



## Prevalence and Associated Infection Risk Factors of Tick-Borne Hemoparasites in Cattle and Buffalo

Syed Abdullah Bukhari<sup>1</sup>, Muhammad Taimoor<sup>2\*</sup>, Sarwat Tahira<sup>3</sup>, Asad Ali Alamgir<sup>4</sup>

<sup>1</sup>Faculty of Veterinary Sciences, Bahauddin Zakariya University, 61000-Multan, Pakistan

<sup>2</sup>Research and Development Division, Veterinary Research Institute, Zarrar Shaheed Road, Lahore Cantt-54810, Pakistan

<sup>3</sup>Provincial Diagnostic Laboratory, Livestock & Dairy Development Department, 54000-Lahore, Pakistan

<sup>4</sup>Institute of Animal and Dairy Science, Faculty of Animal Husbandry, University of Agriculture, Faisalabad-38040, Pakistan

\*Correspondence: [dr.taimoor7@gmail.com](mailto:dr.taimoor7@gmail.com)

### Article Info

**Keywords:** Hemoparasites, *Theileria*, *Babesia*, *Anaplasma*, *Trypanosoma*, Cattle, Buffalo

### Date:

Received: 28 August 2025

Accepted: 10 November 2025

Published: 15 December 2025

Volume: 05, 2025



**Copyright:** © 2025 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions. (<https://creativecommons.org/licenses/by/4.0/>).

### Abstract

*Theileria*, *Babesia*, and *Anaplasma* species caused haemoparasitic infections which represent major constraints to cattle and buffalo productivity in subtropical and tropical areas. This study has evaluated the prevalence and risk factors of these hemoparasites in Lahore District, Punjab, Pakistan, through microscopic examination of blood smears of 2,176 cattle and buffaloes, with reference to associated risk factors, including age, sex, and management system. The total prevalence was 10.3% (224/2,176 positive samples). Among positive *Theileria* spp. were the most predominant positives (94.6% 212/224), followed by *Babesia* spp. (3.6% 8/224), and *Anaplasma* spp. (1.8% 4/224) meanwhile, there were no positive results of *Trypanosoma* spp. or mixed infections. The rates of infection were notably higher in animals below 2 years of age (15.6%, 109/700) than in those at age 2 years and older (7.8% 115/1476;  $p=0.001$ ) and in females (11.6%, 160/1376) than in males (8.0, 64/800;  $p=0.01-0.04$ ), probably because of immunological immaturity and reproductive stress. The prevalence of animals in extensive/ grazing systems was almost twice (13.9%, 136/976) when compared to semi-intensive stall-fed systems (7.3%, 88/1200;  $p=0.003$ ), and this indicates higher exposure to ticks in open grazing. These results affirm that tropical theileriosis is endemic in peri-urban Punjab with less burdens of babesiosis and anaplasmosis potentially attributed to the ecological conditions of vectors and their management. The microscopy is probably underestimating actual prevalence because there is low parasitemia in the carriers.

### Introduction

Among the greatest limitations to livestock productivity in the tropical and subtropical areas are the tick-borne hemoparasitic infections, mainly due to the *Theileria*, *Babesia* species, and *Anaplasma* species. They cause anemia, fever, lymphadenopathy, and significant production losses, which ultimately decrease milk yield, growth, affect

fertility, and survival and are transmitted by ixodid ticks, including *Hyalomma* and *Rhipicephalus* spp (Asif et al., 2022; Sultan et al., 2022). The epidemiology of such infections is multifactorial and is based on the climatic conditions, abundance of vectors, susceptibility of hosts, and management practices (Ahmad et al., 2023). One of these pathogens is *Theileria annulata*, the causative agent of

**How to cite:** Bukhari S A., Taimoor M., Tahira S, Alamgir AA, 2025. Prevalence and Associated Infection Risk Factors of Tick-Borne Hemoparasites in Cattle and Buffalo, *Frontiers in Microbiology and Biotechnology* 5, 1-8. DOI: <https://doi.org/10.54219/fmb.05.01.2025.325>

tropical theileriosis, which is so far one of the most economically devastating bovine diseases in Asia, and in particular, in Pakistan (Vale et al., 2021). Infected animals exhibit pyrexia, anemia, enlargement of superficial lymph nodes, and high mortality in susceptible cattle breeds. Recent molecular surveys have reported *T. annulata* prevalence ranging from 15% to 33% across Punjab Province, underscoring its endemic status and continued impact on livestock health (Sultan et al., 2022).

Bovine babesiosis is caused by *Babesia* species and predominantly by *B. bovis* and *B. bigemina* which lead to intravascular hemolysis, hemoglobinuria, and anemia. The disease causes significant economic losses in the endemic regions, with the regional prevalence range of 10-35% (Ahmad et al., 2023; Khan et al., 2020). Crossbred cattle are frequently more susceptible than indigenous breeds, because they have less adaptive immunity (Ahmad et al., 2023). On the same note, *Anaplasma marginale*, the causative agent of bovine anaplasmosis, induces gradual *anaemia*, weight loss, abortion and reduction in milk production. Reported prevalence in Pakistan has ranged between 8% and 25% and depends on age, sex, season and level of tick infestation (Badshah et al., 2023). *Theileria*, *Babesia*, and *Anaplasma* co-infections are common and contribute to worse clinical outcomes making the diagnosis more difficult (Atif et al., 2025). Host-related factors such as age and sex are critical determinants of infection risk. Younger animals are more susceptible due to immature immunity, while females may be predisposed because of physiological stress during lactation and gestation (Ullah et al., 2021). The tick exposure and infection dynamics are also modulated by specific environmental and management aspects especially the dichotomy between the extensive grazing and intensive stall-feeding. Changing climatic conditions and changing husbandry systems also change the ecology of vectors, which might increase the range of distribution and spread of diseases (Asif et al., 2022).

The Lahore District in Punjab, Pakistan is a high-risk area because it has abundant livestock and possesses mixed farming systems. Although cattle and buffalo production have been crucial in this area, updated information on disease and risk factors of tick-borne hemoparasites is limited. The most commonly used diagnostic method in the majority of field laboratories is microscopy, but it is not sensitive enough to identify carrier or low-parasitemia infections. Molecular tests like polymerase chain reaction (PCR) have better sensitivity and specificity and may facilitate detection of subclinical infections (Atif et al., 2025). Thus, the purpose of the study was to identify the prevalence and distribution of the species of *Theileria*, *Babesia*, and *Anaplasma* in the cattle and buffalo populations of Lahore District, Punjab, Pakistan, and to measure how the factors related to the host (age, sex) and

management practices (grazing versus stall-feeding) influenced the risk of infection. The results will be useful in promoting evidence-based tick and disease control interventions necessary for achieving sustainable livestock production in the area.

## Materials and Methods

### Study Area and Duration

The research area targeted was district Lahore, Punjab, Pakistan, located between 31°15' - 31°45' north-south and 74°01' - 74°39' east-west with an elevation of about 214m, where the weather is hot semi-arid or humid subtropical, with temperatures ranging between -2°C to 48°C. The district was chosen due to abundant livestock populations, and high hemoparasitic infection rates reported clinically in the district (Ali et al., 2020). Throughout the course of the study, blood samples were taken from both clinically suspicious and apparently healthy animals that attended the local veterinary hospitals and field clinics (Orono et al., 2019).

### Sample Collection

The study collected 2,176 blood samples of cattle and buffaloes. Aseptically, 5 ml disposable syringes were used to collect blood samples from the jugular vein. Samples were taken in vacutainer tubes with EDTA anticoagulant (ATLAS-LABOVAC, Pakistan) to prevent coagulation and preserve cell morphology following standard protocols (Atif et al., 2023). Each sample was labeled with animal ID, location, and collection date. Alongside sample collection, epidemiological data such as species (cattle or buffalo) and management system were recorded for each animal using a structured questionnaire. This categorization allowed assessment of potential risk factors for hemoparasitic infection (Eygelaar et al., 2015). The samples taken were put in an ice box (4-8°C), transported within 24 hours to be examined under the microscope.

### Preparation of Blood Smears

Clean and grease-free glass slides were used to prepare thin blood smears. The smears were left to be air-dried and then fixed in absolute methanol for a 2-minute period and then stained using 10% Giemsa stain for 30 minutes. Stained slides were then washed with buffered distilled water (pH 7.2), dried under air and placed in slide boxes until microscopic analysis as described in other hemoparasite studies (Khan et al., 2004).

### Microscopic Examination

The slides were observed under compound microscope at 40x and oil-immersion 100x objective lens. A minimum of 50 microscopic fields per slide were observed in order to

detect accurately. The identification of the parasites was conducted on the basis of morphological characteristics including shape, size, location in the erythrocytes, and staining patterns based on conventional parasitological keys (Ali et al., 2020). Particular identification was for *Theileria* spp., *Babesia* spp., *Anaplasma* spp., and *Trypanosoma* spp.

Detection of Mixed Infections

Animals showing more than one type of hemoparasite within the same blood smear were categorized as mixed infections. Prevalence of each type of parasite was determined individually and in combination in the cases of mixed infections. Other bovine hemoparasite surveys have also reported mixed infections in Pakistan (Khan et al., 2004).

Data Recording and Analysis

A structured record sheet was included with all of the collected samples including animal species (cattle or buffalo) and location. The presence or absence of hemoparasites of the genera *Babesia*, *Theileria*, *Anaplasma*, and *Trypanosoma* was observed. The occurrence of each parasite was determined as a percentage of positive cases within the total number of specimens of animals examined in general and by host species. Descriptive statistics were used to analyze the data to get the prevalence rates, Chi-square test was used to compare the groups on categorical variables. The statistical significance was determined at  $p < 0.05$  (Thrusfield et al.,2018).

Results

Prevalence of Hemoparasites

Out of 2,176 blood samples collected from Lahore, 224

(10.29%) were found positive for hemoparasites based on microscopic examination. Among the identified hemoparasites, *Theileria* spp. was predominant, accounting for 94.6% (212/224) of total positive samples. In contrast, *Babesia* spp. and *Anaplasma* spp. were detected in only 8 (3.57%) and 4 (1.7%) cases, respectively, while *Trypanosoma* spp. and mixed infections were not observed, as shown in Table 1.

Age-wise prevalence of Hemoparasites

Age-related distribution showed that young animals (<2 years) were more susceptible to hemoparasitic infections than adults ( $p < 0.05$ ), possibly due to underdeveloped immunity and higher exposure during grazing, as shown in Table 2.

Sex-wise prevalence of Hemoparasites

Sex-based differences in infection prevalence were also evident. Female animals had a prevalence of 11.6%, compared to 8.0% in males, which shows that females are more prone to parasitic infections than males (Table 3). These results imply that the physiological stress of lactation and pregnancy increases susceptibility to hemoparasitic infections in females.

Management system and prevalence of hemoparasites

Animals under grazing or extensive systems showed significantly higher prevalence (13.9%) compared to semi-intensive stall-fed animals (7.3%) (Table 4).

Table 1. Prevalence of Hemoparasites in Lahore

| District | Total samples | Total Positive (%) | <i>Theileria</i> (%) | <i>Babesia</i> (%) | <i>Anaplasma</i> (%) | <i>Trypanosoma</i> (%) | Mixed Infections (%) |
|----------|---------------|--------------------|----------------------|--------------------|----------------------|------------------------|----------------------|
| Lahore   | 2176          | 224 (10.29%)       | 212 (94.6%)          | 8 (3.57%)          | 4 (1.78%)            | 0                      | 0                    |

Table 2. Age-related Distribution of Hemoparasite Infections in Lahore

| Age group | No. examined | No. positive | Prevalence (%) | <i>p-value</i> |
|-----------|--------------|--------------|----------------|----------------|
| <2 years  | 700          | 109          | 15.6           | 0.001          |
| ≥2 years  | 1476         | 115          | 7.8            | 0.02           |
| Total     | 2176         | 224          | 10.3           | —              |

Table 3. Sex-related Distribution of Hemoparasitic Infections in Lahore

| Sex    | No. examined | No. positive | Prevalence (%) | <i>p-value</i> |
|--------|--------------|--------------|----------------|----------------|
| Male   | 800          | 64           | 8.0            | 0.01           |
| Female | 1376         | 160          | 11.6           | 0.04           |
| Total  | 2176         | 224          | 10.3           | —              |

Table 4. Management System and Hemoparasitic Infections in Lahore

| Management type            | No. examined | No. positive | Prevalence (%) | <i>p-value</i> |
|----------------------------|--------------|--------------|----------------|----------------|
| Stall-fed (semi-intensive) | 1200         | 88           | 7.3            | 0.01           |
| Grazing/Extensive          | 976          | 136          | 13.9           | 0.003          |
| Total                      | 2176         | 224          | 10.3           | —              |

## Discussion

The present study revealed an overall hemoparasite prevalence of 10.29% in large ruminants from Lahore, with *Theileria* spp. being the most frequently detected parasite. This predominance is consistent with earlier reports from Punjab and neighboring regions, where tropical theileriosis is regarded as the most prevalent tick-borne disease of cattle and buffaloes (Ali et al., 2020; Jabbar et al., 2015). The same trends were reported by Khan et al. (2004) who indicated that, there was a high prevalence of *Theileria annulata*, on the basis of microscopic detection (Khan et al., 2004). The large burden in Lahore is consistent with previous findings indicating that intensive farming and tropical climatic conditions were linked to an increase in tick populations and, thus, increasing risk of transmission (Atif et al., 2023). The infection was more common in cattle than in buffaloes, which aligns with past studies that have indicated that zebu and crossbred cattle tend to be more susceptible to tick-borne hemoparasites than riverine buffaloes (Ghafar et al., 2021; Jabbar et al., 2015). This disparity has been explained by differences in innate immunity, skin thickness and grooming behavior.

The prevalence of *Babesia* in Lahore (8/224) (3.57%) is very low, which may be attributed to the local ecology and the composition of the vectors. This aligns with previous findings where *Babesia bigemina* was detected at low to moderate levels in Punjab, typically ranging from 5–15% (Atif et al., 2012; Khan et al., 2004). *Rhipicephalus (Boophilus) microplus*, the principal vector of *B. bigemina*, is more abundant in irrigated and riverine zones; peri-urban Lahore, with semi-intensive farming and less suitable habitat for that tick, would therefore have a reduced *Babesia*

transmission potential. Differences in acaricide practices and host breed also influence *Babesia* occurrence. The higher infection prevalence in grazing animals (13.9%) compared to stall-fed (7.3%) in our study supports this ecological explanation, as grazing increases contact with tick-infested pastures. Studies reported significantly higher *Babesia* and *Theileria* infection rates in animals managed under extensive grazing systems (Atif et al., 2012; Selim et al., 2020).

*Anaplasma* spp prevalence (1.78%) in this study was also lower than previously documented rates of 6–18% in central Punjab (Atif et al., 2012). These differences may reflect variations in tick vector distribution, management systems, or host susceptibility. The lack of *Trypanosoma* spp. in the present study aligns with previous findings that show bovine trypanosomiasis is infrequent in Pakistan due to their association with insect vector presence at different places (Jabbar et al., 2015). It is also interesting that *Anaplasma* spp. was detected with a rather low prevalence (1.78%). Previous research in central Punjab had found higher rates, e.g., 12.5% in Sargodha (Atif et al., 2012). This can be explained by the variation in the species composition of the vectors ticks, sensitiveness of the diagnostic methods, or management approaches. Moreover, carrier animals carrying parasites that cannot be microscopically seen can be detected by molecular techniques, like PCR, which implies that the actual prevalence of the problem in Lahore is potentially lower than expected (Ashraf et al., 2013). We also reported a higher prevalence in females (11.6%) over males (8.0%) which could be due to reproductive and metabolic stresses related to lactation and pregnancy. Similar sex - based susceptibility has been reported by

(Kamani et al., 2010) in Nigeria (Masum et al., 2021) in Bangladesh, highlighting that physiological stress may reduce immune competence against tick-borne hemoparasites. The absence of *Trypanosoma* spp. supports earlier reports that bovine trypanosomiasis is not endemic in Punjab, unlike in northern areas of Pakistan, where tsetse-like mechanical vectors (e.g., tabanids) are more common (Desquesnes et al., 2013). This absence reduces the immediate concern of trypanosomiasis for Lahore, but surveillance should continue as climate and vector ecology shift under global warming scenarios.

The strong predominance of *Theileria* spp. observed in this study is in line with the endemic status of tropical theileriosis in South Asia. Studies in India and Bangladesh have similarly reported *Theileria annulata* as the leading hemoparasite in cattle, with prevalence ranging between 15–45% depending on season and management (Selim et al., 2020). The high prevalence observed in Lahore may be linked to the peri-urban dairy farming model, where animals are kept under semi-intensive systems with frequent tick exposure and limited acaricide use. Our age-stratified analysis further confirmed that calves and young animals (<2 years) had markedly higher prevalence (15.6%) compared to adults (7.8%). This finding supports previous observations by (Ullah et al., 2021) in Khyber Pakhtunkhwa and (Glass et al., 2003), who noted that younger animals are immunologically naive and thus more prone to haemoparasitic infections.

Host age and management practices were seen to affect the prevalence of haemoparasitic infections in the current study. It is always seen that young animals especially those less than two years of age are more susceptible to *Theileria annulata* and other hemoparasites, owing to incomplete protection immunity and higher chances of tick contact during grazing. On the other hand, old animals can be reservoirs, where they will contain subclinical infections that can be detected through molecular approaches but not necessarily on microscopy. The age-specific prevalence was studied, and the results indicated that the young (<2 years) animals had a significantly higher infection rate of 15.6% in comparison to adults (7.8%). This trend has been observed in past literature which has reported calves and young stock as more vulnerable as they have less immunity and higher susceptibility to tick attack during grazing. As an example, (Ullah et al., 2021) found that the infection rates of *Theileria annulata* were much higher in calves than in adult cattle in Khyber Pakhtunkhwa, Pakistan. On the same note, (Glass et al., 2003) emphasized that *Bos indicus* calves have partial resistance to *Bos taurus* breeds, although; general susceptibility is increased in younger calves until immunity is established. These results indicate that specific

tick management of young stock would have a significant impact on the general disease burden.

There are also breed-related susceptibilities i-e, Exotic breeds and cross-breeds were more prone than indigenous breeds, which is consistent with the previously reported evidence that *Bos indicus* breeds (such as Sahiwal) are partially resistant to *T. annulata* by default (Parveen et al., 2021). Such results assist in understanding why differences at the district level are common with the breed composition being different in different regions. Furthermore, seasonal influences cannot be overlooked. The prevalence in the Layyah was higher during summer (when the density of ticks is the highest), whereas infection rates were lower in winter (Parveen et al., 2021). The patterns may also be behind the comparatively moderate prevalence observed in Lahore in the current study depending on time of collection of sample.

There are contradictions in comparing *Babesia* prevalence (3.57%) with the one reported in the southern Punjab, where it has been observed to be as high as 18% (Ali et al., 2020). This may be as a result of a change in ecological conditions, that affects the abundance of the most important *Rhipicephalus* (*Boophilus*) *microplus*, the major parasite of *B. bigemina*, which is more widespread in irrigated and riverine regions than in the peri-urban Lahore habitat. Similarly, in Lahore, no mixed infection was found, which could be associated with low levels of vectors or competitive segregation among hemoparasites. The management-related results of this study indicate that semi-intensive stall-fed systems continue to demonstrate moderate prevalence (7.3%), and grazing systems have almost doubled the risk of infection (13.9%). The findings confirm a great parasitism rate in intensively grazed livestock in Pakistan, and emphasize the need to deploy integrated tick management approaches based on the characteristics of diverse management systems.

## Conclusion

This study demonstrates that *Theileria* spp. is highly prevalent in Lahore, and the level of *Babesia* and *Anaplasma* is lower with no *Trypanosoma* or mixed infections. Infection rates were more frequent in younger animals (<2 years old), as well as females, which means that specific control, nutritional assistance and supervision during pregnancy and lactation are necessary. There was almost twice the rate of infection of grazing animals compared to stall-fed animals, showing the effect of husbandry practices. Tick control, education of farmers, the use of acaricides, rotation of grazing and the preference for raising tick-resistant breeds of livestock animals are essential in order to mitigate losses. The dependence on

microscopy should have probably underestimated actual prevalence and thus it is advisable that molecular diagnostics and additional risk factor research be conducted to ensure effective control and optimal livestock productivity sustainability.

## Funding

No funding was received for this study.

## Acknowledgment

None

## Conflict of Interest

The authors declare no conflict of interest.

## Authors' Contribution

Conceptualization, Muhammad Taimoor; Writing—original draft preparation, Syed Abdullah Bukhari, Muhammad Taimoor, Sarwat Tahira, Asad Ali Alamgir; Writing—review and editing, Syed Abdullah Bukhari, Muhammad Taimoor, Sarwat Tahira, Asad Ali Alamgir; All authors have read and agreed to the published version of the manuscript.

## References

- Ahmad, A., Ali, Z., & Lashari, M. H. (2023). Study on spatio-temporal prevalence and hematological attributes of bovine Babesiosis in cattle population of Layyah, Southern Punjab, Pakistan. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 75(05), 787-799.
- Ali, S., Ijaz, M., Ahmed, A., Aziz, M., Naveed, M., Javed, M., Nawab, Y., Ghumman, N., & Ghaffar, A. (2020). Prevalence and associated risk factors of bovine babesiosis in Lahore, Pakistan. *Agrobiol Records*, 2, 17-23.
- Ashraf, Q. U., Khan, A. U., Khattak, R. M., Ali, M., Shaikh, R. S., & Iqbal, F. (2013). A report on the high prevalence of *Anaplasma* sp. in buffaloes from two provinces in Pakistan. *Ticks and tick-borne diseases*, 4(5), 395-398.
- Asif, M., Said, M. B., Parveen, A., Ejaz, A., Ikram, M., Awais, M. M., Ozubek, S., Aktas, M., Baber, M., & Iqbal, F. (2022). Seasonal survey, risk factor's analysis and genotyping of *Theileria annulata* infecting cattle in Punjab province, Pakistan. *Acta tropica*, 234, 106587.
- Atif, F., Hussain, K., Iqbal, U., Roheen, T., Jabbar, M., & Tahir, A. (2025). Evaluation of Vector competence of adult Ixodid ticks for *Anaplasma marginale*, *Babesia bigemina* and *Theileria annulata* in cattle

from central punjab, pakistan. *Journal of Animal & Plant Sciences*, 35(5), 1446-1456.

- Atif, F. A., Khan, M. S., Iqbal, H. J., Arshad, G. M., Ashraf, E., & Ullah, S. (2012). Prevalence of *Anaplasma marginale*, *Babesia bigemina* and *Theileria annulata* infections among cattle in Sargodha District, Pakistan. *Afr. J. Agric. Res*, 7(22), 3302-3307.
- Atif, F. A., Nazir, M. U., Abbas, R. Z., Mehnaz, S., Saeed, M. A., & Said, M. B. (2023). Molecular epidemiology, associated risk factors, and phylogeny of *Theileria annulata* infecting buffaloes and cattle from different agro-climatic regions of Punjab, Pakistan. *Iranian Journal of Veterinary Research*, 24(3), 247.
- Badshah, F., Ullah, K., Kamal, M., Rafiq, N., Usman, T., De los Rios-Escalante, P. R., & Said, M. B. (2023). Epidemiological analysis of anaplasmosis in cattle from Khyber Pakhtunkhwa, Pakistan. *Veterinary World*, 16(11), 2287.
- Desquesnes, M., Holzmüller, P., Lai, D.-H., Dargantes, A., Lun, Z.-R., & Jittaplapong, S. (2013). *Trypanosoma evansi* and *surra*: a review and perspectives on origin, history, distribution, taxonomy, morphology, hosts, and pathogenic effects. *BioMed research international*, 2013(1), 194176.
- Eyelaar, D., Jori, F., Mokopasetso, M., Sibeko, K. P., Collins, N. E., Vorster, I., Troskie, M., & Oosthuizen, M. C. (2015). Tick-borne hemoparasites in African buffalo (*Syncerus caffer*) from two wildlife areas in Northern Botswana. *Parasites & vectors*, 8(1), 26.
- Ghaffar, A., Gasser, R. B., Abbas, T., Rehman, A., Gauci, C. G., & Jabbar, A. (2021). Ticks and tick-borne diseases of bovines in a smallholder livestock context: The Pakistani example. *Advances in Parasitology*, 114, 167-244.
- Glass, E. J., Craigmile, S. C., Springbett, A., Preston, P. M., Kirvar, E., Wilkie, G. M., Eckersall, P. D., Hall, F. R., & Brown, C. D. (2003). The protozoan parasite, *Theileria annulata*, induces a distinct acute phase protein response in cattle that is associated with pathology. *International Journal for Parasitology*, 33(12), 1409-1418.
- Jabbar, A., Abbas, T., Sandhu, Z.-u.-D., Saddiqi, H. A., Qamar, M. F., & Gasser, R. B. (2015). Tick-borne diseases of bovines in Pakistan: major scope for future research and improved control. *Parasites & vectors*, 8(1), 283.
- Kamani, J., Sannusi, A., Egwu, O., Dogo, G., Tanko, T., Kemza, S., Tafarki, A., & Gbise, D. (2010). Prevalence and significance of haemoparasitic

- infections of cattle in North-Central, Nigeria. *Veterinary World*, 3(10), 445-448.
- Khan, A., Noushin, R., Attaullah, M., Khan, S. N., Hussain, R., Dawar, F. U., Rehman, F. U., Ijaz, M., & Ullah, K. (2020). Prevalence of tick-borne Babesia infection in domestic cattle of Khyber Pakhtunkhwa, Pakistan. *Pak J Zool*, 52(6), 2401-2403.
- Khan, M., Zahoor, A., Jahangir, M., & Mirza, M. A. (2004). Prevalence of blood parasites in cattle and buffaloes. *Pak. Vet. J*, 24(4), 193-194.
- Masum, M. R. (2021). Prevalence of common hemoprotozoan diseases of cattle in Pabna district of Bangladesh.
- Orono, S. A., Gitao, G. C., Mpatwenumugabo, J. P., Chepkwony, M., Mutisya, C., Okoth, E., Bronsvort, B. M. d. C., Russell, G. C., Nene, V., & Cook, E. A. J. (2019). Field validation of clinical and laboratory diagnosis of wildebeest associated malignant catarrhal fever in cattle. *BMC Veterinary Research*, 15(1), 69.
- Parveen, A., Ashraf, S., Aktas, M., Ozubek, S., & Iqbal, F. (2021). Molecular epidemiology of *Theileria annulata* infection of cattle in Layyah District, Pakistan. *Experimental and Applied Acarology*, 83(3), 461-473.
- Selim, A., Das, M., Senapati, S., Jena, G., Mishra, C., Mohanty, B., Panda, S., & Patra, R. (2020). Molecular epidemiology, risk factors and hematological evaluation of asymptomatic *Theileria annulata* infected cattle in Odisha, India. *Iranian Journal of Veterinary Research*, 21(4), 250.
- Sultan, S., Zeb, J., Ayaz, S., Rehman, S. U., Khan, S., Hussain, M., Senbill, H., Husain, S., & Sparagano, O. A. (2022). Epidemiologic profile of hard ticks and molecular characterization of Rhipicephalus microplus infesting cattle in central part of Khyber Pakhtunkhwa, Pakistan. *Parasitology research*, 121(9), 2481-2493.
- Thrusfield, M. (2018). *Veterinary epidemiology*. John Wiley & Sons.
- Ullah, R., Shams, S., Khan, M. A., Ayaz, S., Akbar, N. u., Din, Q. u., Khan, A., Leon, R., & Zeb, J. (2021). Epidemiology and molecular characterization of *Theileria annulata* in cattle from central Khyber Pakhtunkhwa, Pakistan. *PloS One*, 16(9), e0249417.
- Vale, D. L., Lage, D. P., Machado, A. S., Freitas, C. S., de Oliveira, D., Galvani, N. C., Fernandes, B. B., Luiz, G. P., Oliveira, J. S., & Oliveira-da-Silva, J. A. (2021). Serodiagnosis of canine leishmaniasis using a novel recombinant chimeric protein constructed with distinct B-cell epitopes from antigenic *Leishmania infantum* proteins. *Veterinary Parasitology*, 296, 109513.

**Disclaimer/Publisher's Note:** The views, opinions, and data presented in all publications are exclusively those of the respective author(s) and contributor(s) and do not reflect the stance of Pagepal or its editorial team. Pagepal and the editor(s) disclaim any responsibility for harm to individuals or damage to property resulting from the use of any ideas, techniques, instructions, or products mentioned in the content.