REVIEW ARTICLE
AGROBIOLOGICAL RECORDS
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

BRIEF ACCOUNT OF BOVINE THEILERIOSIS PREVALENCE IN SOME SOUTH ASIAN COUNTRIES

M Arfan Zaman[1], Uzma Mehreen[1], Warda Qamar[1], M Fiaz Qamar[1], Muhammad Kashif[1], Zohaib Shahid[1] and Rao Zahid Abbas[2]

[1]Department of Pathobiology, College of Veterinary and Animal Sciences, Jhang, Sub-campus University of Veterinary and Animal Sciences, Lahore-Pakistan; [2]Department of Parasitology, Faculty of Veterinary Sciences, University of Agriculture, Faisalabad, Pakistan

*Corresponding author: *arfan.zaman@uvas.edu.pk*

ABSTRACT

Theileriosis is an intracellular parasitic disease in tropical and subtropical countries and acts as a potential killer causing major constraint on animal's productions leading to high morbidities and even mortalities. This review presents the actual status of Bovine Theileriosis (BTH) and their associated risk factors in Pakistan, China, India, Iran, and Bangladesh. Within this review also ascertains the correlation of BTH with tick abundance, seasonality, and cattle susceptibility. To identify the related papers from different internet databases including Google Scholar, Science Hub, PubMed, Science Direct and Scientific Information database were appraised for articles published during last decade. The research data collected from 5 Asian countries indicate highly variable prevalence of BTH ranging from 2.69-39%. Based on critical analysis of current data (2000-2019) of 5 Asian countries, the highest prevalence rate of BTH was recorded in China (39%) followed in order by Iran (33%), India (31.7%), Pakistan (21.2%) and Bangladesh (2.69%). The difference can be attributed to the ecological and graphical factors and may be different in housing systems. Main vector involves in the transmission of Theileriosis was *Hyalomma* (80%). June through September was the most favorable months for Theileriosis in all the Asian countries' understudies. Exotic cattle were observed more prone to BTH than local breeds. As far as diagnostic techniques were concerned, understudies data showed that in Asian countries the most adopted method for the diagnosis BTH was the conventional method (41%) after this, polymerase chain reaction (PCR) (21%) and serological mixed techniques (23%) were used. Our results suggested updates and highlight the imperative information on the true burden of BTH in some Asian countries.

Keywords: Bovine Theileriosis, Prevalence, PCR, Giemsa staining, Ticks

Article History (2020-0413): Received: 16 Apr 2020 || Revised: 20 May 2020 || Accepted: 28 June 2020 || Published Online: 08 July 2020

INTRODUCTION

Globally, dairy animals have been facing a lot of infectious threats (Haque et al. 2018; Pervez et al. 2018) and Bovine Theileriosis (BTH) is considered as the most significant one among parasitic diseases (Jenkins 2018). They are of great economic impact on livestock affecting 80% of the world cattle population and cause economic losses due to high morbidity and mortality (Kasozi et al. 2014). Genus *Theileria* is distinguished due to its unique organelles called apical complex (Liu et al. 2016; Storey et al. 2018). About 250 million cattle are at risk to tropical Theileriosis worldwide (Erdemir et al. 2012). Among other *Theileria* species, *Theileria parva* and *Theileria annulata* are the most pathogenic (Kohli et al. 2016). Season or environment condition has been found as one of the important risk factor that affects the prevalence of this parasite. Being located in the sub-tropical zone, a major part of the Asian countries including Pakistan, China, India, Iran, and Bangladesh has favorable environmental conditions for tick infestations. This situation coupled with a lack of proper management practices leads to heavy economic losses (Ayadi et al. 2016; Kerario et al. 2018; Elsheikha et al. 2019). Against this backdrop, an attempt is made to review the current picture of the prevalence of BTH in different parts of Pakistan, China, India, Iran, and Bangladesh. This review also intended to compare the best diagnostic techniques (microscopy, polymerase chain reaction (PCR) and loop-mediated isothermal amplification (LAMP). Current status of BTH principal pathogens, principal hosts, principal vectors, and distribution in Asian countries is also provided (Table 1).

1. Epidemiology

The most studied Theileriosis in Pakistan is the Bovine Theileriosis. To date 28% of studies for Pakistan and 71% of International studies of China, India, Iran, and Bangladesh were reported about the prevalence of Theileriosis. Most studies of *Theileria* were conducted in cattle than in buffaloes. These studies were carried out

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

mainly on sub-clinical infected animals located either on public livestock research centers, or on private dairy farms in the approachable range of veterinary institutes (Colleges, hospitals or Research institutions). Convenient methods for collection of blood samples were used in all of these studies (Tables 2 to 6).

Although epidemiological studies provide some insights, the interpretation from various investigations but all studies do not consider the all other factors which play important role for increasing the prevalence of tick-borne diseases like seasons, structure of bovine populations, methods for diagnostic techniques, sampling strategies. In this review most of the studies were conducted to determine the prevalence of Theileriosis regarding season, sex, age and methods used for diagnosis of the BTH. In Pakistan, the highest prevalence (96.5%) was recorded in June and the lowest in September (5.14%) while in China, the highest prevalence (67.5%) was recorded in August and lowest in April (Table 7).

Table 1: Bovine Theileriosis: Principal pathogens, principal hosts (cattle and Asian buffalo), principal vectors, and distribution and potential vectors in Asia

Principle pathogens	Principle Tick vectors	Distribution	Possible tick vectors in Asian countries	References
Theileria Annulata	*Hyalomma detritum detritum,* *H. anatolicum* *H. dromedarii* *H. lusitanicum*	Southern Europe, Middle East, North Africa, Sudan, Central Asia, and Indian subcontinent	*H. anatolicum anatolicum* *H. dromedarii,* *H. marginatum marginatum*	Durrani et al. (2008) Darghout et al. (2010)
T. parva	*Rhipicephalus appendiculatus* *R. zambeziensis.*	Eastern, central and southern part of Africa	N/A	Durrani et al. (2008)
T. mutans	*Amblyomma spp.*	Sub-Saharan Africa	N/A	Figueroa et al. (2010) Jabbar et al. (2015)
T. orientalis	*Haemaphysalis longicornis*	Cosmopolitan	N/A	Sajid et al. (2008)
T. velifera	*Amblyomma spp.*	Sub-Saharan Africa	N/A	Chaisi et al. (2013)

Table 2: List of key studies of Bovine Theileriosis in Pakistan

Host	Location	Study population and sampling design	Detection method	Sampling period	Positive animals (%)		References
					Cattle	Buffalo	
Cattle (Red Sindhi, Dhani and cross breeds)	Faisalabad	Suspected animals from local areas	Blood smear (BS)	Apr-July	9.2	N/A	Saleem et al. (2014)
Cattle (Bos indicus) Buffalo (Babulus, bubalis)	Peshawar	Research institute Parasitological Laboratory	Blood smear PCR (Polymerase chain reaction)	`June	69.23	27.27	Rashid et al. (2018a)
Holstein Friesian	Rajanpur	Private Commercial dairy farm	Blood Smear, PCR	June 2015	41.5	N/A	Rashid et al. (2018b)
Cattle (local breed)	Chakwal, Faisalabad, Jhang	Private dairy farm local	PCR and recombinant PCR	N/A	7.66	N/A	Hassan et al. (2018)
Cattle (local breed)	Kohat, Peshawar	Private dairy farm local	Blood smear	Nov-Feb 2011	BS 5.3 PCR 34	N/A	Khattak et al. (2012)
Cattle (exotic, local)	Sargodha, Rawalpindi, Khushaab	Private farms local	Blood smear	Sep-Aug	5.14	N/A	Atif et al. (2012)
Cattle (exotic, local)	Sargodha	Private farms local	Blood smear	Aug 2008 July 2009	B.S 6.7 Mixed 26	N/A	Atif et al. (2012)
Buffalo cattle (local)	Vehari Muzaffargarh Bahawalnaga rMultan Bakhar, Layyah	Private farms local	Blood smear, PCR	N/A	BS 3 PCR 19	N/A	Shahnawaz et al. (2011)
Jersey and Holstein Friesian	Sahiwal	Private farms local	Blood smear	Sep 2009	38.3	N/A	Qayyum et al. (2010)
Friesian cattle	Kasur	Private farms local	Blood smear, PCR	N/A	BS 14 PCR36	N/A	Durrani et al. (2008)
Buffalo	Lahore	Suspected from private farms	Blood Smear	Sep 2003	17.5	N/A	Durrani et al. (2006)

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Table 3: List of key studies of Bovine Theileriosis in cattle in different areas of China

Location	Study population and sampling design	Detection method	Sampling period	Positive Animals (%)		References
				Cattle	Buffalo	
Qingyuan Moaming (Guangdong China Province)	Randomly selected	Smear method, PCR, ELISA	Aug 2016	67.5	N/A	Zhao et al. (2017)
Changehun, Jilin (Jilin China Province)	Randomly selected	Smear method, PCR, ELISA	2016	67.3	N/A	Zhao et al. (2017)
Yanan (Shanxi China Province)	Randomly selected	Smear method, PCR, ELISA	2016	47.8	N/A	Zhao et al. (2017)
Linxia, Zhangye (Gansu China province)	Randomly selected	Smear method, PCR, ELISA	2016	43.5	N/A	Zhou et al. (2019)
Lhasa (Tibet China province)	Randomly selected	ELISA	2016	33.3	N/A	Zhou et al. (2019)
Fuling, Tongnan, Khaizou, Rongchang, (Sichuan China province)	Randomly selected	PCR	April 2017	27	N/A	Zhou et al. (2019)
Jiangjin, Wanzhou (Chongqing China province)	Randomly selected	ELISA	2016	26.3	N/A	Zhou et al. (2019)
Qianjiang (Hubai China province)	Randomly selected from apparently healthy animals	PCR	April 2017	6.67	N/A	Zhou et al. (2019)
Changshou (Hunan China province)	Randomly selected	PCR	April 2017	2	N/A	Zhou et al. (2019)

Table 4: List of key studies of Bovine Theileriosis in different areas of India

Host	Location	Study population and sampling design	Detection method	Sampling period	Positive animals (%)		References
					Cattle	Buffalo	
Cattle (Crossbred) and Buffalo	District Gujrat India	Samples from various Veterinary sub centres	Blood smear method	March 2010	82.94	84.29	Vahora et al. (2012)
Cattle	Odisha state India	Samples collected from Veterinary institutes	Giemsa's staining method and PCR	March 2012-Feb 2015	74	N/A	Acharya et al. (2017)
Cattle (Crossbred)	Banglore north India	Sample collected from diseases animals	Blood smear method	July-Oct. 2009	71	N/A	Ananda et al. (2009)
Cattle (Crossbred and Indigenous cattle)	Rajastan India	Sample from clinically suspected cattle	Giemsa's staining method,	Apr 2005-March 2014	42.28	N/A	Bhatnagar et al. (2015)
Cattle (Crossbred) and Buffalo	Telangana state of India	Samples collected under mobile veterinary clinics	Giemsa's staining method	Sep-Dec 2017	38.80	7	Kumar et al. (2018)
Cattle (Crossbred and Indigenous)	Patna Bihar state India	Randomly selected	Giemsa's staining method	May 2015-Apr 2016	31.05	N/A	Kala et al. (2018)
Cattle and Buffalo	Karnatka state India	Randomly selected	Giemsa's staining method	Apr 2012-March 2013	28.8	12.9	Ananda et al. (2016)
Cattle (Crossbred)	Uttarkhand India	Randomly selected form apparently healthy animals	Giemsa staining, PCR	July and Oct. 2012	27	N/A	Afifi et al. (2014)
Cattle (crossbred and native) and Buffalo	Maharashtra state India	Randomly selected	PCR	March 2017	15.8	8.7	Kolte et al. (2017)
Cattle	Mizoram State India (4 different districts)	Randomly selected	Giemsa's staining method	Apr 2017-March 2018	10.75	N/A	Gosh et al. (2018)

Table 5: List of key studies of Bovine Theileriosis in different areas of Iran

Host	Location	Study population and sampling design	Detection method	Sampling period	Positive Animals (%)		References
					Cattle	Buffalo	
Cattle	Ahvaz (Khouzestan Province Iran)	Animals selected from veterinary hospitals	Giemsa's staining method and PCR	June-Sep 2014	86	N/A	Jalali et al. (2016)
Cattle (Holstein Friesian and Sistani)	Sistan (Province Iran)	Randomly selected	Giemsa's staining method and PCR	Jan 2013	46.8	N/A	Majidiani et al. (2016)
Cattle	Dehgolan Iran	Randomly selected from different villages	Giemsa's staining method	2012-2016	27.68	N/A	Hasheminasan et al. (2018)
Cattle (Local breed)	Tabriz Iran	Randomly selected	Indirect Immunoflorescent Assay	June 2009	22	N/A	Farhang et al. (2017)
Cattle (Local breed)	Ardabil (Azarbaijan Province Iran)	Randomly selected	Giemsa's staining method and PCR	June-Sep 2013	15.94	N/A	Yamchi et al. (2016)

Table 6: List of key studies of Bovine Theileriosis in different areas of Bangladesh

Host	Location	Study population and sampling design	Detection method	Sampling period	Positive animals (%)		References
					Cattle	Buffalo	
Cattle (Local breed)	Mimensing District Bangladesh	Randomly selected from different Divisions	Reverse line hybridization assay	2018	55.2	N/A	Roy et al. (2018)
Cattle (Holstein Friesian, crossbred, local breed)	Rajshahi District Bangladesh	Randomly selected from different Areas	ELISA	Nov 2012-Dec 2014	34	N/A	Ali et al. (2016)
Cattle (Crossbred and local)	Sirajgang District Bangladesh	Field diseases Investigation Laboratory	Giemsa's staining method	December 2013-2014	5.82	N/A	Al Mahmud et al. (2015)
Cattle (Local breed)	Dinajpur District Bangladesh	Sadar Upzila veterinary hospitals	Giemsa's staining method	Mar 2016-Feb 2017	0.29	N/A	Mohammad et al. (2017)

In India, the highest prevalence rate was recorded in March (83.36%) and the lowest in April (10.75%). In Iran, the highest prevalence rate was recorded in June (86%) and the lowest in June-September (15.94%). In Bangladesh, the highest prevalence rate was recorded in June (55.2%) and the lowest in Feb-March (0.29%) Figure 1. Overall June through September was the most favorable month for BTH in all the Asian countries' understudies. In Pakistan, overall, four seasons e.g. autumn (Sept-Oct), summer (May-Aug), winter (Nov-Feb) and spring (Mar-Apr) in Pakistan (Atif et al. 2012) are observed. In China, climates conditions tend to be subtropical with annual temperature of 16-18°C with monsoon/humid climate in Chongqing municipality and August is the second warmest month of the year in Qingyuan China (Zhou et al. 2019). India and Iran have most favorable weather for tick activity during monsoon season (June-Sep) as compared to winter and summer. Iran has four complete seasons as compared to other Asian countries (Ananda et al. 2016; Jalali et al. 2016). Bangladesh is hot and humid with conducive climatic conditions except winter, which is a favorable season for tick activity (Al Mahmud et al. 2015). The above-mentioned information regarding to BTH-Season wise prevalence in descending orders for different Areas of Pakistan, China, India, Iran, and Bangladesh is summarized in Table 7.

Comparatively, more studies of BTH were conducted in cattle (76.92%) than in buffaloes (23.07%). These studies were carried out mainly on sub-clinical infected animals located either on public livestock research centers or on private dairy farms in the approachable range of veterinary institutes (Colleges, hospitals or research institutions). Convenient methods for the collection of blood samples were used in all of these studies. The high prevalence rate was detected by using the molecular technique (Polymerase Chain Reaction) than the conventional methods (Staining and serological methods). Many risk factors were identified related to tropical Theileriosis in bovines in Pakistan. There was more susceptibility among the young calves of crossbred cattle. The onset of the clinical disease stared from February, reached its peak in June and abruptly diminished in December through January. The disease was more prevalent in June due to high tick activity (Muhammad et al. 1999; Vahora et al. 2012). Most of the studies were dedicated to determining the prevalence of Theileriosis regarding season, sex, age of the animal. Time to time updates in the evaluation of the efficiency of the control measure of Theileriosis is essential for resource-limited farmers across the world.

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Table 7: Bovine Theileriosis: Season wise prevalence in descending orders for different regions of Pakistan, China, India, Iran and Bangladesh

Country/District	Month	Prevalence (%)			Reference
		Cattle	Buffalo	Total	
Pakistan					
Peshawar	June	69.23	27.27	96.5	Rashid et al. (2018a)
Kasur	NA	50	NA	50	Durrani et al. (2008
Kohat, Peshawar	November	39	NA	39	Khattak et al. (2012)
Sahiwal	September	38.3	NA	38.3	Qayyum et al. (2010)
Sargodha	August	32.7	NA	32.7	Atif et al. (2012)
Lahore	September	NA	17.5	17.5	Durrani et al. (2006)
Vehari, Muzaffarabad Bahawalnagar, Multan, Bhakhar Layyah	NA	12	N/A	12	Shahnawaz et al. (2011)
Rajanpur	June	10.8	NA	10.8	Rashid et al. (2018b)
Faisalabad	April-July	9.2	NA	9.2	Saleem et al. (2014)
Chakwal,Jhang and Faisalabad	NA	7.6	NA	7.6	Hassan et al. (2018)
Sargodha, Rawalpindi, Khushab	September	5.14	NA	5.14	Atif et al. (2012)
China					
Qingyuan, Moaming	August	67.5	N/A	67.5	Zhao et al. (2017)
Changehun, Jilin	August	67.3	N/A	67.3	Zhao et al. (2017)
Yanan	August	47.8	N/A	47.8	Zhao et al. (2017)
Linxia, Zhangye	August	43.5	N/A	43.5	Zhou et al. (2019)
Lhasa	August	33.3	N/A	33.3	Zhou et al. (2019)
Fuling, Tongnan, Khaizou Rongchang	April	27	N/A	27	Zhou et al. (2019)
Jiangjin, Wanzhou	April	26.3	N/A	26.3	Zhou et al. (2019)
Qianjiang	April	6.67	N/A	6.67	Zhou et al. (2019)
Changshou	April	2	N/A	2	Zhou et al. (2019)
India					
Gujrat	March	82.94	84.29	83.36	Vahora et al. (2012)
Odhisha	March	74	N/A	74	Acharya et al. 2017)
Banglore	July	71	N/A	71	Ananda et al. (2009)
Rajastan	April	42.28	N/A	42.28	Bhatnagar et al. (2015)
Telangana	September-December	38.80	7	38.83	Kumar et al. (2018)
Patna Bihar	May-April	31.05	N/A	31.05	Kala et al. (2018)
Karnatka	April	28.8	12.9	28.86	Ananda et al. (2016)
Uttarkhand	July-October	27	N/A	27	Afifi et al. (2014)
Maharashtra	March	15.8	8.7	15.84	Kolte et al. (2017)
Mizoram	April	10.75	N/A	10.75	Gosh et al. (2018)
Iran					
Ahvaz	June	86	N/A	86	Jalali et al. (2016)
Sistan	January	46.8	N/A	46.8	Majidiani et al. (2016)
Dehgolan	N/A	27.68	N/A	27.68	Hasheminasan et al. (2018)
Tabriz	June	22	N/A	22	Farhang et al. (2017)
Ardabil	June-September	15.94	N/A	15.94	Yamchi et al. (2016)
Bangladesh					
Mimensing	N/A	55.2	N/A	55.2	Roy et al. (2018)
Rajshahi	November-December	34	N/A	34	Ali et al. (2016)
Sirajgang	December	5.82	N/A	5.82	Al Mahmud et al. (2015)
Dinajpur	March-February	0.29	N/A	0.29	Mohammad et al. (2017)

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

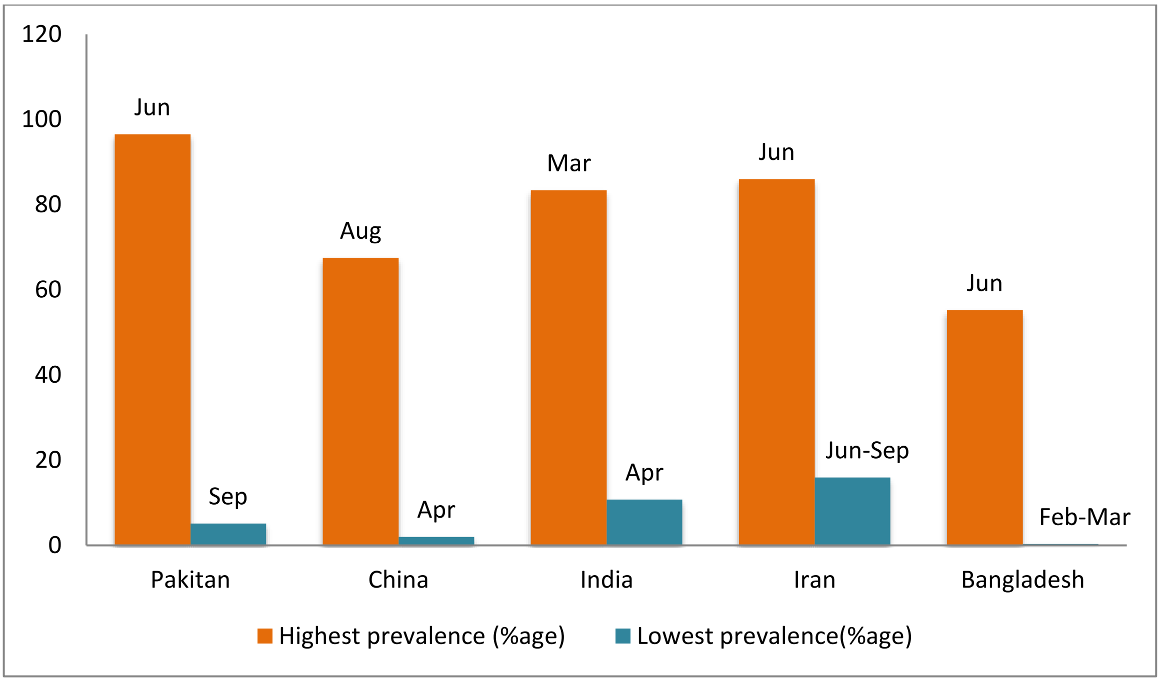

Figure 1: Bovine Theileriosis-Season wise prevalence for different regions of Pakistan, China, India, Iran and Bangladesh.

2. Diagnostic methods

2.1. Microscopic Examination

Traditionally, Giemsa staining has been used that involve microscope-based detection of piroplasm in blood cells and macrochizonts in lymph node biopsy smear for live animals., Whereas, for dead animals, impression smears of spleen and lymph node has been used (Aktas et al. 2002; Afifi et al. 2014; Lemperuer et al. 2017; Rashid et al. 2018). Due to having unique morphological properties, *Theileria* can be easily differentiated from other parasites (Aktas et al. 2006). These methods are comparatively economical. However, due to low sensitivity, the staining methods are not suitable for the detection of subclinical infection, thus, making it an unreliable technique for effective control of Theileriosis. Further, *T. parva* and *T. annulata* are similar in morphological features, so, the microscope-based examination is inconclusive (Azizi et al. 2008; Hoghooghi et al. 2011; Saeid et al. 2013; Kohli et al. 2014).

2.2. Serological Tests

Serological tests reveal the diagnostic identification of antibodies in the serum (Manev et al. 2018). For the detection of circulating antibodies in the blood, an indirect fluorescent antibody test (IFAT) has been used in the serological survey for decades (Mangano et al. 2019). Piroplasm IFAT is less sensitive as compared to schizont IFAT (Molad et al. 2006). An enzyme-linked immunosorbent assay (ELISA) was developed for *T. annulata* merozoite surface antigen after this recombinant protein was used having a specific surface molecule (Tams1-1) on it (Gubbels et al. 2000). However, a major disadvantage associated with these methods is the lack of authenticity because the chance of cross-reactivity with antibodies may encounter false positive and false negative results (Burridge et al. 1954). The results were also alleged due to deficient antibody levels during the carrier phase and due to having a less immune response (Molad et al. 2006). Animals may still be infected despite negative serological results because antibodies incline to disappear, but *Theileria spp.* may be present in the erythrocytes of the long-term carrier animals (Shahnawaz et al. 2011).

2.3. DNA-Based Examination

2.3.1. *Polymerase Chain Reaction (PCR):* PCR based diagnostic procedures have been preferred over other methods as they help in the identification of parasites even at strain level (Birkenheuer et al. 2003; Kundave et al. 2014; Khatoon et al. 2015; Dandasena et al. 2018). In a comparison among staining methods, PCR, IFAT, their efficiencies were found to be 37.4 and 34.9%respectively showing PCR as a more reliable method for parasite detection (Dumanli et al. 2005). Similar results were found in a study conducted in Southwest Iran for the detection of *Theileria spp.* in blood samples and PCR was found 75% more sensitive than staining method (22%) (Dehkordi et al. 2012). Another research conducted in a province of Iran Golestan showed that PCR (7.5%) give better results than smear method (3.75%) out of collected samples. This shows that PCR has more sensitivity for carrier cattle having *Theileria* infection (Georges et al. 2001; Hassan et al. 2018a, 2018b). Despite high sensitivity, however, PCR does not provide quantitative data and it is a laborious and time-consuming method. Further, the chances of contamination of the sample are high that leads to false-positive results (Yusufmia et al. 2010). In Pakistan, only one report is available about comparing efficacies of these three tests (PCR, IFA, and staining method). The efficacies of PCR, IFA, and Smear method were found to be 41.2, 23.5 and 6.8%, respectively (Durrani et al. 2010). In India, there is one report available about the comparison of PCR and smear method, where 25 clinically suspected cases were found negative by blood smear examination were subjected to molecular diagnosis using PCR (Acharya et al. 2017). In Iran, there was a comparative study about the detection of *Theileria annulata* by using Semi-nested PCR and blood smear examination their efficacies were 7.5 and 3.75% respectively (Hoghooghi-Rad et al. 2011).

2.3.2. ***Loop-Mediated Isothermal Amplification (LAMP):*** LAMP is comparatively a new diagnostic test of *Theileria* and it works at isothermal temperature. This method could be performed in a water bath (Paris et al. 2007). LAMP uses four primers that enhance ten times more sensitivity as compared to PCR (Parida et al. 2008; Liu et al. 2012a, 2012b; Liu et al. 2013). Further, it is time effective and could be concluded within 30-60 minutes. It could be performed without DNA extraction as compared to PCR (Njiru et al. 21008). However, the development of primers, as well as lack of sequencing of DNA, was major set-backs associated with LAMP. There is no report available on comparison of LAMP with other diagnostic techniques.

3. DISCUSSION

Theileriosis is a major setback against the livestock industry all over the world as well as in Pakistan. Lack of accurate data on the epidemiology of BTH and their vectors makes it difficult to assess their economic impacts on water buffaloes and cattle production in different ecological zones of Pakistan. The previous studies of bovine Theileriosis in Asian countries have (i) Estimated the prevalence of Theileriosis (around public livestock research stations and major veterinary research institutes) by using conventional diagnostic methods. The highest prevalence rate of Theileriosis was recorded in China (39%) followed in order by Iran (33%), India (31.7%), Pakistan (21.2%) and Bangladesh (2.69%). This difference might be attributed to poor tick-control practices in areas having high prevalence as compared to the areas having low prevalence. (ii) Correlation of occurrence of Theileriosis with tick abundance, seasonality, and cattle susceptibility was also observed. *Hyalomma* tick species were the main vectors of tropical Theileriosis in Asian countries as already mentioned in the previous studies (Ghosh et al. 2007; Akhtar et al. 2019; Rehman et al. 2019). *Hyalomma spp.* are the only ticks with strong resistance to face harsh environment (temperature, humidity) (Estrada et al. 2015). Further, adaptability of the environment and changes in the physiological processes were the key factors that contributed to the high rate of prevalence of *Hyalomma spp.* as compared to others (Spengler et al. 2018).

June through September was the most favorable months for Theileriosis in all the Asian countries' understudies. The overall high prevalence rate was recorded during June, August, March, June-September, and November for Pakistan, China, India, Iran, and Bangladesh respectively. The difference can be attributed to the ecological and graphical factors and may be different in housing systems. This is in accord with the earlier reports that the geo-climatic condition of the major part of Sub-tropical areas was correlated with concurrent with the high rate of ticks after Theileriosis especially during monsoon (June-September) due to high humidity and temperature (Vahora et al. 2012).

There was more prevalence rate recorded in exotic & cross-bred cattle then local breeds of Asian countries mentioned in this review. This is in agreement with previous reports that exotic cattle were more prone to Theileriosis than local breeds due to lack of passive immunity and high tick-affinity (Sajid et al. 2009; Naik et al. 2016). So, un-controlled cross-breeding and mixed farming should be avoided. It might be a source of infection transfer from an endemically stable population to other livestock.

Conclusion: In the light of findings of this study, the necessary attention to developing specific managemental strategies and sensitive tests for diagnosis of parasitic infection is a dire need of time. PCR-Based tests are the most augmentative diagnostic tool to date followed by blood and lymph node smear examination and serological tests. Tick obliteration by using acaricides and combustion of pasture efficaciously limits the impact of Theileriosis. Currently used prophylactic measurements against Theileriosis are expensive and also have some limitations regarding efficacy and sustainability. Through bridging the gap between farmers and lab facilities to promote the integration of control strategies with PCR-based diagnostic tests are recommended.

Declaration of competing interests: None

Acknowledgments: This study was funded by the HEC (Higher education commission) of Pakistan. Project Entitled" Molecular assay Development for *Theileriosis* and *Babesiosis*" NRPU # 9947.

ORCID

Muhammad Arfan Zaman https://orcid.org/0000-0001-7281-4781
Uzma Mehreen https://orcid.org/0000-0003-1891-4938
Muhammad Fiaz Qamar https://orcid.org/0000-0003-4979-5847
Muhammad Kahif https://orcid.org/0000-0001-9539-1726
Zohaib Shahid https://orcid.org/0000-0001-6727-7475
Rao Zahid Abbas https://orcid.org/0000-0001-7344-6212

REFERENCES

Acharya AP, Panda SK and Prusty BK, 2017. Diagnosis and confirmation of *Theileria annulata* infection in cattle in Odisha, India. Journal of Entomology and Zoology Studies 5: 1543-1546.

Afifi NA, Shihata IM, El-Zorba HY and Ismail IM, 2014. Prevalence of theileriosis in cross-bred cattle: its detection through blood smear examination and polymerase chain reaction in Dehradun district, Uttarakhand, India. Veterinary World 7: 168-171.

Ahmed JS, Glass EJ, Salih DA and Seitzer U, 2008. Innate immunity to tropical theileriosis. Innate Immunity 14: 5-12.

Akhtar K, Anees R, Karim T, Gul SU, Ur H, Rehman AA, Wazir MI, Khan F and Achakzai SK, 2019. Prevalence of tick infestation in cows of various Regions of district Karak. Pakistan 7: 791-795.

Aktas M, Altay K and Dumanli N, 2006. A molecular survey of bovine *Theileria* parasites among apparently healthy cattle and with a note on the distribution of ticks in eastern Turkey. Veterinary Parasitology 138: 179-185.

Aktas M, Dumanli N, Cetinkaya B and Cakmak A, 2002. Field evaluation of PCR in detecting *Theileria annulata* infection in cattle in eastern Turkey. The Veterinary Record 150: 548-549

Al Mahmud MA, Belal SS and Hossain MA, 2015. Prevalence of theileriosis and babesiosis in cattle in the Sirajganj district of Bangladesh. Research in Agriculture Livestock and Fisheries 2: 79-86.

Ali MW, Alauddin M., Azad MTA, Hasan MA, Appiah-Kwarteng C, Takasu M, Baba M, Kitoh K, Rahman M and Takashima Y, 2016. *Theileria annulata* seroprevalence among different cattle breeds in Rajshahi Division, Bangladesh. Journal of Veterinary Medical Science 78: 1577-1582

Ananda KJ and Adeppa J, 2016. Prevalence of Haemoprotozoan infections in bovines of the Shimoga region of Karnataka state. Journal of Parasitic Diseases 40: 890-892.

Ananda KJ, D'Souza PE, and Puttalakshmamma GC, 2009. Prevalence of Haemoprotozoan diseases in crossbred cattle in Banglore north. Veterinary World 2: 15-16.

Atif FA, Khan MS, Iqbal HJ and Roheen T, 2012. Prevalence of tick-borne diseases in Punjab (Pakistan) and hematological profile of *Anaplasma marginale* infection in indigenous and crossbred cattle. Pakistan Journal of Science 64: 11-15.

Atif FA, Khan MS, Iqbal HJ, Arshad GM, Ashraf E and Ullah S, 2012. Prevalence of *Anaplasma marginale, Babesia bigemina* and *Theileria annulata* infections among cattle in Sargodha District, Pakistan. African Journal of Agriculture Research 7: 302-3307.

Ayadi O, Gharbi M and Elfegoun MCB, 2016. Milk losses due to bovine tropical theileriosis (*Theileria annulata* infection) in Algeria. Asian Pacific Journal of Tropical Biomedicine 6: 801-802.

Azizi H, Shiran B, Dehkordi AF, Salehi F and Taghadosi C, 2008. Detection of *Theileria annulata* by PCR and its comparison with the smear method in native carrier cows. Biotechnology 7: 574-577

Bhatnagar CS, Bhardwaj B, Sharma DK and Meena SK, 2015. Incidence of Haemoprotozoan diseases in cattle in Southern Rajasthan, India. International Journal of Current Microbiology & Applied Sciences 4: 509-514.

Birkenheuer AJ, Levy MG and Breitschwerdt EB, 2003. Development and evaluation of a semi-nested PCR for detection and differentiation of *Babesia gibsoni* (Asian genotype) and *B. canis* DNA in canine blood samples. Journal of Clinical Microbiology 41: 4172-4177.

Burridge M.J, Brown CGD and Kimber CD, 1974. *Theileria annulata:* cross-reactions between a cell culture schizont antigen and antigens of East African species in the indirect fluorescent antibody test. Experimental Parasitology 35: 374-380.

Chaisi ME, Collins NE, Potgieter FT and Oosthuizen MC, 2013. Sequence variation identified in the 18S rRNA gene of *Theileria mutans* and *Theileria velifera* from the African buffalo (Syncerus caffer). Veterinary Parasitology 191: 132-137.

Dandasena D, Bhandari V, Sreenivasamurthy GS, Murthy S, Roy S, Bhanot V, Arora JS, Singh S and Sharma P, 2018. A Real-Time PCR based assay for determining parasite to host ratio and parasitemia in the clinical samples of Bovine Theileriosis. Scientific Reports 8: 1-7.

Dehkordi FS, Parsaei P, Saberian S, Moshkelani S, Hajshafiei P, Hoseini SR, Babaei M and Ghorbani MN, 2012. Prevalence study of *theileria annulata* by comparison of four diagnostic T. Bulgarian Journal of Veterinary Medicine 15: 123-130.

Dumanli N, Aktas M, Cetinkaya B, Cakmak A, Koroglu E, Saki CE, Erdogmus Z, Nalbantoglu S, Ongor H, Simşek S and Karahan MU, 2005. Prevalence and distribution of tropical theileriosis in eastern Turkey. Veterinary Parasitology 127: 9-15.

Durrani, AZ and Kamal N, 2008. Identification of ticks and detection of blood protozoa in Friesian cattle by polymerase chain reaction test and estimation of blood parameters in district Kasur, Pakistan. Tropical Animal Health and Production 40: 441-447.

Durrani AZ, Kamal N and Khan MS, 2006. Incidence of theileriosis and estimation of packed cell volume, total erythrocyte count and hemoglobin in buffaloes. Journal of Animal and Plant Sciences 16: 85-88.

Durrani AZ, Mehmood N and Shakoori AR, 2010. Comparison of three diagnostic methods for *Theileria annulata* in Sahiwal and Friesian cattle in Pakistan. Pakistan Journal of Zoology 42: 467-472.

Durrani AZ, Shakoori AR., and Kamal N, 2008. Bionomics of *Hyalomma* ticks in three districts of Punjab. Journal of Animal and Plant Sciences 18: 121-124.

Erdemir A, Aktas M, Dumanli N and Turgut-Balik D, 2012. Isolation, cloning and sequence analysis of the lactate dehydrogenase gene from Theileria annulata may lead to design of new antitheilerial drugs. Veterinarni Medicina 10: 559-567.

Estrada-Peña A, de la Fuente J, Latapia T and Ortega C, 2015. The impact of climate trends on a tick affecting public health: a retrospective modeling approach for *Hyalomma marginatum (Ixodidae).* PLoS One 10: e0125760.

Elsheikha H, 2019. Management of ticks and tick-borne diseases: challenges and opportunities. The Veterinary Nurse 10: 60-63.

Farooqi SH, Ijaz M, Rashid MI, Aqib AI, Ahmad Z, Saleem MH, Hussain K, Islam S, Naeem H and Khan A, 2017. Molecular epidemiology of Babesia Bovis in bovine of Khyber Pakhtunkhwa, Pakistan. Pakistan Veterinary Journal 37: 275-80.

Georges K, Loria GR, Riili S, Greco A, Caracappa S, Jongejan F and Sparagano O, 2001. Detection of haemoparasites in cattle by reverse line blot hybridization with a note on the distribution of ticks in Sicily. Veterinary Parasitology 99: 273-286.

Ghosh S, Patra G, Kumar Borthakur S, Behera P, Tolenkhomba TC, Deka A and Biswas P, 2018. Prevalence of haemoprotozoa in cattle of Mizoram, India. Biological Rhythm Research 51: 76-87

Gubbels MJ, d'Oliveira C, and Jongejan F, 2000. Development of an indirect Tams1 enzyme-linked immunosorbent assay for diagnosis of *Theileria annulata* infection in cattle. Clinical and Diagnostic Laboratory Immunology 7: 404-411.

Gul N, Ayaz S, Gul I, Adnan M, Shams S, and Akbar N, 2015. Tropical theileriosis and east coast fever in cattle: present, past and future perspective. International Journal of Current Microbiology & Applied Sciences 4:1000-1018.

Haque AS, Masood S and Akbar H, 2018. Prevalence of Neosporacaninum using milk and serum ELISA and its hematological effect in dairy buffaloes. Pakistan Veterinary Journal, 38: 281-285.

Hasheminasab SS, Moradi P and Wright I, 2018. A four year epidemiological and chemotherapy survey of babesiosis and theileriosis, and tick vectors in sheep, cattle, and goats in Dehgolan, Iran. Annals of Parasitology 64: 43-48.

Hassan MA, Liu J, Sajid MS, Mahmood A, Zhao S, Abbas Q, Guan G, Yin H. and Luo J, 2018. Molecular detection of *Theileria annulata* in cattle from different regions of Punjab, Pakistan, by using recombinase polymerase amplification and polymerase chain reaction. Journal of Parasitology 104: 196-202.

Hassan MA, Liu J, Sajid MS, Rashid M, Mahmood A, Abbas Q, Guan G, Yin H and Luo J, 2018. Simultaneous detection of *Theileria annulata* and *Theileria orientalis* infections using recombinase polymerase amplification. Ticks and Tick-Borne Diseases 9: 1002-1005.

Hoghooghi-Rad N, Ghaemi P, Shayan P, Eckert B and Sadr-Shirazi N, 2011. Detection of native carrier cattle infected with *Theileria annulata* by semi-nested PCR and smear method in Golestan Province of Iran. World Applied Sciences Journal 12: 317-323.

Jabbar A, Abbas T, Siddiqui HA, Qamar M.F and Gasser RB, 2015. Tick-borne diseases of bovines in Pakistan: major scope for future research and improved control. Parasites & Vectors 8: 283.

Jalali SM, Jolodar A, Rasooli A and Darabifard A, 2016. Detection of *Theileria lestoquardi* cross-infection in cattle with clinical theileriosis in Iran. Acta Parasitological 61: 756-761.

Jenkins C, 2018. Bovine theileriosis in Australia: a decade of disease. Microbiology Australia 39: 215-219.

Kala S, Deo BG and Kumari N, 2018. Epidemiological Aspects of Theileriosis in Cattle in and around Patna, Bihar, India. International Journal of Current Microbiology and Applied Sciences 7: 1183-1191.

Kasozi KI, Matovu E, Tayebwa DS, Natuhwera J, Mugezi I and Mahero M, 2018. Epidemiology of increasing hemo-parasite burden in Ugandan cattle. Open Journal of Veterinary Medicine 10: 220.

Kerario II, Simuunza M, Laisser EL and Chenyambuga S, 2018. Exploring knowledge and management practices on ticks and tick-borne diseases among agro-pastoral communities in Southern Highlands, Tanzania. Veterinary World 11: 48-57.

Khatoon S, Kolte SW, Kurkure NV, Chopde NA and Jahan A, 2015. Detection of tropical bovine theileriosis by polymerase chain reaction in cattle. Journal of Parasitic Diseases 39: 53-56.

Khattak RM, Rabib M, Khan Z, Ishaq M, Hameed H, Taqddus A, Faryal M, Durranis S, Gillani QUA, Allahyar R and Shaikh R.S, 2012. A comparison of two different techniques for the detection of blood parasite, *Theileria annulata*, in cattle from two districts in Khyber Pukhtoon Khwa Province (Pakistan). Parasite: Journal de la Société Française de Parasitologie 19: 91-95.

Kohli S, Atheya UK, Srivastava SK, Banerjee PS and Garg R, 2014. Outbreak of theileriosis and anaplasmosis in the herd of Holstein crossbred cows of Dehradun district of Uttranchal, India: A Himalyan region. International Journal 5: 182-185.

Kolte SW, Larcombe SD, Jadhao SG, Magar SP, Warthi G, Kurkure NV and Shiels BR, 2017. PCR diagnosis of tick-borne pathogens in Maharashtra state, India indicates fitness cost associated with carrier infections is greater for crossbreed than native cattle breeds. PloSone 12: e0174595.

Kumar CR., Shaikh HA, Kandarpalle AV and Ramteke SS, 2018. Prevalence of haemoprotozoan infections during September to December 2017 in bovines of Telangana state of India. Haryana Veterinarian 57: 229-231.

Kundave VR, Patel AK, Patel PV, Hasnani JJ and Joshi CG, 2014. Qualitative and quantitative assessment of *Theileria annulata* in cattle and buffaloes Polymerase Chain Reaction. Tropical Biomedical 31: 728-735

Lempereur L, Beck R., Fonseca I, Marques C, Duarte A, Santos M., Zúquete S, Gomes J, Walder G, Domingos A and Antunes S, 2017.Guidelines for the detection of *Babesia* and *Theileria* parasites. Vector-Borne and Zoonotic Diseases 17: 51-65.
Liu A, Guan G, Du P, Gou H, Liu Z, Liu J, Ma M, Yang J, Li Y, Niu Q and Ren Q, 2012a. Loop-mediated isothermal amplification (LAMP) method based on two species-specific primer sets for the rapid identification of Chinese *B. bovis* and *B. bigemina.* Parasitology International 61: 658-663.
Liu A, Guan G, Du P, Gou H, Zhang J, Liu Z, Ma M, Ren Q, Liu J, Yang J and Li Y, 2013. Rapid identification and differentiation of *Theileria sergenti* and *Theileria sinensis* using a loop-mediated isothermal amplification (LAMP) assay. Veterinary Parasitology 191: 15-22.
Liu A, Guan G, Du P, Liu Z, Gou H, Liu J, Yang J, Li Y, Ma M., Niu Q and Ren Q, 2012b. Loop-mediated isothermal amplification (LAMP) assays for the detection of *Theileria annulata* infection in China targeting the 18S rRNA and ITS sequences. Experimental Parasitology 131: 125-129.
Liu J, Yang J, Guan G, Liu A, Wang B, Luo J and Yin H, 2016. Molecular detection and identification of piroplasms in sika deer (Cervus nippon) from Jilin Province, China. Parasites & Vectors 9: 156.
Majidiani H, Nabavi R, Ganjali M and Saadati D, 2016. Detection of *Theileria annulata* carriers in Holstein–Friesian (*Bos taurus taurus*) and Sistani (*Bos taurus indicus*) cattle breeds by polymerase chain reaction in Sistan region, Iran. Journal of Parasitic Diseases 40: 1184-1188.
Manev I, Genova K, Lavazza A and Capucci L, 2018. Humoral immune response to different routes of myxomatosis vaccine application. World Rabbit Science 26: 149-154.
Mangano VD, Perandin F, Tiberti N, Guerriero M, Migliaccio F, Prato M and Bisoffi Z, 2019. Risk of transfusion-transmitted malaria: evaluation of commercial ELISA kits for the detection of anti-Plasmodium antibodies in candidate blood donors. Malaria Journal 18: 17.
Mohammed MO, Rahman MS, Hoque MF, Rumi NA. and Afrah OH, 2017. Study on prevalence of bovine diseases at sadar upazila in dinajpur district of Bangladesh. Asian Journal of Medical and Biological Research 3: 446-453.
Molad T, Mazuz ML, Fleiderovitz L, Fish L, Savitsky I, Krigel Y, Leibovitz B, Molloy J, Jongejan F and Shkap V, 2006. Molecular and serological detection of *A. centrale*-and *A. marginale*-infected cattle grazing within an endemic area. Veterinary Microbiology 113: 55-62.
Muhammad G, 1999. Clinico-epidemiological and therapeutic aspects of bovine theileriosis. Bull Calf Appear Female 36: 32.
Naik BS, Maiti SK and Raghuvanshi PDS, 2016. Prevalence of tropical theileriosis in cattle in Chhattisgarh State. Journal of Animal Research 6: 1043-1045.
Njiru ZK, Mikosza ASJ, Matovu E, Enyaru JCK, Ouma JO, Kibona SN, Thompson RCA and Ndung'u JM, 2008. African trypanosomiasis: sensitive and rapid detection of the sub-genus Trypanozoon by loop-mediated isothermal amplification (LAMP) of parasite DNA. International Journal for Parasitology 38: 589-599.
Nourollahi-Fard SR, Khalili M and Ghalekhani N, 2015. Detection of *Theileria annulata* in blood samples of native cattle by PCR and smear method in Southeast of Iran. Journal of Parasitic Diseases 39: 249-252.
Parida M, Sannarangaiah S, Dash PK, Rao PVL and Morita K, 2008. Loop-mediated isothermal amplification (LAMP): a new generation of innovative gene amplification technique; perspectives in clinical diagnosis of infectious diseases. Reviews in Medical Virology 18: 407-421.
Paris DH, Imwong M, Faiz AM, Hasan M, Yunus EB, Silamut K, Lee SJ, Day NP and Dondorp AM, 2007. Loop-mediated isothermal PCR (LAMP) for the diagnosis of falciparum malaria. The American Journal of Tropical Medicine and Hygiene 77: 972-976.
Pervez A, Anjum FR., Bukhari AA, Anam S and Arshad MI, 2018. Isolation and Virulence Genes Characterization of Diarrheagenic *Escherichia coli* from Calves. Pakistan Veterinary Journal 18: 133-136.
Qayyum M, Farooq U, Samad HA and Chauhdry HR, 2010. Prevalence, clinicotherapeutic and prophylactic studies on theileriosis in district Sahiwal (Pakistan). Journal of Animal and Plant Sciences 20: 266-70.
Rashid M, Akbar H, Rashid I, Saeed K, Ahmad L, Ahmad AS, Shehzad W, Islam S and Farooqi S, 2018. Economic significance of tropical theileriosis on a Holstein Friesian dairy farm in Pakistan. Journal of Parasitology 104: 310-312.
Rashid M, Rashid MI, Akbar H, Ahmad L, Hassan MA, Ashraf K, Saeed K and Gharbi M, 2019. A systematic review on modeling approaches for economic losses studies caused by parasites and their associated diseases in cattle. Parasitology 146: 129-141.
Rashid MI, editor, 2018. Epidemiology of tick-borne infection in ruminants in Peshawar. Journal of Advances in Parasitology 5: 6-10.
Rehman A, Conraths FJ, Sauter Louis C, Krücken J and Nijhof AM, 2019. Epidemiology of tick borne pathogens in the semi-arid and the arid-agroecological zones of Punjab province, Pakistan. Transboundary and Emerging Diseases 66: 526-536.
Roy BC, 2018. Molecular diagnosis and characterization of ticks and tick-borne pathogens infecting cattle in Mymensingh district of Bangladesh (Doctoral dissertation).
Sajid MS, Iqbal ZA, Khan MN and Muhammad GH, 2008. Point prevalence of hard ticks (Ixodids) infesting domestic ruminants of lower Punjab, Pakistan. International Journal of Agriculture and Biology 10: 349-351.
Sajid MS, Iqbal Z, Khan MN, Muhammad G and Khan MK, 2009. Prevalence and associated risk factors for bovine tick infestation in two districts of lower Punjab, Pakistan. Preventive Veterinary Medicine 92: 386-391.
Saleem MI, Tariq A, Shazad A and Mahfooz SA, 2014. Clinical, epidemiological and therapeutic studies on bovine tropical theileriosis in Faisalabad, Pakistan. Iraqi Journal of Veterinary Sciences 28: 87-93.

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Shahnawaz S, Ali M, Aslam MA, Fatima R., Chaudhry ZI, Hassan MU and Iqbal F, 2011. A study on the prevalence of a tick-transmitted pathogen, *Theileria annulata*, and hematological profile of cattle from Southern Punjab (Pakistan). Parasitology Research 109: 1155.

Spengler JR and Estrada-Peña A, 2018. Host preferences support the prominent role of *Hyalomma* ticks in the ecology of Crimean-Congo hemorrhagic fever. PLoS Neglected Tropical Diseases 12: e0006248.

Storey-Lewis B, Mitrovic A and McParland B, 2018. Molecular detection and characterization of *Babesia* and *Theileria* in Australian hard ticks. Ticks and Tick-borne Diseases 9: 471-478.

Vahora SP, Patel JV, Patel BB, Patel SB and Umale RH, 2012. Seasonal incidence of Haemoprotozoal diseases in crossbred cattle and buffalo in Kaira and Anand districts of Gujarat, India. Veterinary World 5: 223.

Yamchi JA and Tavassoli M, 2016. Survey on infection rate, vectors and molecular identification of *Theileria annulata* in cattle from North West, Iran. Journal of Parasitic Diseases 40: 1071-1076.

Yusufmia SB, Collins NE, Nkuna R., Troskie M., Van den Bossche P and Penzhorna BL, 2010. Occurrence of *Theileria Parva* and other haemoprotozoa in cattle at the edge of Hluhluwe-iMfolozi Park, KwaZulu-Natal, South Africa. Journal of the South African Veterinary Association 81: 45-49.

Zhao S, Liu J, Zhao H, Li Y, Xie J, Liu A, Hassan M.A, Yin H, Guan G and Luo J, 2017. Evaluating an indirect rMPSP enzyme-linked immunosorbent assay for the detection of bovine *Theileria* infection in China. Parasitology Research 116: 667-676.

Zhou Z, Li K, Sun Y, Shi J, Li H, Chen Y, Yang H, Li X, Wu B, Li X and Wang Z, 2019. Molecular epidemiology and risk factors of *Anaplasma spp., Babesia spp.* and *Theileria spp.* infection in cattle in Chongqing, China. PloS One 14: e0215585.