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Seasonal Distribution of Births in Anatolian Buffaloes and Effects of the Season on Some Milk and Reproductive Traits of Cows and Growth Traits of Calves

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ABSTRACT

The aims of this study were i) to evaluate the seasonal changes in births of Anatolian buffaloes, ii) to examine the changes of some milk [lactation milk yield (LMY) and lactation length (LL)] and fertility [first calving age (FCA) and calving interval (CI)] according to seasons and iii) to investigate the effects of seasons on the growth traits of calves [birth weight (BW_0), live weight at 6 mo (LW_6) and live weight at 12 mo (LW_{12})]. A total of 8614 to 15605 yield records were evaluated including milk yield and fertility traits of buffalo cows and growth traits of calves between 2012 and 2023. The mean temperature, relative humidity, the duration of sunshine, and temperature humidity index (THI) values were calculated for these years. While the highest birth rate was observed in the summer season (34.27%), the lowest birth rate was determined in the winter season (11.99%). The BW_0, LW_6 and LW_{12}, LMY, LL, FCA, and CI values of the calves were determined as 30.8±0.04 kg, 107.6±0.23 kg, 172.6±0.27 kg, 994.7±2.05 kg, 262.6±0.22 d 1175.5±3.46 d and 561.7±1.84 d, respectively. Except for CI, all characteristics were significantly affected by seasonal changes ($P<0.001$). The growth traits of the calves born in autumn were higher than the other seasons. The LMY values in spring and winter were higher than those determined in the different seasons. Also, the highest FCA was obtained in heifers born in the winter. It was concluded that the season could affect both some fertility and milk yield characteristics of buffalo cows and the growth performance of calves.

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Introduction

Buffalo breeding is a livestock activity with very old history and stands out with its traditional features. Today, buffalo has mostly been raised in the Asian continent and has also been raised on a significant scale in some European, African, and South American countries (Minervino et al., 2020). Buffaloes, which are spread over a wide geography in the world, consist of different breeds that are distinguished from each other by different adaptation and productivity aspects according to the countries in which they are located. It has long been known that these breeds are significantly affected by the climate and geography of the countries or continents where they are located.

The climate characteristics of the regions have different effects on the ecosystem and vegetation, and depending on this situation, different feeding conditions and productivity levels can be observed (Marai and Haeeb, 2010a). Although there are a total of 123 buffalo breeds in the world today, three breeds (Murrah, Nili-Ravi, and Mediterranean Buffaloes) are widely raised due to their high milk yields (Petrocchi Jasinski et al., 2023).

The Anatolian buffalo is a milk and meat-producing breed that is raised in Türkiye and is included in the Mediterranean buffalo group. Anatolian buffalo raised in different regions of Türkiye are mostly raised in the provinces of Samsun, Diyarbakır, and Istanbul. Seasonal differences and vegetative changes in pasture resources observed in the regions where this breed has been raised may cause the differences in production. This may cause births as well as reproductive traits in buffaloes to change according to seasonal conditions (Şahin et al., 2013; Ermetin, 2017).

It has long been known that climatic factors have an important influence on the regulation of reproductive traits in farm animals. Environmental stress factors such as changes in day length or increased temperature cause reproductive organ growth or functional decline in many animal species (Vale, 2007). While Vale, (2007) emphasizes that buffaloes are a non-seasonal polyestrous species, many authors report that buffaloes have a seasonal breeding characteristic (Singh et al., 2000; Hassan et al., 2007; Presicce, 2007; Mondal et al., 2008; Vijayakumar et al., 2011; Hozyen et al., 2016; Phogat et al., 2016; Petrocchi Jasinski et al., 2023). It has been pointed out that this feature is closely associated with ambient temperature, photoperiod, and feeding conditions (Phogat et al., 2016; Petrocchi Jasinski et al., 2023), and hormonal control of estrus is suggested by Singh et al. (2000) to eliminate the adverse cases. Photoperiod effects (duration and intensity of light) impacts pineal gland activity (Das and Khan, 2010; Kushwaha et al., 2011) and melatonin secretion (Chandra Prasad et al., 2014). This effect can alter the estrous cycle and estrous intensity in buffaloes in many countries (Chandra Prasad et al., 2014; Verma et al., 2021), except in regions close to the equator where photoperiod remains almost similar throughout the year (Vale, 2007; Verma et al., 2021). Petrocchi Jasinski et al. (2023) reported that temperature increases by regional conditions also causes the decline in milk yield, composition, and reproductive functions in buffaloes. Several authors reported that the thermo-neutral zone of buffaloes is 13.0 – 18.0 ˚C, with relative humidity between 55% and 60% (Marai and Haeeb, 2010b; Napolitano et al., 2023a). When the body temperature of buffaloes exceeds the normal values of 37.5 ˚C to 39 ˚C, they show a number of physiological and behavioral reactions to return these values to normal and maintain their health and productivity (Napolitano et al., 2023b).

There are some studies on the effects of seasonal changes on the reproductive traits (Tekerli et al., 2001; Koçak et al., 2019; Akyol, 2023) and milk yield traits of buffaloes (Akyol, 2023; Kul et al., 2016; Soysal et al., 2018), as well as the growth traits of calves (Alkoyak and Öz, 2022). In a study on Purnathadi buffaloes, Thokal et al. (2004) reported that calving during the rainy season (June to September) was higher than calving during winter (December to January) and summer (February to May). While the effect of seasonal changes on calving interval (CI) was found to be insignificant in a study conducted on buffaloes (Soysal et al., 2018), some studies also reported that this reproductive trait was affected by seasonal changes (Tekerli et al., 2001; Koçak et al., 2019; Alkoyak and Öz, 2020; Akyol, 2023; Alkoyak et al., 2023). Several authors reported that first calving age (FCA) in buffaloes varies due to seasonal effects (Akyol, 2023; Penchev et al., 2014). Similarly, a large number of authors emphasized that the milk yield traits [lactation milk yield (LMY) and lactation length (LL)] of Anatolian buffaloes change due to the temperature stress created by seasonal differences in the breeding regions and the changes in feeding adequacy, especially in pasture conditions (Kul et al., 2016; Koçak et al., 2016; Soysal et al., 2018; Alkoyak and Öz, 2020; Akyol, 2023). In a study conducted on Anatolian buffaloes (Alkoyak and Öz, 2022), it was determined that the growth traits [birth weight (BW_0), live weight at 6 months (LW_6), and live weight at 12 months (LW_{12})] of buffalo calves were affected by the calving season.

To our knowledge, there are several studies on the effects of calving season on milk yield and fertility traits of buffalo cows as well as growth traits of calves. However, studies those evaluating climatic changes according to seasons are limited. Therefore, the results obtained from this study will offer significant contributions to filling the gap in this field. Our hypothesis was that calving season affects i) CI and FCA values of buffaloes cows, ii) LMY and LL values of buffalo cows, and iii) BW_0, LW_6, and LW_{12} values of calves. The aims of this study were i) to evaluate the seasonal changes in births of Anatolian buffaloes, ii) to examine the changes in some milk (LMY and LL) and fertility traits (FCA and CI) according to seasons, and iii) to investigate the effects of seasons on the growth traits (BW_0, LW_6, and LW_{12}) of calves.

Material and Method

This study was conducted in Samsun province, located in the Black Sea region of Türkiye. The Samsun province is located at 40° 50′-41° 51′ N, 37° 08′-34° 25′ E, and generally has a mild climate. However, the climate in the coastal and inland areas shows different characteristics. On the coast (Central district, Terme, Çarşamba, Bafra, Alaçam, 19 Mayıs, Tekkeköy, and Yakakent), the effects of the Black Sea climate are observed. Summers are hot and humid, and winters are warm and rainy on the coastline. Mean values of some climate indicators between the years 2012-2023, when the data were collected, are presented in Tables 1 and 2. The climatic indicators in the study were calculated from the data of the General Directorate of Meteorology.

The Community Based Animal Breeding Project that started in Samsun in 2011, is still proceeding. Within the scope of the relevant project, records are kept by breeders and the technical staff of the Buffalo Breeders Association in the province. There are a total of 93 farms and 3300 buffaloes in the project (in 5 districts; Bafra, 19 Mayıs, Çarşamba, Vezirköprü, and Ladik), and the calves born from these animals are used in herd renewal. Although pasture resources are mainly used in feeding of the animals, additional feeding, including silage, straw, and concentrate is offered due to the winter season and insufficient pasture.

All data on buffalo cows and their calves are recorded in the database called "Manda Yıldızi". Buffalo cows are milked once a day in the morning. Milking process is maintained with portable machines on most farms, but in small-scale farms, this procedure is performed manually. A total of 8614 to 15605 yield records obtained between 2012 and 2023 were evaluated.

The BW_0, LW_6, and LW_{12} values of the calves and the lactation and birth information of the buffalo cows were recorded in the program called "Manda Yildizi". The data were evaluated in the Excel program with permission from the General Directorate of Agricultural Research and Policies of the Turkish Ministry of Agriculture and Forestry.

Groups were formed by determining the year and season (Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, and November) according to their calving information. Seasonal calving rates (%) were determined by dividing the calving number in each season by the total calving number for that year. The total calving number for the years 2012-2023 was also divided into seasons, and proportional distributions were determined.

Table 1. Temperature and relative humidity values in the study region according to years and seasons*

Years	Temperature means (°C)					Relative humidity means (%)				
	Winter	Spring	Summer	Autumn	Means	Winter	Spring	Summer	Autumn	Means
2012	7.1	12.2	23.7	18.5	15.4	65.6	74.4	68.4	70.3	69.7
2013	8.7	13.8	23.3	16.3	15.5	61.3	71.3	66.6	64.7	66.0
2014	10.1	13.1	23.9	17.0	16.0	66.0	74.1	66.4	68.8	68.8
2015	8.3	11.8	23.5	18.4	15.5	62.1	72.5	66.9	66.4	67.0
2016	8.2	13.6	24.2	16.6	15.7	61.5	70.4	67.1	63.2	65.6
2017	8.6	11.6	23.5	17.3	15.3	57.8	73.5	67.1	62.2	65.2
2018	9.6	14.1	24.6	17.9	16.6	67.2	72.9	64.5	68.5	68.3
2019	9.6	12.5	23.9	18.3	16.1	64.2	73.2	73.6	73.0	71.0
2020	9.7	12.5	23.7	18.7	16.2	67.9	77.5	72.4	73.9	72.9
2021	10.4	11.9	23.7	16.6	15.6	61.7	78.4	76.3	72.2	72.2
2022	9.4	11.2	23.7	17.8	15.5	66.0	72.3	72.8	70.5	70.4
2023	10.3	12.4	23.7	18.8	16.3	63.8	81.1	72.7	69.3	71.8
Means	9.2	12.6	23.8	17.7	15.8	63.8	74.3	69.6	68.6	69.1

* Calculated from the data of the General Directorate of Meteorology, Türkiye

Table 2. THI and means of monthly sunshine duration in the study region according to years and seasons*

Years	THI					Monthly means of sunshine duration (h)				
	Winter	Spring	Summer	Autumn	Means	Winter	Spring	Summer	Autumn	Means
2012	47.3	54.5	71.7	64.1	59.4	86.4	160.8	268.2	161.0	169.1
2013	49.9	57.0	71.0	60.7	59.5	93.1	172.4	279.7	162.2	176.8
2014	51.6	55.9	71.8	61.8	60.3	94,6	173,8	274,2	158,5	174,9
2015	49.3	54.0	71.3	63.8	59.5	99.8	155.6	236.4	145.7	159.4
2016	49.1	56.7	72.3	61.1	59.8	73.9	174.0	257.1	155.1	165.0
2017	49.9	53.6	71.3	62.0	59.2	112.4	161.4	248.5	173.6	174.0
2018	50.9	57.5	72.7	63.1	61.2	61.8	187.4	304.9	137.7	173.0
2019	51.0	55.0	72.5	63.9	60.5	105.9	191.2	276.8	184.2	189.5
2020	51.0	54.9	72.1	64.5	60.7	92.2	199.8	303.0	174.3	192.3
2021	52.3	54.0	72.5	61.3	59.7	125.9	184.2	275.2	135.2	180.1
2022	50.6	53.0	72.1	63.0	59.6	94.2	183.0	262.1	145.0	171.1
2023	52.0	54.7	72.1	64.5	60.8	98.4	126.6	288.5	162.3	168.9
Means	50.4	55.1	72.0	62.8	60.0	94.9	172.4	272.8	157.8	174.5

* Calculated from the data of the General Directorate of Meteorology; Temperature Humidity Index (THI), Türkiye

Temperature Humidity Index (THI) is a unitless index that includes the effects of ambient temperature and relative humidity. This index is widely used to indicate heat stress in dairy cattle (Jeelani et al., 2019). Using temperature (°C) and humidity (%) values from meteorological data, THI was calculated separately for each year and for each season in the same year with the help of the following formula (Kalyan et al., 2022; Yadav et al., 2022; Aatralarasi et al., 2024).

$$THI=(0.8\times Tdb)+[(RH/100)\times(Tdb-14.4)]+46.4 \quad (1)$$

Where;

THI is Temperature Humidity Index (THI)

Tdb is air temperature in a dry-bulb thermometer (°C)

RH is the air relative humidity (%)

The data consists of LMY and LL values of cows calving between 2012 and 2023, as well as BW_0, LW_6, and LW_{12} values of calves. Moreover, the birth dates of cows calving between these years were also recorded. FCA and CI values were calculated from these data. The following formulas were used in these calculations:

FCA(mo)=Cow's first calving date-Cow's birth date (2)

CI (d) = Last calving date - Previous calving date (3)

Statistical Analysis

To investigate the effect of calving season on growth traits (BW_0, LW_6, and LW_{12}) of calves as well as lactation traits (LMY and LL) and reproductive traits (FCA and CI) of cows, variance analysis (General Linear Model) was performed. Statistically significant differences among the means were determined according to Duncan's multiple comparison test (P<0.05).

The effect of season was evaluated with the following linear model:

$$Y_{ij}=\mu + a_i + e_{ij}$$

Where Y_{ij} = an observed value of LMY, LL, FCA, and CI in cows, BW_0, LW_6, and LW_{12} in calves; μ = the overall mean; a_i= the effect of calving season (j = Winter, Spring, Summer, Autumn); and e_{ij}= the random error. All statistical analyses were performed using the SPSS 21.0 (IBM Corp., Armonk, New York, USA) package program.

Results

The seasonal distribution of Anatolian buffaloes calving between 2012 and 2023 is presented in Figure 1. As seen, 34.27% of calving occurred in the summer season, and this rate is higher than the calving rates in other seasons. The calving rates in spring and autumn are very close to each other. The season with the least calving is winter, and 11.99% of the total calving occurred in this season.

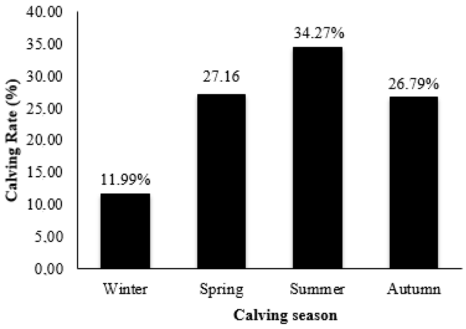

Figure 1. Seasonal distribution of calving between 2012 and 2023

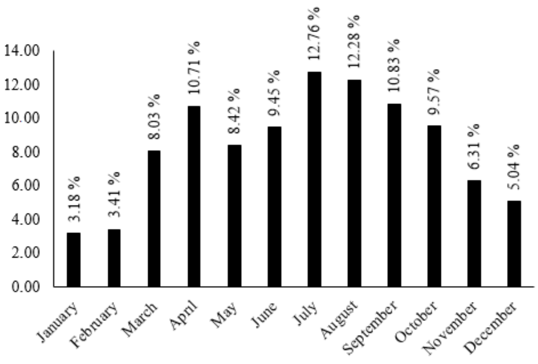

Figure 2. Caving rates by month between 2012-2023

Table 3. Distribution of seasonal calving rates by year (%)

Years	Calving Seasons				
	n	Winter	Spring	Summer	Autumn
2012	533	5.07	25.52	42.03	27.39
2013	583	10.12	32.42	38.25	19.21
2014	814	11.29	27.18	40.66	20.87
2015	1441	11.38	23.39	42.96	22.28
2016	1251	12.23	21.66	36.93	29.18
2017	1333	13.43	25.51	34.73	26.33
2018	1701	12.99	29.39	33.63	23.99
2019	1419	12.68	28.82	34.39	24.10
2020	1518	13.11	32.15	31.36	23.39
2021	1801	11.38	25.26	34.43	28.93
2022	1445	10.93	27.27	25.74	36.06
2023	1756	10.08	28.19	30.13	31.61

Table 4. Seasonal changes of live weight values of buffalo calves

Seasons	BW_0 (kg)		LW_6 (kg)		LW_{12} (kg)	
	n	$\bar{X}\pm S\bar{x}$	n	$\bar{X}\pm S\bar{x}$	n	$\bar{X}\pm S\bar{x}$
	***		***		***	
Winter	1815	31.0 ± 0.12^{b}	1440	108.4 ± 0.69^{b}	1288	175.3 ± 0.82^{b}
Spring	4238	30.1 ± 0.07^{a}	3626	104.5 ± 0.40^{a}	2945	170.8 ± 0.55^{a}
Summer	5383	30.8 ± 0.06^{b}	4844	106.6 ± 0.38^{ab}	3854	171.5 ± 0.45^{a}
Autumn	4169	31.6 ± 0.07^{c}	3289	112.1 ± 0.46^{c}	2908	174.7 ± 0.49^{b}
Mean	15605	30.8±0.04	13199	107.6±0.23	10995	172.6±0.27

$^{a-c}$Mean values in the same column with different superscripts differ (P<0.001); ***P<0.001; BW_0: Birth weight; LW_6: 6^{th} month live weight; LW_{12}: 12^{th} month live weight

Similarly, the distribution of calving rates by month in each season is shown in Figure 2. The months with the highest calving between 2012 and 2023 are July and August (12.75% and 12.28%, respectively). It has been observed that these two months are quite close to each other, and the sum of the two months corresponds to approximately ¼ of the total calving. Likewise, it was determined that calving in April and September (10.71% and 10.83%, respectively) and in June and October (9.45% and 9.57%, respectively) were quite close to each other.

As shown in Figure 1, when the distributions are examined by month in the winter season when births are the least, January and February are quite close to each other (3.18% and 3.41%, respectively), but December is slightly higher than other winter months (5.04%).

The changes in the seasonal distribution of calving from year to year are presented in Table 3. In 2012, it was observed that the calving rate in winter was quite low (5.07%) compared to the general mean (11.99%). The rate of calving in summer in 2012, 2014, and 2015 (42.03%, 40.66%, and 42.96% respectively) was found to be higher than other years and the general mean (34.27%). In 2022 and 2023, the calving rate in the autumn season (36.06% and 31.61%, respectively) was higher than in the other seasons. In 2020, the rate of calving in the spring season was found to be 32.15%, which was higher compared to the different seasons.

Seasonal means of BW_0, LW_6 and LW_{12} values of the calves and differences between groups are presented in Table 4. In the conditions of Samsun province, BW_0, LW_6, and LW_{12} means were determined as 30.8±0.04 kg, 107.6±0.23 kg and 172.6±0.27 kg, respectively. It was observed that there were seasonal differences between BW_0, LW_6 and LW_{12}, which are considered important indicators of the growth characteristics of the calf ($P < 0.001$ The highest BW_0 value was observed in those born in autumn (31.6±0.07 kg), while the lowest BW_0 value was determined in those born in spring (30.1±0.07 kg).

Table 5. Seasonal changes of milk and reproductive traits of buffalo cows

Seasons	LMY (kg)		LL (d)		FCA (d)		CI (d)	
	n	X̄±Sx	n	X̄±Sx	n	X̄±Sx	n	X̄±Sx
	***		***		***		NS	
Winter	1563	1002.6±6.12^{bc}	1561	261.3±0.72^{ab}	290	1230.7±11.09^{b}	1036	569.4±5.42
Spring	3849	1022.1±3.69^{c}	3835	266.8±0.39^{c}	778	1173.5±6.55^{a}	2371	561.2±3.53
Summer	4464	967.5±3.40^{a}	4460	261.8±0.35^{b}	989	1166.8±5.96^{a}	3010	560.2±3.11
Autumn	3294	995.9±4.28^{b}	3293	259.3±0.48^{a}	929	1169.1±6.36^{a}	2197	560.5±3.56
Mean	13170	994.7±2.05	13149	262.6±0.22	2986	1175.5±3.46	8614	561.7±1.84

*P<0.001; NS: Not significant; $^{a-c}$ Mean values in the same column with different superscripts differ (P<0.001); LMY: Lactation milk yield; LL: lactation length; FCA: first calving age; CI: calving interval

A similar distribution was observed for LW_6 and the highest value was in those born in the autumn season (112.1±0.46 kg). The lowest LW_6 value was determined in those born in spring (104.5±0.40 kg). Also, no statistical difference was observed between the LW_6 value of those born in spring and summer. While the highest LW_{12} mean value was observed in calves born in winter, the lowest LW_{12} value was determined in calves born in spring.

The LMY value examined was significantly affected by seasonal factors (P<0.001; Table 5). The mean LMY value was determined as 994.7±2.05 kg, the highest LMY value was in those born in spring and winter (1022.1±3.69 kg and 1002.6±6.12 kg, respectively). Also, the mean LMY value was the lowest in those born in summer (967.5±3.40 kg). The average value of the total 13149 calculated LL values was determined as 262.6±0.22 d. The longest LL value was observed in cows calved in spring, while the shortest period was determined in cows calved in autumn (P<0.001).

While the FCA value of buffalo cows was affected by seasonal conditions (P<0.001), the effect of the season on CI was statistically insignificant (Table 5). The average FCA of the cows was determined as 1175.5±3.46 d, and the average CI was determined as 561.7±1.84 d. The FCA (1230.7±11.09 d) value of buffalo cows born in winter was higher than those born in other seasons (P<0.001). It was observed that the FCA values of cows born in spring, summer and autumn were similar (P<0.001). Similarly, it was observed that the CI means obtained from the data of the all populations in four different seasons were quite close to each other and there was no statistical difference by birth season conditions.

Discussion

In water buffaloes, the reproductive cycle has seasonal traits, and reproductive traits associated with day length, defined as photoperiod, as well as temperature and feeding conditions (Vijayakumar et al., 2011; Hozyen et al., 2016) may show regional differences (Phogat et al., 2016; Petrocchi Jasinski et al., 2023). The results obtained in this study also support the above information. According to 12-year data analysis collected from Anatolian buffaloes, the highest birth rate was observed in the summer season (Figure 1). The increase in births in the summer season indicates that estrus also increases in the autumn season and the pregnancy rate increases in this season. Examining the results of many studies, Marai and Haeeb (2010a) and Vale (2007) reported that buffaloes tend to reproduce less in hot summer months and there is an increase in estrus signs in cooler seasons. The results obtained from the data of these studies also support our facts. Apart from the summer season, the birth rates in spring and autumn were close to each other, while the birth rate in winter was determined to be the lowest at 11.99%. These results also reveal that the reproductive characteristics of the Anatolian buffaloes show seasonal changes. Marai and Haeeb (2010a) emphasized that there is a decrease in ovarian activity in the summer season, while this activity rate increases in cooler seasons. Another author has noted that seasonal changes in photoperiod have a decisive effect on reproductive activity (Vale, 2007). In addition, Ryan et al. (2007) underlined that the highest birth rates were in January, February, and March in their study on African buffalo. Barile (2005) reported that calving in Mediterranean buffalo cows occurs mostly in July and December, with a longer calving interval for births between February and June. The author related these findings with a decrease in conception rates in the spring-summer seasons. It was also noted that this result is related to climate, especially photoperiod (melatonin secretion). Similarly, in the study conducted by Hussain (2007) on Nili-Ravi buffaloes, seasonal fluctuation in births was observed; the highest birth rate was in August (34.46%) and the lowest in April (0.14%).

As observed in similar previous studies (the above mentioned studies), buffaloes generally appear to have a seasonal reproductive characteristic. Reproductive seasons may vary by region depending on a number of reasons, such as temperature, humidity, sunshine duration (or day length) and seasonal feeding conditions. When the climate data of the region where the current study was conducted were examined, as expected, the hottest season was summer; the average temperature was 23.8°C and the relative humidity was 69.6% (Table 1). The THI value calculated from these data was 72.0 and the monthly average sunshine duration was 272.8 days in summer (Table 2). The high birth rate in summer means that estrus mostly occurs in autumn, in which temperature, relative humidity THI and monthly average sunshine duration were determined as 17.7°C, 68.8%, 62.8 and 157.8 h, respectively. It is thought that the decrease in the duration of sunbathing in particular stimulates the onset of estrus in buffaloes. Indeed, it was stated above that this effect of the season was also emphasized in previous studies. Phogat et al. (2016) reported that in buffalo, estrus signs are shorter and less obvious in hot summer months, and the months when estrus signs are seen more (59%) are between September and February. These findings seem to be consistent with the result that estrus also occurs in autumn for the higher proportion of summer births determined in this study. It was reported that the THI value at which heat stress begins in buffaloes is 68-69, and that changes in biochemical parameters in animals begin at these values (Umar et al., 2021). However, it was also stated that more significant changes in biochemical parameters are observed when the THI value is 73-76. In the distribution of births by month, it was observed that the highest birth rate was obtained in July and August (Figure 2), and in this case, it could be said that inseminations become more frequent in the autumn months. These results are partially similar to the findings of Barile (2005) and Hussain (2007), but differ from the results of Thokal et al. (2004), Ryan et al. (2007) and Kushwaha et al. (2011). It can be said that inseminations for the months of January and February, when the lowest birth rates are obtained, are in the spring season, and the estrus rates in this season are considerably reduced.

There are some changes in the seasonal distribution of birth rates for each year compared to the average of all years, and these data are given in Table 3. While the summer season had a higher rate in terms of birth rates in the years 2012-2019 and 2021, the birth rates in spring in 2021 and in autumn in 2022 and 2023 were slightly higher than other seasons. It is thought that these changes mainly depend significantly on the climatic changes seen from year to year as well as the care and feeding conditions during the pregnancy period for each birth. Although the changes in the last four years deviated from the averages of all years, it was observed that the change intervals were not too much in other years except for 2022. In 2022, autumn births were 36.06%, while the following season was spring with 27.27%. These changes are thought to be due to climatic changes and variations in animal feeding practices (or: conditions/regime). Such that, it was emphasized by Vijayakumar et al. (2011), Hozyen et al. (2016), Phogat et al. (2016) and Petrocchi Jasinski et al. (2023) that these changes are related to the feeding conditions as well as the ambient temperature and photoperiodic changes.

The growth status of calves in BW_0, LW_6 and LW_{12} phases was also evaluated. As a result of weighing 15605, 13199 and 10995 calves in these periods, respectively, the average values were determined as 30.8±0.04 kg for BW_0, 107.6±0.23 kg for LW_6 and 172.6±0.27 kg for LW_{12}. The BW_0 value was higher than the values determined for the same breed by Alkoyak and Öz (2022), Uğurlu et al. (2016), Yilmaz et al. (2017), and Kul et al. (2018), but was consistent with the values reported by Akkulak and Kul (2023) and Kaplan and Tekerli (2024). On the other hand, Genç et al. (2019), who worked on Anatolian buffaloes, found the BW_0 (34.62±0.11) value higher than the results of the current study and similar studies. Different results were obtained in similar studies for LW_6 and LW_{12} values. For example, Kaplan and Tekerli (2024), who studied the same breed, found the LW_6 value higher than the result of this study, while the LW_{12} value was lower than the result of this study. Yilmaz et al. (2017) found the LW value in both growth periods to be lower than the result of this study. In addition, the LW_6 value found by Alkoyak and Öz (2022) was higher than the current study result, but the LW_{12} values were similar. The variation among the results of studies conducted on the same breed indicates that the growth characteristics of calves can vary significantly depending on the rearing conditions.

The effect of calving season on three growth periods of calves was significant in this present study. The highest value for BW_0 was obtained in those born in autumn (31.6±0.07 kg), while the lowest value was determined in those born in spring (30.1±0.07 kg). This case largely shows that the dam benefits better from pasture conditions during pregnancy. This difference in BW_0 value continued for the following periods, and the highest value for LW_6 (112.1±0.46 kg) was obtained in those born in autumn. As for LW_{12} value, calves born in both autumn and winter had higher growth performance compared to those born in other seasons. In summary, the lowest values for all periods were determined in those born in spring. Our hypothesis was that calves were less able to benefit from pasture in spring and summer and that their nutrition was inadequate in barn conditions during the pasture period. In addition, we concluded that calves born in spring and summer may be adversely affected by hot and humid climate conditions. In a similar study, Alkoyak and Öz (2022) reached similar results for the effect of season on calf growth. Kaplan and Tekerli (2024) stated that there was no effect of season on BW_0, but LW_6 and LW_{12} values were statistically different according to seasons; the highest value was in those born in winter in both periods. Contrary to the current study, Kul et al. (2018) reported that the lowest BW_0 was in the autumn season. This effect of the season also varies regionally, the climate characteristics of each growing region and the feeding conditions created by these characteristics significantly affect the growth characteristics of the buffaloes. The season affects the milk production and feed intake of pregnant buffaloes after birth, the buffaloes' ability to give enough milk, and the conditions for the buffaloes to benefit from the pasture.

We focused specifically on some productivity traits, such as milk and reproductive traits, that are most affected by seasonal changes. It is known that these traits are largely affected by environmental factors. As seen in Table 5, the average values for LMY and LL were determined as 994.7±2.05 kg and 262.6±0.22 d respectively. The LMY value determined by Soysal et al. (2018), who worked on Anatolian buffaloes in Istanbul province, is higher than the result of this study, but the LL value is lower than the study's mean. LMY and LL values were significantly affected by seasonal conditions. The highest milk yield was in cows calving in spring and winter. Although the LMY values of cows calving in spring appeared numerically higher than those calving in winter, there was no statistically significant difference between the two seasons. In a previous study on Anatolian buffaloes (Kaplan and Tekerli 2024), the highest LMY was found in cows calving in winter and autumn. Similarly, in our study, the longest LL was determined in cows calving in spring with 266.8±0.39 d. These results could result from the positive or negative effects of seasonal differences on the nutrition of animals rather than the climatic effects of the season. By the reason of region where the study was conducted, buffaloes have generally been raised in extensive conditions and pastures. It is thought that LMY and LL were higher than other seasons due to the encouraging effect of pastures in spring and summer on milk yield of buffalo cows calving in spring and winter. It is also emphasized by many authors that milk yield changes positively due to the improvement of feeding conditions in pastures in spring and summer (Kul et al., 2016; Soysal et al., 2018; Koçak et al., 2019; Alkoyak and Öz, 2020; Akyol, 2023). The effects of seasonal differences on milk yield of buffaloes have also been reported in previous studies. Similar to our findings, Uğurlu et al. (2016) reported that LMY and LL values of cows calving in spring-winter months were higher than those calving in summer-autumn months. While Koçak et al. (2019) reported that the longest LL value was in those calving in winter, Soysal et al. (2018) determined the highest LMY value in winter and autumn, and the longest LL value in autumn. In a previous study on Egyptian buffaloes (Basant et al., 2017), it was reported that cows calving in winter had higher 305-day milk yield, similar to the current study's findings.

When the FCA and CI values were examined in the study, the FCA (mean 1175.5±3.46 d) value was affected by seasonal changes (P<0.001), but the CI (mean 561.7±1.84 d) value was not affected by this environmental factor. The FCA value of heifers born in spring was higher than the FCA value of those born in other seasons. The average FCA value for this season (winter) was determined as 1230.7±11.09 days, i.e. approximately 41 mo. Regarding this issue, it was reported that when the age of sexual maturity coincides with the seasons when estrus is less in terms of reproduction, the first pregnancy may extend until the next season, which will increase the FCA value (Verma et al., 2021). The same authors emphasized that there may be large variations in FCA in buffaloes according to countries, population rearing conditions and breeds. The authors reported that in Indian conditions, 70-80% of buffaloes conceived between July and February and less insemination was needed during this period. Therefore, it was stated that FCA value for calves born in winter months was lower than those born in summer months. On the contrary, Penchev et al. (2014) emphasized that the FCA value of those born in winter is longer. It is thought that the FCA value determined in the current study can be reduced by improving the rearing and feeding conditions.

It was concluded that seasonal changes did not affect the CI value and the mean value was 561.7±1.84 day. However, it might be expected that a buffalo cow's re-estrus and re-pregnancy after giving birth would vary due to seasonal climatic and nutritional differences. Such an effect has not been observed under current population and rearing conditions. In a previous study, the average CI value for Anatolian buffalo raised in Istanbul province conditions was determined as 417±1.73 d, which is considerably lower than the average of this study (Soysal et al., 2018). The authors reported that the season did not affect the CI value, in line with the results of this study. In contrast to the current study, Kaplan and Tekerli (2024) reported that the CI value was affected by seasonal changes, with the highest CI values reported in buffaloes calving in summer and autumn. Similarly, El-Wakeel et al. (2013) noted that the season on CI, with the highest CI values determined in spring calving. In contrast to the current study, Kaplan and Tekerli (2024) reported that the highest CI value was in buffaloes calving in summer and autumn. In a previous study, El-Wakeel et al. (2013) noted that the highest CI value was determined in buffaloes calving in spring. Koçak et al. (2019) determined the highest CI value in buffaloes calving in winter. In the current study, the determined CI value is high, and reducing this value is important for profitable production.

Conclusion

As a result, the reproductive, milk and growth characteristics of Anatolian buffaloes are affected by seasonal conditions; therefore, in planning herd management and feeding requirements, the climatic characteristics of the region and the feeding opportunities provided by these climatic conditions should be carefully examined. As determined in many breeds and different regions, the reproductive characteristics of Anatolian buffaloes also show seasonal changes, and births increase in certain seasons. In addition, milk yield and growth characteristics in buffaloes are also affected by these climatic changes. Although this situation can be partially overcome in intensive farms, it does not seem possible to eliminate climatic factors such as seasonal temperature, humidity and sunshine duration in the near future. Therefore, a selection program that can increase tolerance to seasonal factors and herd management practices that will reduce the effect of the season are needed.

Declarations

Ethical Approval Certificate

In the current study, previously collected data and records from the Samsun Province Buffalo Breeding Project carried out by the Turkish Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies, and other project stakeholders were used. Therefore, Ethics committee approval was not required for this study.

Author Contribution Statement

İ.C.O., S.A. and H.E.: Data collection, investigation, formal analysis, and. S.A. and H.E.: Conceptualization, methodology, review, and editing S.A. and İ.C.O.: Data collection and investigation

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Conflict of Interest

The authors declare no conflict of interest.

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