



Productive and reproductive performances of buffaloes in Bhola district of Bangladesh

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ARTICLE INFO

Article history:

Received: 20 August 2024

Revised: 6 September 2024

Accepted: 27 September 2024

Published: 30 September 2024

Keywords:

Livestock farming, pastoral grazing system, household farming system, milk production, milk pricing, reproductive efficiency

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ISSN: 0003-3588



ABSTRACT

This study aimed to evaluate the productive and reproductive performance of buffaloes across five sub-districts (*Burhanuddin, Lalmohan, Char Fasson, Bhola Sadar, and Tazumuddin*) in the Bhola district of Bangladesh. A face-to-face survey was conducted with 309 buffalo farmers. Daily milk yield ranged from 1.2 to 4.3 liters/cow/day, with over 90% of farmers selling to *Goalas* (local milk collectors) at BDT 87±22/liter. Lower milk prices were often reported due to pre-arranged advance loans from milkmen. Significant difference ($p < 0.05$) was observed in milk yield across lactation stages, with the highest yields (2.9–3.9 L/day/buffalo) during the first 90 days. Most farmers (82%) relied solely on grazing in the *Bathan* system, without supplemental concentrate feed. Reproductive parameters showed significant variation ($p < 0.05$) across the sub-districts, with *Lalmohan* having the lowest age at sexual maturity (2.98±0.08 years) and the shortest postpartum heat period (57.1±13.62 days). *Bhola Sadar* had the shortest calving intervals (11.92±0.43 months) and gestation periods (297.10±6.97 days). *Burhanuddin* had the lowest number of services per conception (1.46±0.50). To improve buffalo farming outcomes, it is decisive to establish local cooperatives for fair milk pricing, introduce supplemental feeding, enhance access to breeding resources, and bolster financial support, educational programs, and infrastructure.

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Introduction

Buffaloes hold a vital position within the livestock sector, particularly in tropical and subtropical

regions, where they are essential to dairy production systems (Hegde, 2019; Wanapat and Chanthakhoun, 2015). In South Asia, including Bangladesh, India, Pakistan, and Afghanistan, dairy buffaloes have historically played a crucial

How to Cite

I Jahan, N Sarker, S Alam, MK Rahman, MK Alam, MMH Khandakar, MS Bari, MR Habib, MA Islam (2024). Productive and reproductive performances of buffaloes in Bhola district of Bangladesh. *Bangladesh Journal of Animal Science* 53 (3): 111 - 120. <https://doi.org/10.3329/bjas.v53i3.76546>

role in agriculture due to their remarkable ability to convert low-quality fibrous feeds into milk and meat. This conversion efficiency, coupled with their resilience to diseases and lower management requirements, enables buffaloes to outperform cattle in productivity under challenging conditions (Hegde, 2019; Subbanna et al., 2021). Despite their significant contribution to dairy production in neighboring countries, the full potential of buffaloes in Bangladesh remains untapped. Currently, buffaloes account for only a modest portion (4-5%) of the national milk supply, insufficient to meet the growing demand for dairy products (Habib et al., 2017; Samad, 2020).

Buffalo farming in Bangladesh predominantly follows traditional, small-scale systems, where these animals are reared mainly for milk, meat, and draught power (Sarkar et al., 2013; Uddin et al., 2016). The prevailing systems are characterized by low-input, low-output approaches, often involving scavenging conditions with minimal supplemental feeding. Despite these constraints, buffaloes have shown an impressive capacity to convert suboptimal fibrous feeds into valuable outputs (Haque et al., 2020; Rahim et al., 2018; Rahman et al., 2019). They are documented to digest up to 5% more crude fiber than high-yielding cows and to utilize metabolizable energy 4-5% more efficiently for milk production (Aquino et al., 2024; Hegde, 2019).

The southern coastal regions of Bangladesh, particularly the Bhola district, offer a unique landscape for buffalo rearing, characterized by favorable climatic conditions, abundant grazing areas, and socio-economic factors that encourage extensive buffalo farming (Habib et al., 2022; Samad, 2020). In these areas, buffaloes are reared both at the household level and through collective, free-range *Bathan* systems (Uddin et al., 2016). However, this traditional form of buffalo farming is undergoing significant challenges, including inefficient marketing systems, inadequate nutritional management, and limited knowledge of reproductive health, all contributing to suboptimal productivity and breeding inefficiencies (Boro et al., 2020; Habib et al., 2017, 2022; Uddin et al., 2016).

The reproductive performance of buffaloes, both domestically and internationally, is marked by several hurdles. These include delayed puberty, with buffaloes reaching sexual maturity at 37

months for household and 38 months for *Bathan* farming in Bangladesh (Uddin et al., 2016). In contrast, river buffaloes generally reach sexual maturity between 15 to 18 months, and swamp buffaloes between 21 to 24 months in global context (Borghese, 2005). Moreover, the calving interval is extended, averaging 18 to 24 months, compared to the more desirable 12 to 14 months seen in optimized systems (Habib et al., 2017; Uddin et al., 2016). Conception rates in less optimized systems are often lower than those reported for well-managed herds, where higher reproductive efficiency is observed (Otava et al., 2021). These reproductive inefficiencies are exacerbated by poor nutrition and seasonal challenges, such as heat stress during the summer, which reduce estrus expression and fertility (Boro et al., 2020; Siddiki et al., 2016; Uddin et al., 2016).

Despite these obstacles, buffaloes in Bangladesh, particularly in the coastal regions, have demonstrated a robust potential for productivity, underpinned by their ability to thrive on poor-quality roughages, inherent disease resistance, and adaptability to local climatic conditions (Habib et al., 2017; Samad, 2020). However, a critical knowledge gap persists regarding effective buffalo husbandry practices in Bhola district, where the productive and reproductive capabilities of buffaloes are still underexplored.

Therefore, this study seeks to assess the productive and reproductive performance of buffalo across different sub-districts of Bhola district, with the aim of identifying the most evident problems where interventions can be given in future to enhance buffalo rearing practices in this region.

Materials and Methods

Study area, buffalo farming and data collection

The study was conducted in the Bhola district of Bangladesh, located at 22.69°N latitude and 90.65°E longitude in the southern part of the Barisal Division. Bhola experiences a tropical wet and dry climate, with an average temperature of 27.66°C and a relative humidity of 71%. Administratively, the district is divided into 5 municipalities, 9 sub-districts, 66 unions, and 473 villages. Covering an area of 3,737 square kilometers. Bhola has a population of 1,932,514, with the majority of the people involved in agriculture and animal husbandry, particularly buffalo farming.

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Buffalo farming in the studied region follows two primary systems: household farming and *Bathan* farming (Figure 1). The household farming system is a small-scale, family-run operation, often integrated with crop farming, where feed is sourced from crop residues, food waste, and local communal grazing, employing basic management practices, and plays a vital role in providing milk, meat, and draft power. The *Bathan* system relies on public lands like *Chars*, for sourcing of green grass for the buffaloes (Uddin et al., 2016). Only a few farmers own or lease land for crop cultivation and use crop by-products like rice straw for buffalo feeding. In the *Bathan* system, buffaloes are raised in open grazing areas throughout the year, where various local grasses are available for grazing. During periods of feed scarcity in *Bathan* areas, some farmers move their buffaloes from the *Bathan* to their homestead areas, where the animals are grazed on fallow land (Habib et al., 2021; Uddin et al., 2016).



Figure 1: *Bathan* (left) and household (right) buffalo farming system in Bangladesh.

To achieve the study objectives, 5 sub-districts of Bhola district were selected for a detailed survey: *Bhola Sadar*, *Burhanuddin*, *Tazumuddin*, *Lalmohan* and *Char Fasson* (Figure 2). The survey questionnaire focused on several key areas, including the socio-economic status of farmers, farm management practices, productive and reproductive parameters of buffaloes, and the existing marketing systems. Data on productive parameters, such as milk yield, were collected based on farmers' estimates and, in some instances, written records. Reproductive parameters were obtained through farmers' experience, recall, assumptions, and available written records. Only farmers who reared at least 3 buffaloes - whether lactating, dry, or previously inseminated - were included in the survey. Utilizing a snowball sampling technique, the survey was conducted with the farmers consent, either at their households or *Bathan*, between November and December 2020. A total of 309 buffalo farmers participated in the survey across the different sub-districts: *Burhanuddin* (n = 50),

Lalmohan (n = 45), *Char Fasson* (n = 125), *Bhola Sadar* (n = 73), and *Tazumuddin* (n = 16). The entire survey process was facilitated by an organization involved in buffalo farming in the study area, 'Grameen Jano Unnayan Sangstha,' which played a key role in coordinating with the farmers.

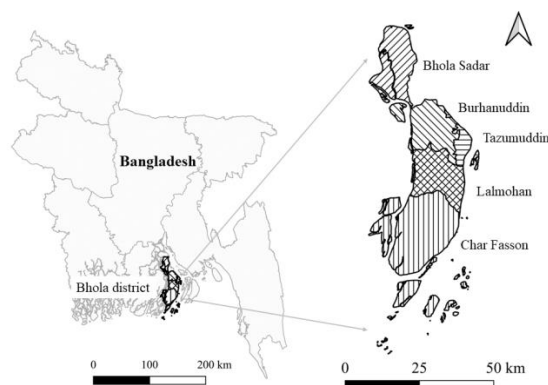


Figure 2. Bangladesh (left), and the sub-districts of Bhola district (right).

Statistical analysis

Data management and ANOVA were performed using SPSS statistical software. Significant differences among groups were further explored using Tukey's HSD tests, with significance set at $p < 0.05$.

Results

In this study, 99% of the surveyed farmers were male and over 25 years old. In the Bhola district, more than 80% of farmers have an education level up to the primary level, with variations across the five sub-districts: *Burhanuddin*, *Lalmohan*, *Char Fasson*, *Bhola Sadar*, and *Tazumuddin*, ranging from 62% to 90% (Table 1). Approximately 19% of farmers have education levels beyond primary school, with a range of 10% to 31% across these sub-districts. Over 70% of farmers in Bhola district rely on buffalo farming as their primary source of income, while 10% depend on crop production, and 20% on a combination of business, jobs, and labor. Notably, in *Burhanuddin*, all surveyed farmers rely exclusively on buffalo farming, compared to 84% in *Bhola Sadar*, 75% in *Char Fasson*, 25% in *Lalmohan*, and 19% in *Tazumuddin*. On average, farmers have more than 7 acres of land available for farming and household purposes, with the range varying from 3.5 to 10.0 acres across the sub-districts.

A total of 6,331 buffaloes were recorded across the 309 surveyed farms, with an average herd size of over 20 buffaloes per farm. Farmers sold approximately 3,800 liters of milk annually, at an average price of BDT 87 per liter (Table 2). Over 90% of the farmers sold their buffalo milk to

contract *Goalas* or milkmen, with 35% expressing dissatisfaction with the prices they received. Additionally, about 85% of the farmers had taken advance payments from contract *Goalas* and 25% reported that this led to receiving prices below the market rate.

Table 1: Socio-economic parameters of surveyed buffalo farmers in 5 sub-districts of Bhola district in Bangladesh.

Parameters	Burhan-uddin (n = 50)	Lal-mohan (n = 45)	Char Fasson (n = 125)	Bhola Sadar (n = 73)	Tazu-muddin (n = 16)	Total (n = 309)
Education level (%)						
Up to primary	90	64	83	62	69	81
Upper than primary	10	36	17	38	31	19
Primary income source (%)						
Buffalo farming	100	25	75	84	19	71
Crop production	0	29	6	5	31	9
Others (Business, job, labor)	0	46	19	11	49	20
Land availability (acre, mean ± SD)	8.3 ± 3.5	7.5 ± 1.4	10.0 ± 12.0	3.5 ± 3.5	7.5 ± 0.71	7.4 ± 4.5

SD, Standard deviation; n, the number of buffalo farmers surveyed in each *sub-district* is indicated within parentheses.

Table 2: Buffalo farm parameters related to population, body weight, breeding policy, milk yield and milk price of surveyed buffalo farmers in 5 sub-districts of Bhola district in Bangladesh.

Parameters	Burhan-uddin (n = 50)	Lal-mohan (n = 45)	Char Fasson (n = 125)	Bhola Sadar (n = 73)	Tazu-muddin (n = 16)	Total (n = 309)
Number of buffaloes	1,534	1,422	1,235	1,908	232	6,331
Number of lactating buffaloes	386	402	386	552	76	1,802
Number of breeding buffalo bulls	36	25	200	49	9	319
Number of breedable female buffaloes	809	150	701	851	63	2,574
Buffalo rearing at <i>Bathan</i> system (%)	100	73	73	100	88	85
Buffalo rearing at household system (%)	0	27	27	0	12	15
Average total milk sold (L/year)	3680	6515	1954	3596	3587	3866
Standard deviation	2379	1656	3384	4194	3180	1648
Average milk price (BDT/L)	60	91	106	67	109	87
Standard deviation	0	11	18	14	13	22
Farmers practiced breeding techniques for buffaloes (%)						
Natural mating	100	93	72	100	87	87
Artificial insemination	0	2	2	0	0	1
Both	0	5	26	0	13	12
Body weight (kg) at 3 years age and lactation traits						
Mean body weight	179.2 ^c	250.2 ^a	205.3 ^b	204.4 ^b	255.4 ^a	-
Standard deviation	13.1	8.3	62.4	56.6	4.26	-
Mean lactation length (days)	180 ^{ab}	198 ^a	177 ^b	184 ^a	186 ^a	-
Standard deviation	0.5	33.5	34.1	22.6	19.6	-
Average milk yield in a lactation (L/head)	302 ^{ab}	337 ^a	372 ^a	360 ^a	384 ^a	-
Standard deviation	40.4	71.1	112.1	82.4	71.4	-

n, the number of buffalo farms surveyed in each *sub-district* is indicated within parentheses. ^{abc}Means in the same row with common superscript differed significantly (P < 0.05).

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More than 85% of farmers use the *Bathan* system for rearing their buffaloes, with 100% of farmers in *Burhanuddin* and *Bhola Sadar*, and 73%, 73%, and 88% in *Lalmohan*, *Char Fasson*, and *Tazumuddin*, respectively, employing this method. Approximately 87% of farmers rely on natural mating for breeding, with 100% of farmers in *Burhanuddin* and *Bhola Sadar*, and 93%, 72%, and 87% in *Lalmohan*, *Char Fasson*, and *Tazumuddin*, respectively, following this practice. In contrast, the use of artificial insemination was minimal, with only 1% to 2% of farmers in some sub-districts adopting this method. However, a higher percentage of farmers in *Char Fasson* (26%) and *Tazumuddin* (13%) used both natural mating and artificial insemination for breeding (Table 2).

The average body weight of buffaloes at 3 years of age varied significantly ($p < 0.05$) across the sub-districts, with the highest recorded at 255 kg in *Tazumuddin* and the lowest at 179 kg in *Burhanuddin*. Similarly, lactation length varied significantly ($p < 0.05$) among the sub-districts, ranging from 177 to 198 days, while milk yield per

lactation ranged from 302 to 384 liters per buffalo.

Milk yield at different stages of lactation also differed significantly across the sub-districts ($p < 0.05$) (Figure 3). During the first 0-3 months of lactation, buffaloes in *Lalmohan*, *Char Fasson*, *Bhola Sadar*, and *Tazumuddin* produced significantly less milk (3.01-3.07 L/head/day) compared to those in *Burhanuddin* (4.0 L/head/day) ($p < 0.05$). In the 4-6-month lactation period, buffaloes in *Burhanuddin* had a higher milk yield (2.71 L/head/day) than those in *Char Fasson*, *Bhola Sadar*, and *Tazumuddin* (2.0 - 2.19 L/head/day). However, the lowest milk yield during this stage was observed in buffaloes from *Burhanuddin* (1.76 L/head/day) ($p < 0.05$). In the 6-9-month lactation period, milk yield was very low in buffaloes from *Burhanuddin*, *Lalmohan*, and *Bhola Sadar* (0.61-0.81 L/head/day), whereas buffaloes from *Char Fasson* and *Tazumuddin* yielded higher amounts (1.06 and 1.22 L/head/day) ($p < 0.05$).

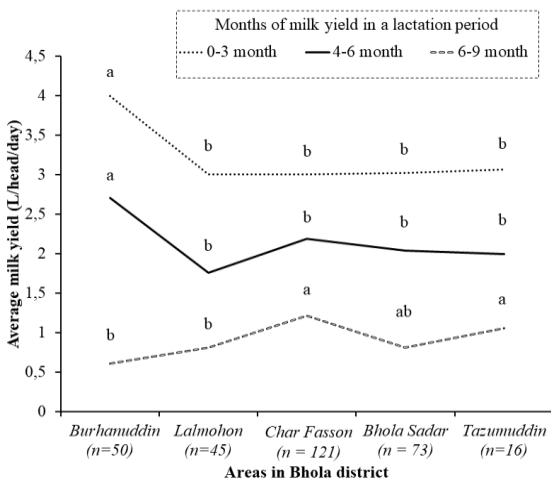


Figure 3. Milk yield at different stages of lactation in buffaloes from surveyed farms across five sub-districts in Bhola district, Bangladesh. Mean values with different superscripts (a, b) in the figure lines differed significantly ($p < 0.05$), n = total number of observations.

Only 14% of farmers provided concentrate feed in addition to green grass to their buffaloes, while more than 82% relied solely on green grass (Table 3). In *Burhanuddin* and *Tazumuddin*, all farmers exclusively used green grass, primarily sourced from *Bathan*. In contrast, 56%, 78%, and 84% of farmers in *Lalmohan*, *Char Fasson*, and *Bhola Sadar*, respectively, also relied on green grass for their buffaloes. Supplementary feeding practices were

adopted by only 14% of farmers. All farmers ensured that their buffaloes received vaccinations, anthelmintic treatments, and regular bathing. Approximately 70% of farmers cleaned the sheds regularly, and 45% provided access to clean drinking water for their buffaloes. Water sources included rivers for 53% of farmers, ponds for 21%, and tube wells for 26%.

Table 3: Feeding management of buffalo farms in 5 sub-districts of Bhola district in Bangladesh.

Parameters	Burhanuddin (n = 50)	Lalmohon (n = 45)	Char Fasson (n = 125)	Bhola Sadar (n = 73)	Tazumuddin (n = 16)	Total (n = 309)
Regular providing of concentrate feed (%)	0	44	22	16	13	14
Regular supplying of green grass (%)	100	56	78	84	100	82
Supplementary feeding practices (%)	0	16	22	13	13	14
Regular cleaning of shed (%)	0	73	78	96	100	70
Supply of clean drinking water (%)	0	33	38.4	99	31	45
Source of water (%)						
River	0	13	4	97	0	53
Pond	0	13	48	3	40	21
Tube well	0	74	48	0	60	26

n, the number of buffalo farms surveyed in each sub-district is indicated within parentheses.

The age at sexual maturity of buffaloes varied significantly across the sub-districts ($p < 0.05$). Buffaloes in *Burhanuddin* had the highest average age at sexual maturity at 3.4 years, while those in *Char Fasson* had the lowest at 3.0 years (Table 4). The age at first calving also showed significant differences, with the highest age in *Burhanuddin* (4.4 years) and the lowest in *Char Fasson* (4.0 years) ($p < 0.05$). The postpartum heat period was longest in buffaloes from *Burhanuddin* and *Bhola Sadar* (71 days) and shortest in *Lalmohon* (57 days) ($p < 0.05$). The number of

services per conception was highest in *Char Fasson* (2.78) and lowest in *Bhola Sadar* (1.3). The calving interval was longest in *Char Fasson* (14.9 months) and shortest in *Bhola Sadar* (11.9 months) ($p < 0.05$). Additionally, the gestation period was longest in *Burhanuddin* (303 days) and shortest in *Bhola Sadar* (297 days) ($p < 0.05$). These reproductive parameters did not vary significantly based on the farming system (*Bathan* vs. household), except for the number of services per conception ($p < 0.01$).

Table 4. Reproductive characteristics of buffalo at different sub-districts of Bhola district in Bangladesh.

Parameters	Age at sexual maturity (yr.)	Age at first calving (yr.)	Postpartum heat period (days)	Number of services per conception	Calving interval (months)	Gestation period (days)
Based on areas						
<i>Burhanuddin</i> (n = 50)	3.4 ^a ± 0.25	4.4 ^a ± 0.33	71 ^a ± 12.3	1.46 ^c ± 0.50	14.5 ^a ± 1.25	303 ^a ± 8.5
<i>Lalmohon</i> (n = 45)	3.0 ^c ± 0.08	4.1 ^b ± 0.04	57 ^b ± 13.6	1.53 ^c ± 0.50	13.4 ^b ± 1.50	301 ^{ab} ± 3.7
<i>Char Fasson</i> (n = 125)	3.0 ^c ± 0.30	4.0 ^b ± 0.31	62 ^b ± 26.5	2.78 ^a ± 1.21	14.9 ^a ± 1.52	299 ^b ± 5.3
<i>Bhola Sadar</i> (n = 73)	3.1 ^b ± 0.29	4.0 ^b ± 0.21	71 ^a ± 17.8	1.30 ^c ± 0.35	11.9 ^c ± 0.43	297 ^c ± 6.9
<i>Tazumuddin</i> (n = 16)	3.0 ^c ± 0.65	4.1 ^b ± 0.15	60 ^b ± 1.3	1.88 ^b ± 0.35	14.6 ^a ± 1.03	299 ^b ± 2.5
Based on farming system						
<i>Bathan</i> (n=261)	3.1 ± 0.30	4.1 ± 0.30	65 ± 20.90	2.01 ^a ± 1.13	13.8 ± 1.72	299 ± 6.70
Household (n = 48)	3.0 ± 0.22	4.0 ± 0.20	63 ± 20.80	1.89 ^b ± 0.67	14.6 ± 1.75	300 ± 4.20

Mean values with different superscripts (a, b, c) within the column differed significantly ($p < 0.05$). n = total number of observations.

The occurrence of estrous, pregnancy, and calving in buffaloes across Bhola district displayed distinct seasonal patterns throughout the year. Estrous

activity was highest from October to December, with an average of 71% of buffaloes showing heat, peaking at 80% in *Burhanuddin*. Conversely,

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the lowest estrous activity occurred between April and May, with an average of 29% across the sub-districts. Pregnancy rates were highest during February and March, averaging 66%, with *Burhanuddin* recording the highest rate at 76%. In contrast, the lowest pregnancy rates were observed in June and July, with an overall average of 34%.

Calving was most frequent in September and October, with 68% of buffaloes giving birth during this period, again highest in *Burhanuddin* at 78%. The lowest calving rates were noted between December and January, with an average of 32% across the sub-districts. These indicate a clear seasonal pattern in reproductive events among buffaloes in Bhola district.

Table 5: Fluctuation (%) of estrous, pregnancy and calving seasons of buffalo over the year at Bhola district in Bangladesh.

Parameters	Level	Name of months	<i>Burhanuddin</i> (n = 19)	<i>Lalmohan</i> (n = 37)	<i>Char Fasson</i> (n = 106)	<i>Bhola Sadar</i> (n = 70)	<i>Tazumuddin</i> (n = 14)	Total (n = 246)
Heat shows	Highest	Oct-Dec	80	67	68	72	68	71
	Lowest	Apr-May	21	33	32	28	32	29
Pregnancy shows	Highest	Feb-Mar	76	59	68	72	58	66
	Lowest	Jun-Jul	24	41	32	28	42	34
Newborn calves	Highest	Sep-Oct	78	62	68	72	59	68
	Lowest	Dec-Jan	22	38	32	28	41	32

n = total number of observations.

Discussion

This study provided a comprehensive analysis of the productive and reproductive performances of buffaloes across various sub-districts in Bhola district, Bangladesh, based on a detailed face-to-face survey. The findings offer valuable insights into the socio-economic conditions, buffalo population dynamics, milk yield, feeding practices, breeding policies, and reproductive status within the region. Buffalo farming in the study areas was predominantly male-dominated, with most farmers having only a primary level of education. This aligns with observations from *Subornochar sub-district* in Noakhali district, Bangladesh (Amin et al., 2015). Over 70% of farmers in our study relied on buffalo farming as their primary income source, a pattern consistent with Noakhali district but differing from Bagerhat district, where only half of the farmers reported the same dependency (Sarkar et al., 2013). In India, similar trends were observed, with around 60% of buffalo farmers in Bihar and Jharkhand having primary-level education and relying heavily on buffalo farming (Singh et al., 2013, 2011). Additionally, farmers in our study had, on average, more than 7 acres of land, significantly more than the 1 acre reported in Jamalpur district, Bangladesh (Haque et al., 2020). This discrepancy is attributed to the

availability of *Char* land in Bhola, which supports more extensive buffalo farming compared to the land constraints in Jamalpur.

The average price of buffalo milk was around BDT 87 per liter, slightly higher than previously reported prices in the same district (Habib et al., 2022). Lower prices in some instances were linked to the practice of milkmen collecting milk directly from farmers' homes, often in exchange for loans (Rahman et al., 2019).

In this study, it was observed that 72% to 100% of farmers across the sub-districts of Bhola district predominantly practiced natural mating for breeding buffaloes (Table 2). These findings are consistent with Uddin et al. (2016), who reported that natural mating was the predominant breeding method (95%) among household farmers in Bangladesh, despite the limited availability of breeding bulls. In contrast, the use of artificial insemination for breeding buffaloes was almost negligible, with only 1% to 2% of farmers in some sub-districts practicing it (Table 2). This is similar to the findings of Hasan et al. (2016), who reported that farmers in Bhola district showed little interest in artificial insemination and had limited access to these facilities.

The average lactation length of approximately 180 days and a milk yield of about 350 liters per

lactation in our study showed some variation compared to other findings. For instance, Samad (2020) reported lower yields, while Habib et al. (2017) documented higher yields in different farming systems. The decrease in milk yield during later lactation stages aligns with findings from other districts in Bangladesh (Omar et al., 2024). Feeding practices revealed that over 80% of farmers relied primarily on green grass, a practice also observed in Noakhali (Amin et al., 2015). Predominant grasses included *Dal (Hymenachne amplexicaulis)*, *Durba/ Bermuda grass (Cynodon dactylon)*, *Halancha/water cress (Enydra fluctuans)*, water hyacinth (*Eichhornia crassipes*), and crop by-products. In contrast, farmers in Bagerhat district relied solely on grazing (Sarkar et al., 2013). While green grass is beneficial, the lack of concentrate feed may compromise balanced nutrition (Rahman et al., 2019; Sarkar et al., 2013).

Buffaloes are water-loving animals and require substantial amounts of water, with 53% of farmers sourcing water from rivers and canals, and 26% using tube wells. Despite the advantages of tube-well water, a previous study showed a preference for open water sources due to limited awareness about the benefits of tube-well water (Kabir et al., 2020). The continued reliance on open water sources represents a missed opportunity for improving water quality for buffaloes (Kabir et al., 2020; Rahim et al., 2018).

Significant variations in the age at sexual maturity among buffaloes were observed in this study, influenced by feeding practices and management strategies. Adequate nutrition and improved management promote earlier sexual maturity, whereas inadequate nutrition can delay puberty (Heinrichs et al., 2005). The age at first calving in our study ranging from 48 to 52 months that was longer than reported in other districts of Bangladesh but similar to delays observed in Indian buffaloes (Boro et al., 2020; Rahman et al., 2019; Uddin et al., 2016). These delays can be attributed to factors such as improper nutrition, seasonal breeding patterns, slower growth rates, genetic factors, and environmental stressors (Bhatti et al., 2007; Hegde, 2019).

Reproductive efficiency varied, with the number of services per conception ranging from 1.3 to 2.8, which is lower compared to the 3.4 services reported in Siddiki et al. (2016). Indian buffaloes

have shown similar variations in services per conception, ranging from 1.9 to 3.9 (Khan et al., 2009). The postpartum heat period in our study (57 and 71 days) was shorter than previously reported (90 to 159 days) studies (Habib et al., 2023; Rahman et al., 2019; Siddiki et al., 2016). The gestation period and calving interval were consistent with earlier findings (Habib et al., 2023; Siddiki et al., 2016). The variations in services per conception observed in this study for indigenous x Nili-Ravi buffaloes differed from those reported by Saacke (2001) and Khan et al. (2009), who noted 2 and 2.8 services for cross-bred and Murrah buffaloes, respectively. The higher number of services per conception in some cases may be due to poor heat detection, postpartum complications, and imbalanced nutrition (Akthar et al., 1994; Ingawale et al., 2004; Samad, 2020).

Conclusion

This study highlights significant variations in the productive and reproductive performance of buffaloes across different sub-districts in Bhola district, Bangladesh, emphasizing the influence of local conditions on buffalo productivity. *Lalmohan* buffaloes showed the lowest age at sexual maturity, while *Bhola Sadar* buffaloes had the shortest calving intervals, and *Burhanuddin* buffaloes had the lowest number of services per conception, pointing to regional variations in reproductive efficiency. To enhance buffalo farming, efforts should focus on increasing women's involvement, expanding herd sizes, improving feeding practices, and enhancing access to breeding bulls and artificial insemination facilities. Additionally, better marketing strategies and reduced reliance on middlemen are crucial for addressing low milk prices. By implementing these strategies and providing targeted support, the productivity and profitability of buffalo farming in Bhola district can be significantly improved.

Acknowledgements and Funding

The authors gratefully acknowledge the financial and logistic support provided by Grameen Jano Unnayan Sangstha, Bhola and Palli Karma-Sahayak Foundation, Agargaon, Dhaka, Bangladesh.

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Authors' contribution

Ishrat Jahan: Data analysis, visualization, software, and original draft writing; **Nirjon Sarker:** Data collection, analysis, reviewing and editing; **Shahin Alam:** Data analysis, conceptualization, visualization; software, reviewing and editing; **Md. Khalilur Rahman:** Conceptualization, data collection monitoring, reviewing and editing; **Md. Khorshed Alam:** Conceptualization, Data collection monitoring, reviewing and editing; **Md. Mehedi Hasan Khandakar:** Data collection, sorting, reviewing and editing; **Md. Sadakatul Bari:** Data Collection, reviewing and editing; **Md. Rezwatul Habib:** Data collection, reviewing and editing; **Mohammad Ashiqui Islam:** Conceptualization, funding acquisition; resources, supervision; reviewing and editing.

Data Availability Statement

The datasets generated and/or analyzed in the current study are available from the corresponding author for scientific purposes upon written request.

Declaration of Competing Interest

The authors declare no conflict of interest.

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