 ± 0.20^b
		16	+5…+6	38.2 ± 0.07^a	38.5 ± 0.10^a	38.0 ± 0.05^b
		21	+4…+2	39.4 ± 0.18^a	38.7 ± 0.24^a	39.1 ± 0.34^a
	summer	8	+13…+15	38.9 ± 0.14^a	38.2 ± 0.56^{ab}	37.5 ± 0.16^b
		12	+26…+27	40.6 ± 0.10^a	39.4 ± 0.16^b	38.9 ± 0.25^b
		16	+21…+24	39.8 ± 0.15^a	39.1 ± 0.21^a	38.6 ± 0.12^a
		21	+18…+20	$39.2 \pm 0{,}67^a$	40.4 ± 0.23^a	39.0 ± 0.22^a
Breath rate, breaths/min	winter	8	+2…0	26.2 ± 1.07^a	24.8 ± 1.07^a	22.2 ± 1.32^a
		12	+3…+7	30.4 ± 1.29^a	29.4 ± 1.08^a	27.2 ± 1.85^a
		16	+5…+6	28.0 ± 0.89^a	26.1 ± 0.89^a	24.6 ± 0.98^a
		21	+4…+2	27.4 ± 0.87^a	25.4 ± 0.98^{ab}	22.4 ± 1.25^b
	summer	8	+13…+15	34.4 ± 1.44^a	32.8 ± 0.86^a	30.6 ± 2.29^a
		12	+26…+27	38.0 ± 0.45^a	36.4 ± 0.51^a	34.8 ± 1.39^a
		16	+21…+24	35.6 ± 0.87^a	34.0 ± 0.71^a	33.4 ± 1.03^a
		21	+18…+20	35.2 ± 1.16^a	33.2 ± 0.58^a	31.6 ± 1.81^a
Pulse rate, beats/min	winter	8	+2…0	61.2 ± 0.37^a	60.2 ± 1.02^a	58.0 ± 1.97^a
		12	+3…+7	64.4 ± 1.44^a	63.6 ± 1.33^a	61.4 ± 0.93^a
		16	+5…+6	63.4 ± 1.17^a	62.0 ± 0.71^a	60.2 ± 1.74^a
		21	+4…+2	62.8 ± 0.92^a	61.0 ± 0.89^a	59.9 ± 1.14^a
	summer	8	+13…+15	67.8 ± 1.07^a	65.8 ± 1.36^a	63.6 ± 1.50^a
		12	+26…+27	73.0 ± 1.14^a	72.6 ± 2.36^a	69.8 ± 1.02^a
		16	+21…+24	$70.8 \pm 0{,}80^a$	69.4 ± 1.96^a	68.2 ± 2.50^a
		21	+18…+20	69.4 ± 0.93^a	67.4 ± 0.75^{ab}	64.4 ± 1.50^b

During the lambing season in February, the outdoor temperature at noon ranged between +5 to +6 ºC, with fluctuations throughout the day from 0 to +7 ºC. However, when the lambs were weaned from their mothers in June, the temperature increased naturally from +26 to +27 ºC, with fluctuations ranging from +13 to +27 ºC throughout the day. The temperature inside the sheepfold was affected by the temperature outside. In winter, the temperature inside the sheepfold was between +9 and +12 ºC, while in summer it was between +17 and +21 ºC. The temperature inside the sheepfold experienced the most significant changes during the winter due to the mechanized distribution of food and the addition of fresh straw to the sakmans (ewes with suckling lambs of the same age). However, these changes did not exceed the sanitary and hygienic requirements for keeping ewes and young lambs during lambing (Table 8).

The young animals' bodies responded to seasonal changes in climate by slightly adjusting their clinical indicators. These changes remained within the normal range due to their thermoregulation mechanisms working properly. During winter, lambs experienced a decrease in their respiratory and heart rate, while in the summer, they showed an increase of 7.7–8.5 breaths and 6.6–7.3 beats per minute, respectively. This testifies to the dependence of the studied parameters on the air temperature in these periods of the year, both directly inside the room for animal keeping and outside it. It appears that young animals born from mothers inseminated between September 10 and 21 had minimal clinical indicators, likely due to stress on their physiological functions, which caused them to use feed nutrients inefficiently. As a result, the accumulation of live mass was slowed during the period of suckling growth. Specifically, their respiratory rate was slightly lower, with a decrease of 3.9 and 2.3 breaths per minute in winter and 3.2 and 1.5 per minute in summer.

The heartbeat rate was more noticeable than breathing, with an average difference of 3.1 and 1.8 beats lower in winter and 3.8 and 2.3 beats per minute in summer. Young individuals whose mothers were inseminated between August 15–27 and August 28 – September 9 had the most stable body temperature, with no significant differences or daily fluctuations observed. However, during the summer, body temperature increased by 0.4–0.8 ºC compared to winter. Young individuals whose mothers were inseminated between September 10–21 differed from those inseminated between August 15–27 and August 28 September 9 in both winter and summer, with a significant increase in body temperature from morning to 4 p.m. ($P < 0.01–0.05$). This indicates a certain dependence on metabolic processes in their body.

Young animals in both winter and summer showed disruptions in their pulse rhythm during peak temperature stress at noon. This resulted in an increase of 3.2–6.8 beats per minute compared to 8 am. However, in the evening at 9 pm, there was a slight slowdown of 1.5–5.4 beats per minute relative to noon. The number of respiratory movements per minute in young animals increased by 3.6–5.0 breaths from morning to noon, but decreased by 2.8–4.8 breaths in the evening, the values return to their initial state, even though they are statistically unreliable.

Discussion

A key link in the selective improvement of domestic breeds and intrabred types of sheep is the improvement of their body's ability to adapt to climatic conditions, which affects the reproductive capacity in different ways. Each breed has genetic information about the area of breeding and, accordingly, possesses features which are adaptive in a certain way to changes in environmental conditions, finding additional reserves to overcome the adaptation load along with the ability to realize the existing genetic productivity potential.

The air temperature and humidity are essential ecological factors for the survival of living organisms, including sheep. According to the official records from the Kharkiv Regional Center of Hydrometeorology for 1986–1995 and 2010–2021, the average annual outside air temperature had risen by 1.2 ºC or 14.3%, and the average annual precipitation had decreased by 45.4 mm or 8.1%. Based on the data, it can be concluded that the climate is noticeably warming, as highlighted in the report (IPCC, 2007). During the day, experimental ewes had the lowest readings for heart rate, number of respiratory movements, and body temperature in the morning, with the highest values at noon. From 4 pm until evening, the values moderately decreased. The lowest clinical indicators were observed during the insemination of ewes from August 15 to August 27, with an average daily ambient temperature of +27.8 ºC. The highest readings were recorded during the insemination period from August 28 to September 9, with an air temperature of +28.7 ºC. The values for these indicators were intermediate during the insemination period from September 10 to September 21, with an average air temperature of 21.9 ºC.

The conducted studies detailed the peculiarities of the multidirectional effects of the outdoor air temperature on the reproductive capacity of ewes that were inseminated at different times during mating season, the growth and adaptive characteristics of the offspring obtained from them, which is consistent with the data of Santolaria et al. (2014), Abecia et al. (2016) and Van Wettere et al. (2021). It was found that ewes who were inseminated during the hottest period of the mating season, from August 28 to September 9, showed an increase in body temperature, pulse, and breathing rates during mating and lambing. Additionally, there were two stillborn lambs and one case of abortion. The rate of lamb survival until weaning was also lower, by 7.8% and 3.1%, respectively, including decrease in survival rates for ewe lambs, at 15.8% and 10.9% compared to the beginning and end of the insemination period. A study conducted by Kovačić et al. in 2023 came to a similar conclusion. Ewes that were inseminated between September 10th and September 21st had a higher yield of lambs per 100 individuals that gave birth, compared to those inseminated at the beginning and middle of the mating season, with a difference of 7.5% and 15.4% respectively. However, inseminating ewes between August 15th and August 27th, or August 28th to September 9th, led to a decrease in milk yield, likely due to the impact of outside temperatures on their bodies. This coincides with data from Sevi & Caroprese (2012).

Being raised under similar conditions of maintenance and feeding, the young animals of all groups showed a different ability increase live weight. It was established that young lambs born from ewes that were inseminated from August 15 to August 27 demonstrated a greater ability to increase their live weight. This enabled them during almost the entire period of rearing until weaning to have a higher intensity of growth and to achieve a higher live weight at the age of 90 days by 20.1% ($P < 0.01$) and 26.8% ($P < 0.01$) for rams and by 19.1% ($P < 0.01$) and 18.8% ($P < 0.01$) for ewe lambs whose mothers were inseminated in the middle and at the end of the mating season. The dependence of the live weight of young animals on the periods of the mating campaign is emphasized in the work (Martínez-Paredes et al., 2018; Wallace et al., 2021). The higher intensity of growth of young animals born from mothers inseminated at the beginning and in the middle of the mating season was consistent with fluctuations in clinical indicators, but they did not have reliable intergroup and seasonal differences and were within the physiological norm.

Thus, the performed work does not address the heart of the question, but within the framework of its initial implementation, for targeted management of the lambing process farm specialists should take into account not only the timing of insemination of ewes but also the temperature during its implementation, the established regularities of the formation of productivity and changes in clinical indicators of young lambs as indicators in the system of monitoring their state of health and assessment of adaptive capacity.

Conclusion

The peculiarities of the formation of reproductive capacity parameters in ewes under the influence of the temperature factor have been detected: insemination in the period from September 10 to 21 was characterized by a more pronounced effect on improving the yield of lambs per 100 ewes, which increased by 7.5% and 15.4%, while when inseminated in the period from August 28 to September 9, ewes had the lowest adaptive capacity, which led to an increase in the daily fluctuations of body temperature, pulse and breathing rates, the presence of stillborn lambs among the offspring, cases of abortion, and a decrease in the level of preservation of the young animals before weaning by 7.8% and 3.1% in relation to the initial and final phases of the insemination period.

A multidirectional course of metabolic processes in lambs has been detected, depending on the timing of insemination of the mothers and the adaptation capabilities of the organism. The use in reproduction of ewes inseminated in the period from August 28 to September 9 is characterized by the most noticeable increase in the live weight of lambs at the age of 90 days, reaching 26.81 and 24.18 kg, respectively, which is 20.1% ($P < 0.01$) and 26.8% ($P < 0.01$) higher compared to rams and 19.1% ($P < 0.01$) and 18.8% ($P < 0.01$) compared to ewe lambs whose mothers were inseminated in the middle and at the end of the mating season.

Young animals obtained from mothers that were inseminated between September 10 and 21 were characterized by minimal clinical indicators, probably due to the stress of the body's physiological functions, which led to their less efficient use of feed nutrients , and, as a result, a slowdown in the accumulation of live mass during the suckling period, but their values were within the physiological norm.

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References

Abebe, B., & Alemayehu, M. (2021). Challenges and opportunities on estrus synchronization and mass artificial insemination in dairy cows for smallholders in Ethiopia. International Journal of Zoology, 2021, 9914095.

Abecia, J. A., Arrébola, F., Macías, A., Laviña, A., González-Casquet, O., Benítez, F., & Palacios, C. (2016). Temperature and rainfall are related to fertility rate after spring artificial insemination in small ruminants. International Journal of Biometeorology, 60(10), 1603–1609.

Arrébola, F., Sánchez, M., López, M. D., Rodríguez, M., Pardo, B., Palacios, C., & Abecia, J. A. (2016). Effects of weather and management factors on fertility after artificial insemination in Florida goats: A ten-year study. Small Ruminant Research, 137, 47–52.

Dixit, S. P., Dhillon, J. S., & Singh, G. (2001). Genetic and non-genetic parameter estimates for growth traits of Bharat Merino lambs. Small Ruminant Research, 42(2), 101–104.

Dixon, A. B., Knights, M., Winkler, J. L., Marsh, D. J., Pate, J. L., Wilson, M. E., & Inskeep, E. K. (2007). Patterns of late embryonic and fetal mortality and association with several factors in sheep. Journal of Animal Science, 85(5), 1274–1284.

Gharibzadeh, Z., Riasi, A., Ostadhosseini, S., Hosseini, S. M., Hajian, M., & Nasr-Esfahani, M. H. (2015). Effects of heat shock during the early stage of oocyte maturation on the meiotic progression, subsequent embryonic development and gene expression in ovine. Zygote, 23(4), 573–582.

Gibbons, A. E., Fernandez, J., Bruno-Galarraga, M. M., Spinelli, M. V., & Cueto, M. I. (2019). Technical recommendations for artificial insemination in sheep. Animal Reproduction, 16(4), 803–809.

Hansen, P. J. (2009). Effects of heat stress on mammalian reproduction. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1534), 3341–3350.

Hashem, N. M., Elzarkouny, S. Z., Taha, T. F., & Abo-Elezz, Z. R. (2015). Oestrous response and characterization of the ovulatory wave following oestrous synchronization using PGF2α alone or combined with GnRH in ewes. Small Ruminant Research, 129, 84–87.

Joy, A., Dunshea, F. R., Leury, B. J., Clarke, I. J., DiGiacomo, K., & Chauhan, S. S. (2020). Resilience of small ruminants to climate change and increased environmental temperature: A review. Animals, 10(5), 867.

Kovačić, M., Đuričić, D., Sudarić Bogojević, M., Krčmar, S., Dobos, A., & Samardžija, M. (2023). Infuence of climatic elements on the reproductive traits of Romanov sheep in the Bilogora region, Croatia. Veterinarska Stanica, 54(4), 375–381.

Magawana, M., Dugmore, T. J., de Villiers, J. F., & Gcumisa, S. T. (2021). Effect of lambing season, year, sex and birth status on weaning and post-weaning growth performance of Merino lambs. Applied Animal Husbandry and Rural Development, 14(1), 61–68.

Marai, I. F. M., El-Darawany, A. A., Fadiel, A., & Abdel-Hafez, M. A. M. (2007). Physiological traits as affected by heat stress in sheep – A review. Small Ruminant Research, 71(1–3), 1–12.

Martínez-Paredes, E., Ródenas, L., Pascual, J. J., & Savietto, D. (2018). Early development and reproductive lifespan of rabbit females: Implications of growth rate, rearing diet and body condition at first mating. Animal, 12(11), 2347–2355.

Notter, D. R., Borg, R. C., & Kuehn, L. A. (2005). Adjustment of lamb birth and weaning weights for continuous effects of ewe age. Animal Science, 80(3), 241–248.

Ozawa, M., Tabayashi, D., Latief, T. A., Shimizu, T., Oshima, I., & Kanai, Y. (2005). Alterations in follicular dynamics and steroidogenic abilities induced by heat stress during follicular recruitment in goats. Reproduction, 129(5), 621–630.

Putri, C. D., Ismudiono, & Poetranto, E. D. (2021). The effect of the different artificial insemination time periods on the pregnancy rate of Sapudi ewes. World's Veterinary Journal, 11(3), 469–473.

Rizal, M., Peternakan, J., & Pertanian, F. (2006). Fertility of frozen thawed semen from ejaculation and frozen-thawed spermatozoa from cauda epididymis of garut rams. Jurnal Sain Veteriner, 24(1), 49–57.

Santolaria, P., Yániz, J., Fantova, E., Vicente-Fiel, S., & Palacín, I. (2014). Climate factors affecting fertility after cervical insemination during the first months of the breeding season in Rasa Aragonesa ewes. International Journal of Biometeorology, 58(7), 1651–1655.

Sevi, A., & Caroprese, M. (2012). Impact of heat stress on milk production, immunity and udder health in sheep: A critical review. Small Ruminant Research, 107(1), 1–7.

Shakhova, Y. Y., Paliy, A. P., Paliy, A. P., Shkromada, O. I., Musiienko, Y. V., & Bondarenko, I. V. (2021). Influence of ways to thaw bull sperm on its quality. Problems of Cryobiology and Cryomedicine, 31(3), 277–282.

Simmonds, R. C. (2017). Chapter 4. Bioethics and animal use in programs of research, teaching, and testing. In: Weichbrod, R. H., Thompson, G. A. H., Norton, J. N. (Eds.). Management of animal care and use programs in research, education, and testing. Second edition. CRC Press, Taylor & Francis, Boca Raton. Pp. 1–28.

Solomon, S., Qin, D., Mannin, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., & Miller, H. L. (2007). Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Spencer, T. E., Johnson, G. A., Bazer, F. W., & Burghardt, R. C. (2004). Implantation mechanisms: Insights from the sheep. Reproduction, 128(6), 657–668.

Susic, V., Pavic, V., Mioc, B., Stokovic, I., & Ekert Kabalin, A. (2005). Seasonal variations in lamb birth weight and mortality. Veterinary Archives, 75(5), 375–381.

Tekin, N., Uysal, O., Akcay, O., & Yavaş, İ. (2006). Effects of different taurine doses and freezing rate on freezing of ram semen. Ankara Universitesi Veteriner Fakultesi Dergisi, 53, 179–184.

Van Wettere, W. H. E. J., Kind, K. L., Gatford, K. L., Swinbourne, A. M., Leu, S. T., Hayman, P. T., & Walker, S. K. (2021). Review of the impact of heat stress on reproductive performance of sheep. Journal of Animal Science and Biotechnology, 12, 26.

Wallace, J. M., Shepherd, P. O., Milne, J. S., & Aitken, R. P. (2021). Perinatal complications and maximising lamb survival in an adolescent paradigm characterised by premature delivery and low birthweight. PLoS One, 16(11), e0259890.

Yilmaz, O., Denk, H., & Bayram, D. (2007). Effects of lambing season, sex and birth type on growth performance in Norduz lambs. Small Ruminant Research, 68(3), 336–339.

Zapasnikiene, B. (2002). The effect of age of ewes and lambing season on litter size and weight of lambs. Veterinarija ir Zootechnika, 19(41), 112–115.