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Research article

Epidemiology and risk factors of lumpy skin disease outbreak in cattle in the north-west area of Bangladesh

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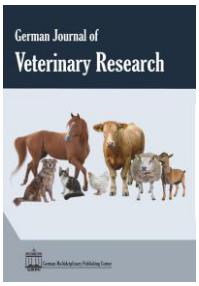

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Abstract

Lumpy skin disease (LSD) is an acute viral disease of cattle that recently emerged in Bangladesh that negatively impacts livestock by reducing animal production, increasing management costs, and death of infected animals. Recently, Bangladesh has faced the ominous effects of LSD, like other countries. Because of this pressing concern, the present cross-sectional study was undertaken to determine the infection status and risk factors of LSD outbreaks from January to December 2023 in Bangladesh's northwest area. A total of 2858 cattle from various randomly selected farms were surveyed. The diagnosis was made on the basis of clinical inspection, clinical history, and owner complaints. The overall attack rate, mortality, and case fatality were 37.6%, 2.8%, and 7.5%, respectively, but in calves (≤1 month), the attack rate, mortality, and case fatality were 44.3%, 9.3%, and 21.3%, respectively. The infection status was discussed based on age, sex, breed, genotype, health status, immune status, coat color, farm size, farming system, separation of affected animals, separation place, use of common utensils, introduction of new cattle, use of vaccine and season of the year. Among them, age, sex, breed, health status, coat color, farm size, farming system, use of common utensils, and introduction of new cattle have no significant relationship with LSD outbreaks, but in calves (≤ 1 year), age has a significant association with the occurrence of LSD. The risk factor analysis revealed that the outbreaks of LSD were significantly ($p<0.05$) associated with genotypes, immune status, separation place, vaccination status of farm, and season of the year. The findings of the present study could provide useful epidemiological data on risk factors associated with LSD to livestock owners, field veterinarians, and government-level livestock regulators, which will help formulate prevention and control strategies and minimize the negative impact of LSD on cattle farming.

Keywords: Emerging disease, Lumpy skin disease (LSD), Cattle, Epidemiology, Prevalence, Risk factor

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Introduction

Lumpy skin disease (LSD) is a non-zoonotic, emerging, transboundary infectious viral disease of cattle that originated in Africa. In recent days, it has emerged in different countries with a severe impact on animal health and production. Genetically, the LSD virus is closely related to the goat pox virus under the genus *Capripoxvirus* and belongs to the family *Poxviridae,* referred to as the Neethling virus (Kiplagat et al., 2020). LSD virus is highly host-specific, and in natural outbreaks, it infects large ruminants like cattle and water buffaloes (Sudhakar et al., 2020). LSD is a vector-born disease and primarily LSD virus transmitted through mosquitoes, biting flies, and ticks (Tuppurainen et al., 2011). LSD can also be transmitted through nodular lesions, saliva, lachrymal secretion, milk, and by sharing of feeding and watering utensils (Hailu et al., 2015; Sprygin et al., 2019). Historically, LSD was limited to the African and Middle East continents, but in 2015, Europe's first incursions occurred through Greece (Kiplagat et al., 2020). Recently, it has spread to different Asian countries, including Bangladesh, China, Nepal, and India (Acharya and Subedi, 2020; OIE, 2019a, 2019b, 2019c). In Bangladesh, the first outbreak of LSD was reported in the Chattogram district in 2019

by the Department of Livestock Services (DLS), which was confirmed by PCR technique and registered in the World Organization for Animal Health (WOAH), where the initial attack rate was 18% with no mortality (FAO, 2019). Clinically, LSD was characterized by fever, superficial raised nodules with few to multiple numbers on different parts of the body, lameness, edematous swelling in the ventral abdomen, lacrimation, nasal secretion, salivation, and swollen superficial lymph nodes. It often becomes fatal in calves due to pneumonia (Radostits et al., 2007; Tuppurainen et al., 2017). LSD is an economically important disease that causes significant production loss. The economic importance of this disease is mainly due to having a high morbidity rather than mortality (Tuppurainen et al., 2011). The disease's significant consequences are permanent skin damage, high reduction of milk yield during the illness, sterility, infertility in both sexes, abortion, mastitis, emaciation, draft power loss, and death (Gupta et al., 2020). The long-term supportive treatment cost and management have a negative impact on cattle farmers, mainly small-scale farmers (FAO, 2019). The average range of morbidity of LSD is 3-85%, depending on the abundance of vectors, the animals' immune status, and the farm's management practices (Tuppurainen and Oura, 2012).

In Bangladesh, earlier studies revealed that the morbidity and mortality due to LSD in cattle were 10–63.3% and 1–2.7%, respectively, in the Jashore, Chattogram, Barishal, and Dinajpur districts (Biswas et al., 2020; Hasib et al., 2021; Khalil et al., 2021). Factors associated with the occurrence and distribution of LSD are the vaccination status, communal grazing system, new cattle introduction, herd size and land type, season, watering systems, and breed (Abera et al., 2015; Gari et al., 2010; Hailu et al., 2014). LSD in cattle has already expanded throughout Bangladesh, and in recent years, it has severely attacked all over the country and caused massive damage to our cattle population. Now, LSD is a pandemic disease, and it is the main concern of the Department of Livestock Services (DLS) and cattle farmers; also, no studies have been published describing the epidemiology and risk factors associated with its occurrence in Bangladesh. However, very few studies were performed and published regarding LSD in our country's context (Biswas et al., 2020; Khalil et al., 2021). So, studies are essential for informing prevention and control strategies and also allocating limited resources for livestock disease control at a farm and national level. Therefore, this study aimed to determine the epidemiological and risk factors for LSD outbreaks through a matched case-control study.

Materials and Methods

Study design, area, and duration

A cross-sectional study was conducted on different (small–large scale) cattle farms of the Joypurhat and Naogaon districts of Bangladesh from January to December 2023. In Bangladesh, there are six seasons, but pre-dominant seasons are summer, rainy, late autumn, and winter, depending on temperature, rainfall, and humidity; therefore, data were collected throughout the year and categorized into four groups. The selection of these two districts was based on the outbreak history of LSD; however, five upazilas (sub-division of the district) from Joypurhat and six upazilas from Naogaon were randomly selected. Five upazilas of the Joypurhat district were Joypurhat Sadar, Akkelpur, Khtlal, Kalai, and Panchbibi, and six upazilas of the Naogaon district were Naogaon Sadar, Dhamerhatr, Patnitola, Shapahar, Porsha and Badolgasi (Figure 1).

Sample size, selection of farmers and cattle

Different small to large-scale cattle farms and household cattle were randomly selected from five upazilas of the Joypurhat district and six upazilas of the Naogaon district. Each farm and household was considered as a cluster, and all the cattle in the farms were included in the study. Thus, the number of studied cattle was 2858 (Joypurhat, n=1475, and Naogaon, n=1383). The list of the farms of each upazila was collected from the respective Upazila Livestock Office and Veterinary Hospital. The sample size (n) was estimated using the following formula with a 5% precision (d), 95% confidence interval (Z=1.96), and an expected proportion (P) of 50% (Thrusfield, 2005). However, n was multiplied by 1.5 as we assumed the conservative design effect to be 1.5 (Anon, 2015). $n=Z2\times P(1-P)/d2$. Thus, the minimum required sample size was 576.

Diagnosis of LSD-affected cattle

The field diagnosis was performed based on the characteristics of clinical signs. Clinical signs

include fever, raised-circular cutaneous nodules, oedematous swelling of legs, ventral abdomen, brisket region, lameness, swollen lymph nodes, lacrimation, and nasal discharge (Figure 2). Case farms were defined based on clinical manifestations of LSD in at least one cattle demonstrating the characteristic clinical sign of raised, circular, firm nodules varying from 1 to 7 cm in diameter (Samuel et al., 2020; Tuppurainen and Oura., 2012; CFSPH 2011). The presented clinical manifestations of LSD were recorded during the physical and clinical examination of the animal, and the farmer's complaints in relation to the affection were also emphasized.

Data and sample collection

A structured questionnaire was made with open and closed-ended questions administered to gather data from the farm owners or animal caretakers through face-to-face interviews. Data on cattle herd size, age, sex, grazing management, the introduction of new animals, vaccination status, treatment cost, milk production condition, abortion rate, mortality rate, treatment cost, etc., were collected. The questionnaire was prepared in English; however, it was translated into Bengali (the local language) during the survey. Farms were visited once; however, a follow-up visit of the affected farms was done to collect data related to economic impact once the outbreak was finished. Regular telecommunication was made to monitor the overall situation of the affected animals.

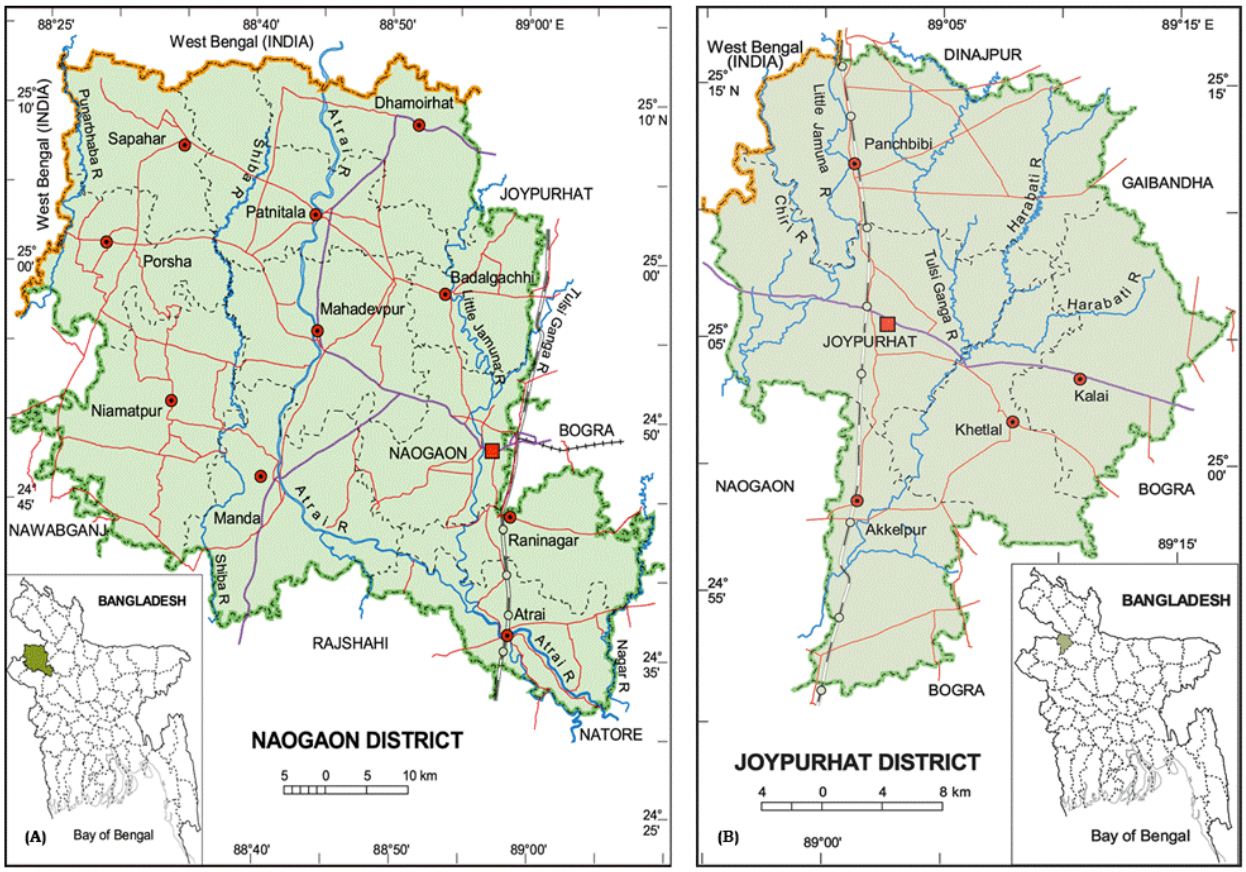

Figure 1. Study area in Bangladesh; A) Naogaon district, B) Joypurhat district.

Ethical consideration and farmers' consent

The experimental procedures and protocols used in this study were approved by the Animal Ethics and Welfare Committee of the Institute of Research and Training, Hajee Mohammad Danesh Science and Technology University (HSTU/IRT/2022/55). Informed and written consent was obtained from the farm owners before collecting data and samples. Animal welfare issues like proper restraint, minimal pain, distress, and discomfort were considered during sample collection.

Statistical analysis

Data entry and management were done using the Microsoft Excel spreadsheet 2010 and then imported to Statistical Package for Social Sciences (SPSS) software version 22. The survey responses were coded, and several continuous variables were transformed into categorical variables. Z-tests for proportions were performed to find out the significant differences in attack rate, mortality, and case fatality. A complex sample bivariable logistic regression analysis was done to identify the relationship between explanatory variables and LSD. The explanatory variables with p≤2 in the bivariable analysis were considered for inclusion in the multivariable logistic regression analysis. Furthermore, the multicollinearity among explanatory variables was assessed by the variation inflation factor (VIF). A pair of variables was considered collinear if VIF was ≥10. Finally, a multivariable logistic regression model was constructed to find out the association between the explanatory variables and the occurrence of LSD. The regression analysis for animal-level and farm-level factors was performed separately. The Hosmer–Lemeshow test for the overall goodness of fit of the final model was performed. The significance level was set at p≤0.05.

Figure 2. Clinical manifestations of LSD: A) Typical nodules in calf, B) Small nodules in adults, C) Some nodules heal up and some rupture, D) Rupture of nodules and sloughing off the epidermis.

Results

Overall attack rate in cattle

In our present study, a total of 2858 cattle were examined, and clinical signs were recorded during the study period (January – December 2023); 1076 cattle were identified as LSD positive, and thus, the attack rate was 37.6%. Overall mortality and the case fatality rate of lumpy skin disease (LSD) were 2.8% and 7.5%, respectively (Table 1). The attack rate of LSD in Joypurhat district (38.4%) was relatively higher than that of Naogaon district (36.8%). There was no major variation in the attack rate of LSD for selected upazila of both districts. Still, in Panchbibi upazila of Joypurhat district the attack rate (40%) was slightly higher than other upazilas. In Naogaon district, the attack rate was relatively higher in Dhamerhat (38.5%) than in other upazilas of the same district (Figure 3).

Table 1. Overall prevalence, mortality, and case fatality rate of lumpy skin disease (LSD) in cattle

District	No. of cattle examined	No. of cattle affected	No. of cattle died	Attack rate (%)	Mortality (%)	Case fatality (%)
Joypurhat	1475	567	43	38.4[a]	2.9[a]	7.6[a]
Naogaon	1383	509	38	36.8[a]	2.7[a]	7.5[a]
Overall	2858	1076	81	37.6	2.8	7.5

Note: Values with the same superscripts within the same column do not differ significantly (p>0.05).

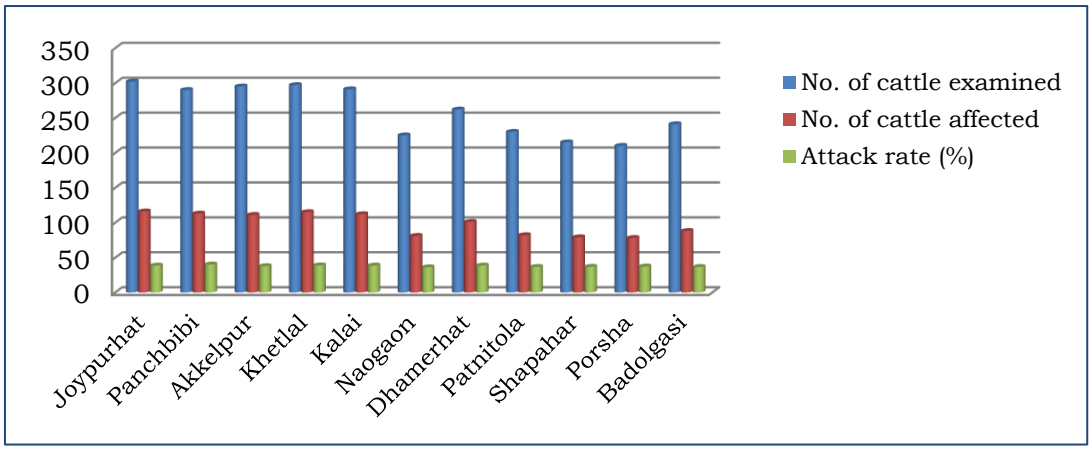

Figure 3. Area-wise infection status of lumpy skin disease (LSD) in cattle

Demographic occurrence and distribution of LSD in cattle

The age, sex, breed, genotypes, health status, immune status, and coat color-wise infection status of LSD in cattle are shown in Table 2. The age-wise occurrence and distribution of LSD revealed that the attack rate was relatively higher in calves aged < 1 year (41.2%) than in young animals aged < 3 years (36.4%) and adults aged >3 years (35.2%), where mortality (4.1%) and case fatality rate (10%) was also high. Male cattle had a somewhat higher attack rate of LSD (38.0%) than female cattle (37.2%). Crossbred cattle (41.2%) were more affected than indigenous cattle (31.8%), and it was a non-significant relationship. Among crossbred cattle, the prevalence rate was significantly higher in indigenous × Sahiwal cattle (49.2%) than in indigenous × Holstein Friesian cattle (32.5%). Good health (37.9%) cattle were more commonly affected than poor health (37%) one [Good health/poor health depending on body condition]. It was observed that the cattle that were immunized with goat pox vaccine/LSD vaccine (Lumpy vac.) were significantly less affected (10.6%) than non-vaccinated cattle (52.1%). It was also observed that the attack rate was higher in white (42.0%) and red (41.1%) coat-color cattle than in others, where black coat color cattle were less commonly infected (28.2%). Therefore, age, sex, breed, health status, and coat color had no significant effect on the occurrence and distribution of LSD, but immunization status (vaccination) and genotype in cross-breed cattle had a significant effect on the occurrence and distribution of LSD in cattle of the research area.

Table 2. Demographic occurrence and distribution of lumpy skin disease (LSD)

Variable	Category	No. of cattle examined	No. of cattle affected	No. of cattle died	Attack rate (%)	Mortality (%)	Case fatality (%)
Age (year)	Calf (< 1 year)	891	367	37	41.2	4.1	10.0
	Young (1-3 years)	947	345	29	36.4	3.0	8.4
	Adult (> 3 years)	1020	359	15	35.2	1.5	4.2
Sex	Male	1520	578	45	38.0	2.9	7.8
	Female	1338	498	36	37.2	2.7	7.2
Breed	Indigenous	1072	341	25	31.8	2.3	7.3
	Cross	1786	735	56	41.2	3.2	7.6
Genotypes	Indigenous x Sahiwal	920	453	31	49.2[a]	3.3	6.8
	Indigenous × HF	742	241	22	32.5[b]	3.0	9.1
	Mixed	124	41	3	33.0	2.4	7.3
Health status	Good health	2015	764	54	37.9	2.7	7.0
	Poor health	843	312	27	37.0	3.2	8.6
Immune status	Vaccinated	998	106	3	10.6[b]	3.0	2.8
	Non-vaccinated	1860	970	78	52.1[a]	4.2	8.0
Coat colour	Red	1145	471	36	41.1	3.1	7.6
	White	478	201	14	42.0	2.9	6.7
	Gray	535	187	15	35.0	2.8	8.0
	Black	280	79	5	28.2	1.8	6.3
	Mixed	420	138	11	32.8	2.6	7.9

Note: a, b: values with different superscripts within the same column for each variable differ significantly ($p \leq 0.05$). [HF – Holstein Friesian]

Prevalence, mortality, and case-fatality of LSD in calves

In our study, a total of 891 calves were examined, which are again categorized into three groups based on the age of the calves. The attack rate**/** prevalence**,** mortality, and case-fatality of 3 age groups of calves are represented in Table 3. Among the three age groups, ≤ 1-month-old calves (44.3%) were more infected with LSD than the other two groups (41.3% and 40.3%), but there were no significant differences in attack rate. The mortality (9.3%) and case-fatality (21.3%) were significantly higher in the ≤ 1-month age group calves than the other two age groups (3.5% and 8.6%; 3.0% and 7.5% (Table 3).

Meteorological/seasonal occurrence and distribution of LSD in cattle

In the present study, it was observed that the prevalence/attack rate of LSD was significantly higher in the rainy season (59.7%) than in summer (39.4%) and Late-autumn (45.3%), whereas the attack rate was very low in winter seasons (2.2%). It was also observed that the mortality (6.0%) and case-fatality (10.0%) were higher in the rainy season than in summer (1.9% and 4.8%) and late autumn (3.0% and 6.6%), but there is no significant relationship. As shown in Table 4 and Figure 4, it was remarkable that, there is no death record of affected cattle in winter seasons.

Table 3. Infection status of lumpy skin disease (LSD) in calves

Age (month)	No. of cattle examined	No. of cattle affected	No. of cattle died	Attack rate (%)	Mortality (%)	Case fatality (%)
≤ 1 month	140	62	13	44.3a	9.3[a]	21.3[a]
> 1 - ≤ 6 month	225	93	8	41.3a	3.5[a]	8.6[a]
> 6 months	526	212	16	40.3a	3.0[b]	7.5[b]
Total	891	367	37	41.2	4.1	10.0

Note: a, b: values with different superscripts within the same column differ significantly (p≤0.05).

Table 4. Meteorological distribution of lumpy skin disease (LSD)

Variable	Category	No. of cattle examined	No. of cattle affected	No. of cattle died	Attack rate (%)	Mortality (%)	Case fatality (%)
Seasons	Summer (March-May)	692	273	13	39.4[a]	1.9[a]	4.8[a]
	Rainy (June-August)	765	457	46	59.7[b]	6.0[b]	10.0[b]
	Late-autumn September-November)	730	331	22	45.3	3.0	6.6
	Winter (December-February)	671	15	-	2.2	-	-

Note: a, b: values with different superscripts within the same column for each variable differ significantly (p≤0.05)

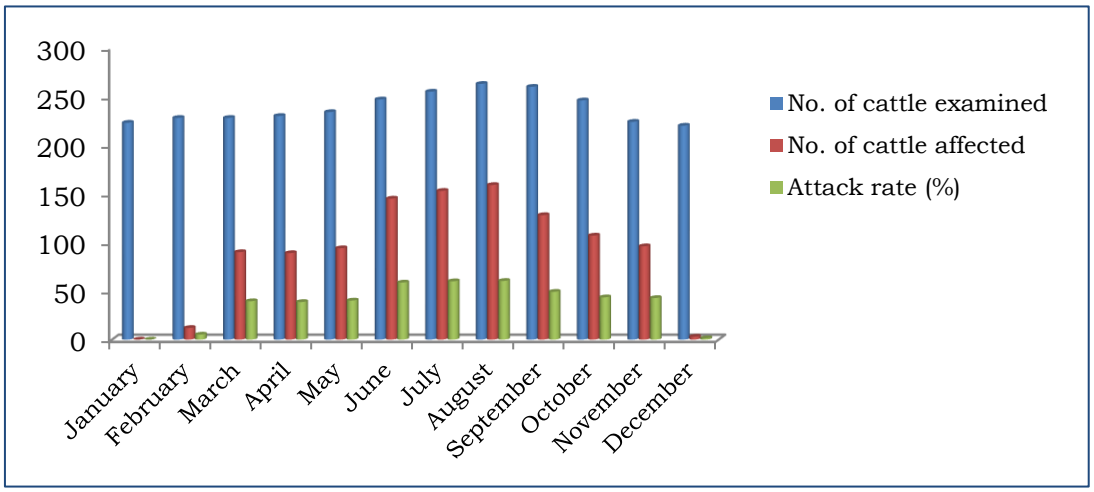

Figure 4. Month-wise infection status of lumpy skin disease (LSD) in cattle

Farm management-related occurrence and distribution of LSD in cattle

There are various factors related to farm management practice, but in our study, we included the following: farm size, farming system, separation of affected animal, separation place, use of common utensils, the introduction of new cattle, and vaccination as a variable to calculate the attack rate, mortality, and case fatality on the study population, which are shown in Table 5. The farm size-related occurrence and distribution of LSD revealed that the attack rate was relatively higher in cattle of medium-scale farms (39.4%) than in small (37.4%) and large-scale farms (35.0%), where mortality (3.1%) and case fatality (8.2%) was high in small size farm. The cattle from the Semi-intensive (38.2%) farming system were slightly more infected than the intensive farming system (37.1%), but mortality (2.8%) was equal. On the farm where affected cattle were separated from the healthy population, there was less attack rate (34.9%) than on the farm (39.7%) where separation is not practiced. It was also recorded that, where animals are separated in different houses, the infection rate was significantly lower (20%) than same house separation (42.2%). It was observed that in the farm where common utensils are used for feeding and watering, there was a high infection rate (38.8%), and in the farm where new cattle were introduced from the market, there was also a slightly high infection rate (37.9%), but there was a no significant relationship. The cattle that were vaccinated with goat pox vaccine/LSD vaccine (Lumpy vac.) are significantly less affected (10.6%) than non-vaccinated cattle (52.1%). Therefore, farm size, farming system, separation of the affected animal, use of common utensils, and introduction of new cattle had no significant effect on the occurrence and distribution of LSD, but separation place and immunization status (vaccination) had a significant effect on infection status and distribution of LSD.

Table 5. Farm management-related distribution of lumpy skin disease (LSD)

Variable	Category	No. of cattle examined	No. of cattle affected	Attack rate (%)	No. of cattle died	Mortality (%)	Case fatality (%)
Farm size	Small (1-5)	1167	436	37.4	36	3.1	8.2
	Medium (6-10)	1085	428	39.4	32	2.9	7.5
	Large (> 11)	606	212	35.0	14	2.3	6.6
Farming system	Intensive	1538	571	37.1	44	2.8	7.7
	Semi-intensive	1320	505	38.2	37	2.8	7.3
Separation of the affected animal	Yes	1243	434	34.9	34	2.7	7.8
	No	1615	642	39.7	47	2.9	7.3
Separation place	Same house	832	352	42.2[a]	23	2.7	7.8
	Separate house	411	82	20.0[b]	11	2.6	8.9
Use of common utensils	Yes	1746	678	38.8	51	2.9	7.5
	No	1112	398	35.8	30	2.7	7.5
Introduction of new cattle	Yes	1086	412	37.9	31	2.8	7.5
	No	1772	664	37.5	50	2.8	7.5
Use of vaccine	Yes	998	106	10.6[b]	-	-	-
	No	1860	970	52.1[a]	81	3.8	7.6

Note: a, b: values with different superscripts within the same column for each variable differ significantly ($p \leq 0.05$).

Demographic risk factors of LSD

In our present study, we collected data and examined cattle based on various animal-level variables and categorized them into different categories to analyze and evaluate the effect of these variables/factors. We observed that among animal-level factors, age, sex, breed, health status, and coat color have no significant effect on the occurrence and distribution of LSD in cattle. Out of seven animal-level factors, genotype difference (Sahiwal× Indigenous) and Immune status were significantly linked with LSD (OR: 2.2 and 9.2%; CS: 3.4 and 27.5) (Table 6). That has a significant effect on the occurrence and distribution of LSD in cattle.

Farm-level and meteorological risk factors of LSD

From our study, it was observed that farm size, farming system, separation of the affected animals, use of common utensils, and introduction of new cattle had no significant effect on the occurrence and distribution of LSD

in cattle. Our study included eight farm-level and meteorological factors in the bivariable analysis. In the final model, three variables were identified as potential risk factors for the occurrence and distribution of LSD (Table 7). These were the separation of affected animals same house (OR: 2.9, CS: 7.9), no administration of any vaccine (OR: 9.2, CS: 27.5), and rainy season (OR: 2.3, CS: 4.5).

Table 6. Animal-level bivariable analysis of risk factors for lumpy skin disease (LSD) in cattle

Risk factors	Category level	OR	CS	p-value
Age (year)	Calf (< 1 year)	1.3	0.6	0.423
	Young (1-3 years)	1.0		0.617
	Adult (> 3 years)	Ref.		-
Sex	Male	1.0	0.0	0.625
	Female	Ref.		-
Breed	Indigenous	Ref.	1.2	-
	Cross	1.5		0.207
Genotypes	Indigenous × Sahiwal	2.2	3.4	<0.001
	Indigenous × HF	Ref.		-
	Mixed	1.0		0.567
Health status	Good health	1.0	0.0	0.607
	Poor health	Ref.		-
Immune status	Vaccinated	Ref.	27.5	-
	Non-vaccinated	9.2		<0.001
Coat colour	Red	1.8	3.7	0.187
	White	1.8		0.190
	Gray	1.4		0.366
	Black	Ref.		-
	Mixed	1.2		0.478

OR: odds ratio, CS: chi-squared

Table 7. Farm-level bivariable analysis of risk factors for lumpy skin disease (LSD) in cattle

Risk factors	Category	OR	CS	p-value
Farm size	Small (1-5)	1.1	0.2	0.755
	Medium (6-10)	1.2		0.627
	Large (> 11)	Ref.		-
Farming system	Intensive	Ref.	0.0	-
	Semi-intensive	1.0		0.886
Separation of the affected animal	Yes	Ref.	0.3	-
	No	1.2		0.607
Separation place	Same house	2.9	7.9	<0.001
	Separate house	Ref.		-
Use of common utensils	Yes	1.1	0.1	0.755
	No	Ref.		-
Introduction of new cattle	Yes	1.0	0.0	0.895
	No	Ref.		-
Use of vaccine	Yes	Ref.	27.5	-
	No	9.2		<0.001
Season	Summer (March-May)	Ref.	4.5	-
	Rainy (June-August)	2.3		<0.001
	Late-autumn (September-November)	1.8		0.177
	Winter (December-February)	-	-	-

OR: odds ratio, CS: chi-square

Discussion

LSD is a vector-borne disease and is primarily transmitted through mosquitoes, biting flies, and ticks (Tuppurine et al., 2011). LSD may be introduced in Bangladesh and also in tested areas through vectors. LSD is responsible for causing heavy economic loss in the livestock industry by giving rise to emaciation, permanent skin damage, hindrance in milk production, abortion, infertility, supportive treatment costs, and death. The present study reports the occurrence, distribution, and risk factors of LSD in the northwest area of Bangladesh. To determine the risk factors of LSD, we analyzed the different variables related to animals, farm management, and meteorology. The overall attack rate of LSD was 37.6% in the present study, which is lower than previous reports in the Dinajpur district-41.06% (Sarkar et al. 2020), 52.38% and 63.33%

in Avoynagor and Monirampur upazilas of Jashore district (Biswas et al. 2020), and higher than other reports – 26.5% in Bangladesh during 2019-2020 (Uddin et al. 2022), 21% in Barishal district (Khalil et al. 2021) and 10% in Chattogram district (Hasib et al. 2021). In other countries, a considerable range of attack rates was reported – 7.1% in India (Sudhakar et al. 2020), 8.1% in Ethiopia (Gari et al. 2010), 74% in Azerbaijan (Zeynalova et al. 2016), 9.11% in Iraq (AlSalihi & Hassan, 2015) and 27.22% in Turkey (Ince & Türk, 2019). The mortality of our study was 2.8%, which was consistent with the earlier reports of Khalil et al. (2021) and Biswas et al. (2020), who recorded 1% and 2.73% mortality, respectively. The prevalence/attack rate varies due to variations in the waste management and biosecurity practices in farms, breed, genotype, immune status of the animals, and the availability of vector densities in different areas (Alemayehu et al. 2015).

Our study showed that there were no significant variations in the attack rate/prevalence of LSD across the age, sex, and breed, although the infection rate was high in calf (41.2%), male (38.0%), and cross breed (41.2%) cattle than adult (35.2%), female (37.2%) and indigenous (31.8%) cattle; which are in line with the earlier reports of Elhaig et al. (2017). Remarkably, the prevalence, mortality, and case-fatality rate were higher in calves aged ≤1 month (44.3%, 9.3%, and 21.3%) than in calves of > 1-month-old (40.3%, 3.0%, and 7.5%); therefore, age of calf have a significant effect on mortality and case-fatality. These variations may be due to impaired immunity and higher susceptibility to infections with LSD virus in young calves (Hunter and Wallace. 2001, Sevik and Dogan. 2017). Therefore, among crossbred cattle, the attack rate/prevalence was significantly higher in indigenous × Sahiwal cattle than in indigenous × Holstein Friesian cattle. This finding could not be explained due to the unavailability of published research; however, this might be due to the thickened skin of those (indigenous × Sahiwal) cattle (farmers and practitioners also agree with this theme), variation in epithelial configuration and immunological status of cattle due genotypic variation.

From this study, it was observed that good health cattle (37.9%) were non-significantly more infected than poor health one (37.0%), but mortality and case fatality were higher in poor health cattle (3.2% and 8.6%) than good health one (2.7% and 7.0%). This finding is difficult to explain due lack of available published literature on this factor; however, it might be due to the availability of potential vectors, variation in farming patterns, farming this variation might be due to location of the farms and variation in farming patterns in the study areas. The present study also observed that coat color has no significant effect on the occurrence and distribution of LSD; however, white (42.0%) and red (41.1%) coat color cattle were more infected than black (28.2%), gray 35.0%) and mixed (32.8%) color cattle. This variation could not be explained precisely due to the unavailability of published literature, but farmers said that various vectors mostly attack white and red color animals than black and other color animals; moreover, this variation might be due to the location of the farms and variation in farming pattern in the study areas.

The present research reports that the vaccination status of cattle has a significant effect on the occurrence and distribution of LSD. The farms were either single or booster doses of goat pox/lumpy vac. the vaccine had been administered to the cattle; there was a significantly very low attack rate (10.6%) and case fatality (2.8%) of LSD compared to the farms that had not been vaccinated (attack rate- 52.1% case fatality- 8.6%). These reports are in agreement with the earlier reports of Chouhan et al. (2022), who stated that the farms that had administered either single or booster doses of goat pox vaccine to cattle experienced less likely the occurrence of LSD compared to the farms that had not. The antigenic homogeneity and the advantages of LSD cross-protection with goat pox vaccination might be the explanation (Ayelet et al., 2014; Brenner et al., 2009 and; Tuppurainen and Oura. 2012).

It was observed that farm size and the farming system had a non-significant effect on the occurrence and distribution of LSD in cattle, although the infection rate was higher in medium-scale farms (39.4%) and semi-intensive (38.2%) farming systems than in small-scale farm (37.4%), large size farm (35.0%) and intensive farming (37.1%) system; which is in agreement with the findings of Chouhan et al. (2022), they observed that, farm size and farming system have no significant effect on the distribution of LSD.

The introduction of new cattle to farms was

found to be a non-significant risk factor for the occurrence of LSD. The practice of no screening of animals while purchasing and keeping animals together without proper quarantine is probably the leading cause of transferring LSDV to healthy herds (Hailu et al., 2014). This study revealed that the attack rate was high in these farms where common utensils were used for feeding and watering, but there was a non-significant relationship. It was observed that most of the farms frequently used common utensils for feeding and watering. This study is in agreement with the findings of Chouhan et al. (2022). The transmission of LSDV is high through direct or indirect contact between animals, mainly through saliva, ocular discharge, and nasal discharge (Degu et al., 2020).

Separation of affected animals also affects the prevalence of LSD; therefore, in the farm where separation was practiced, there is a lower infection rate (34.95%) than there is no practice (39.7%). It was also found that separation place has a significant effect on the infection status of LSD where affected animals were separated in separate houses; the attack rate was very low (20.0%) than where separation was practiced in the same house (42.2%). This study is in agreement with the findings of Chouhan et al. (2022), who report the high attack rate in a farm where there is no practice of affected animal separation. Earlier studies record that the transmission of the LSD virus is high through direct or indirect contact between affected and healthy animals (Degu et al., 2020).

The meteorological factors, especially season, were a potential risk factor for the occurrence and distribution of LSD, which is in agreement with the earlier report of Badhy et al. (2021) and Elmohsen et al. (2019). In this study, the rainy season was found to have a strong association with the occurrence and distribution of LSD. This finding disagrees with the earlier reports of Chouhan et al. (2022), who stated that the attack rate was higher in the summer season; this variation was due to the fact that they did not collect data and samples from the rainy season (the study duration was October–June). This might be due to the greater action and breeding season of vectors engaged in the transmission of the infection (Chihota et al. 2003).

Conclusion

The present study provides insights into the epidemiology (attack rate and risk factors) of LSD in Bangladesh (North-west area). The results of this study revealed that the outbreak of LSD had a non-significant association with the age, sex, breed, health status, and coat color of cattle, but genotype of breed, age of calf, and immune status of animal have a significant association with occurrence and distribution of LSD. This study also revealed that management-level variables like farm size, farming system, separation of the affected animal, use of common utensils, and introduction of new cattle have non-significant effects on the occurrence and distribution of LSD, but separation place, use of the vaccine, and season of the year have significant association outbreak of LSD. Therefore, the potential risk factors for LSD outbreak included- genotype of breed, age of calf, immune status of animal, separation place of affected animal, and season of year. Thus, for prevention and control of this melody necessary action should be taken against those factors. The results of this study could serve as a cornerstone for constructing a necessary framework to control and prevention of this pandemic challenge. For proper preventive measures and control strategy, we should work on the data of another area along with biochemical, histopathological, and molecular studies of this disease.

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