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Parasitic Infections of Cattle in North Eastern Region of India–An Overview

Das M* **and Laha R**

Division of Animal Health, ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya, India

***Corresponding author:** Meena Das, Division of Animal Health, ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya, India, Tel: +918486356433; E-mail: meenad3@gmail.com

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Abstract

The Northeast (NE) India is the eastern most region of India, constitutes about 8% of India's size and its population is approximately 3.1% of the total Indian population. The NE region of India though predominantly dependent on cultivation of crops, animal husbandry is an inseparable part of the economy. They not only contribute to their income but also their best insurance against any natural calamity. The humid climatic conditions of this region are very conducive for the rapid growth and multiplication of parasites. They cause clinical and subclinical parasitism. Subclinical infections are responsible for high morbidity and mortality in young animals and enormous production losses in adults. Different species of gastrointestinal parasites i.e. *Haemonchus*, *Strongyloides*, *Mecistocirrus*, *Cooperia*, *Neoascaris*, *Fasciola gigantica*, *Paramphistomes*, *Bunostomum phlebotomum*, *Nematodirus fillicolis*, *Nematodirus helvetianus*, *Trichostrongylus* sp., *Oesophagostomum raditum*, *Moniezia* sp., *Trichuris* sp., *Eimeria bovis*, *E. zuernii*, *E. subspherica*, *E. bukidnonensis*, *E. auburnensis*, *E. ellipsoidalis*, *E. alabamensis* etc were reported from cattle of this region. Zoonotic parasites such as *Cryptosporidium parvum*, *Giardia duodenalis*, *Cysticercus bovis*, *Fasciola hepatica* and hydatidosis in cattle was also reported. Cattle ticks and tick borne diseases (TBD) such as Babesiosis, Oriental theileriosis and Anaplasmosis are also observed in this region. Many epidemiological factors are responsible for causing parasitic infections in cattle of this region. So, proper monitoring, diagnosis and control of parasitic infections in cattle of this region is required for sustainable growth and development of cattle population.

Keywords: Cattle; Parasites; North East India

Introduction

The Northeast (NE) India is the eastern most regions of India, comprising of seven sister states (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura) and the Himalayan state, Sikkim (Table 1).

Physiographically the region is categorized into the Eastern Himalayas, Northeast hills (Patkai-Naga hills and Lushai hills), and the Brahmaputra and the Barak valley plains [1]. The region lies within the latitude of 21°50′ to 29°34′ N and longitude 85°34′ to 97°50′ E with a geographical area of 2,62,179 km^2. It constitutes about 8% of India's size and its population is approximately 3.1% of the total Indian population [2].

About 90% of its entire border area is shared with China (southern Tibet) in north, Myanmar in the East, Bangladesh in the southwest and Bhutan to the Northwest. The region has a predominantly humid sub-tropical climate with hot, humid summers, severe monsoons and mild to severe winters. The temperature of the region varies from 15°C to 36°C in summer and zero to 26°C in winter season. The region receives about 10,000 mm (Av.) and above rainfall; Mawsynram, located on the Meghalaya plateau is the rainiest place in the world with an annual rainfall of 11,418.7 mm. The region is also considered as a 'biodiversity hotspot' because of its high endemism in higher plants, vertebrates and avian diversity.

Livestock plays an important role in Indian economy and is an important subsector of Indian Agriculture. They play a major role in the rural economy, especially for the small and marginal farmers. Among the livestock population, cattle (190.9 million) plays a major role in India's economy, accounting 37.28% of total livestock population [3]. The NE region though predominantly dependent on cultivation of crops, animal husbandry is an inseparable part of the economy.

State	Area (sq. km)	Human population	Cattle population ('000 number)	Milk production 2011-12 ('000 Tonnes)
Arunachal Pradesh	83,743	13,83,727	503	32
Assam	78,438	3,12,05,576	10,041	752
Manipur	22,327	25,70,390	342	78
Meghalaya	22,429	29,66,889	887	77
Mizoram	21,081	10,97,206	35	17
Nagaland	16,579	19,78,502	470	45
Sikkim	7,096	6,10,577	135	42
Tripura	10,486	36,73,917	954	91
NER Total	2,62,179	4,54,86,784	13,368	1,134
All India	32,87,263	1,21,01,93,422	1,90,904	1,07,934
Source: Basic Statistics of NER (2015), Livestock Census (2012)				

Table 1: Brief information of North Eastern region of India.

Parasite is defined as an organism that lives on or in an organism of another species, known as the host, from which it derives nourishment. Helminths and protozoa are usually endoparasites (living inside the body of the host), while ectoparasites live on the external surface of the host. Haemoparasites are the parasites which live in the blood of the host. They are responsible for causing clinical and subclinical parasitism. Subclinical gastrointestinal nematode infections are among the major health problems limiting the productivity in dairy animals [4,5] and thought to be one of the major constraints in development of dairy cattle worldwide [6]. According to Chowdhury and Tada subclinical G.I. parasitic infections are most common and economically important in cattle of India [7]. Subclinical infections are responsible for high morbidity and mortality in young animals and enormous production losses in adults. In most cases there is no apparent disease in parasitic infection but there is loss in production in terms of depressed growth, reduced appetite, poor feed conversion ratio etc. Severity of the disease depends on the type of the parasite or the numbers of parasites involved. It is a fact that whether the disease is mild or severe, the infected animals become depressed in its growth rate and later be incapable to reach its full growth potential, ultimately results in economic losses for the producers. Calf diarrhea is one of the most common animal health concerns for dairy farmers and mortality in the first year of life is often very high and in many instances, infection of G.I. parasites being one prime cause of mortality. It result up to 20% economic loss and calf mortality reduces dairy net profit by 38% [8] implying loss of future breeding stock, dairy cows and ultimate loss of milk production. It is estimated that USD 2.5 billion is spent on pharmaceutical products in cattle industry for nematode parasite control [9]. Bandyopadhyay et al. from NE India reported high prevalence of G.I. parasitic infections and depending on strategic anthelmintic treatments, the possible estimated economic gain at state level could be Rs. 46 million, Rs. 35 million, and Rs. 14 million [10]. Thus, an effort has been made to compile the available information of prevalent parasitic infections in cattle of NE region of India.

Gastrointestinal (G.I.) parasites of cattle in North East region

Gastrointestinal helminths (Nematodes, Trematodes, Cestodes) and G.I. protozoa (coccidiosis) infections are recognized as a major cause of parasitic infections in cattle. There are various reports of G.I. helminths and protozoan infections in cattle from different states of NE region (Table 2).

State	Infection (%)	Species of G.I. parasites	Reference
Assam	-	*Fasciola gigantica, Paramphistomes, Bunostomum phlebotomum, Mecistocirrusdigitatus* and *Neoascaris vitulorum*	Enderjat [11]
	-	*Paramphistomes, Fasciola, Mecistocirrus*.	Gogoi and Lahkar [12]
	78.2%, 54.1%	Cattle calves (78.2%), adult (54.1%).	Borkakoty et al. [13]
	25%	Moniezia infections in indigenous (5%) and cross-bred cow calves (13.75%)	Borthakur and Das [14]
	5%, 13.75%	Moniezia infections in indigenous (5%) and cross-bred cow calves (13.75%)	Borthakur and Das [15]
	11.97%	*E. bovis* (6.80%), *E. zuernii* (2.35%), *E.subspherica* (0.68%), *E. bukidnonensis*(0.94%), *E. auburnensis* (0.86%), *E. ellipsoidalis* (0.13%) and *E. alabamensis* (0.21%).	Das et al. [26]
	16.43%	*Cryptosporidium parvum* (28.41%) and *Cryptosporidium andersoni* (10.92%)	Das et al. [36]
	17.94%	*Giardia duodenalis* in cattle calves (13.45%) and heifers (21.68%)	Das et al. [39]
Arunachal Pradesh	-	*E. bovis, E. zuernii, E. bukidnonensis, E. auburnensis, E. ellipsodalis, E. canadensis* and *E. cylindrica*	Tayo et al. [27]
Manipur	37.34%	*Strongyle* sp. (35.59%), *Amphistome*(13.55%), *Fasciola* sp. (10.16%), *Moniezia* sp. (8.47%), *Nematodirrus helvetianus* (1.69%) and *Eimeria* sp. (18.64%).	Laha et al. [58]
Meghalaya	53.02%	*Fasciola gigantica* and *E. pancreaticum*	Roy and Tandon [59]
	41.18%	Productivity of cattle in terms of milk yield was considerably higher (3715, 3590 and 3154 L) due to strategic anthelmintic treatment as compared to control group (2928 L)	Bandyopadhyay et al. [10]

	50%	Strongyle infection is 50% dependent on rainfall, 1% increase in rainfall predicts 0.03% increase in Strongyle infection.	Bandyopadhyay et al. [20]
	28.25%	*Strongyle* sp. (65.96 %), *Strongyloides* sp. (25.13%), *Eimeria* sp. (17.80%), *Trichuris*sp. (13.08%), *Moniezia* sp. (10.47%), *Nematodirus helvetianus* (2.61%).	Laha et al. [21]
	74%	High prevalence of Trematodes. *Rumen flukes- Cotylophoron,Paramphistomum, Calicophoron, Gastrothylax* and *Fischoederius*.	Sarmah et al., Tandon and Roy [23,60]
Mizoram	11.66% to 12.50%	*Strongyle* sp. (57.14%), *Eimeria* sp. (42.85%).	Anon [60,61]
	12.24%, 27.45%	*Nematodirus fillicolis, Haemonchuscontortus, Trichostrongylus* sp.,*Oesophagostomum raditum, Toxocaravitulorum, Eimeria bovis*.	Deka et al. [16]
Nagaland	12.2%, 10%	Crossbred cattle (12.2%): Haemonchus (16.67%), Oesophagostomum (4.4%), *Eimeria* sp. (5.5%), *Moniezia expansa* (1.11%) Tho-Tho cattle (10%): Haemonchus (7.77%), Oesophagostomum (16.67%), Cooperia (17.77%), *Toxocara vitulorum* (2.2%), *Bunostomum* (1.1%), *Eimeria* sp. (0.01%), *Moniezia benedeni* (4.4%).	Chamuah and Borkotoky [22]
Sikkim	20.13%	*Strongyles* sp. (18.81%), *Moniezia* sp. (11.22%), *Ascaris* sp. (8.25%), *Strongyloides* sp. (6.6%), *coccidia*(3.96%), *Trichuris* sp. (2.31%), *Nematodirus* sp. (1.66%), *amphistome* (1.65%).	Pal et al. [19]
	27.48%	*Strongyles* (21.65%), *Strongyloides* (10.58%), *Coccidia* (5.91%), *Toxocara* (5.07%), *Moniezia* (4.47%), *Trichuris* sp. (1.10%).	Rahman et al. [18]
	31.53%	*Strongyle* sp.	Pal and Bandyopadhyay [17]
Tripura	-	Amphistomiasis is most prevalent followed by Strongylosis.	Anon [51]

Table 2: G.I. parasites commonly prevalent in cattle of North Eastern States.

Nematodes: Nematodes are cylindrical worms, bilaterally symmetrical having pointed ends at both side. They have an outer cuticle layer, no circular muscles and a pseudocoelom containing all systems (digestive, excretory, nervous and reproductive). Trichostrongyles are the most common nematodes of cattle. It comprises several genera of nematodes within the abomasums, small and large intestines of cattle. The genera that are producing the Trichostrongyle type of eggs are *Bunostomum*, *Chabertia*, *Cooperia*, *Haemonchus*, *Oesophagostomum*, *Ostertagia* and *Trichostrongylus sp.* They have similar life cycle and produce oval, thin shelled eggs.

Trematodes: Trematodes or flukes are dorsoventrally flattened and are unsegmented and leaf like. They have suckers, hooks or clamps for attachment to the host. They are hermaphrodite except *Schistosoma*. Common trematodes of cattle are Paramphistomes. They are commonly known as 'rumen flukes'. They have an oral sucker on the anterior end and a large ventral sucker on the posterior end. The adult flukes are non-pathogenic; the pathogenecity of these flukes lies in the migration of the juvenile forms in the small intestine.

Cestodes: Cestodes are commonly known as tapeworms and are ribbon like, have flat body without a body cavity or alimentary canal. They are hermaphrodite. The adult tapeworm consists of a chain of egg producing units called proglottids. Food is absorbed through the worm's integument. *Moniezia expansa* and *M. benedeni* are the most common cestodes and occurs in the small intestine of cattle mostly calves. Proglottids resemble cooked rice grains.

From North East region of India, Enderjat et al. reported prevalence of *Fasciola gigantica*, Paramphistomes, *Bunostomum phlebotomum*, *Mecistocirrus digitatus* and *Neoascaris vitulorum* in cattle from Assam [11]. Thereafter Gogoi and Lahkar reported paramphistomes as the predominate infections in cattle of Assam [12]. Borkakoty et al. from Kamrup district of Assam reported 78.2% and 54.1% incidence of G.I. parasitic infection in calves and adult cattle, respectively [13]. Common helminthic infections recorded in calves were *Haemonchus* (33.8%), *Strongyloides* (23.4%), *Mecistocirrus* (19%), *Cooperia* (13.8%) and *Neoascaris* (13%). In adults, paramphistomes (31.1%) and *Haemonchus* (14.5%) were predominant. Rajkhowa et al. reported prevalence of *Schistosoma indicum* and *S. spindale* from cattle of Assam [14]. Borthakur and Das reported *Moniezia* infections in

indigenous (5%) and cross-bred cow calves (13.75%), respectively in villages around Guwahati, Assam [15]. From Mizoram, Deka et al. reported 12.24% and 27.45% parasitic infections in cattle on the basis of fecal and carcass examinations, respectively [16]. Nematodes (*Nematodirus fillicolis, Haemonchus contortus, Trichostrongylus* sp., *Oesophagostomum raditum, Toxocara vitulorum*) were observed. Pal and Bandyopadhyay conducted a study to assess the prevalence of G.I. parasitic infections in cattle of subtropical and humid zone of Sikkim and reported 31.53% infections [17]. Rahman et al. also conducted epidemiological study on G.I. parasitic infections in cattle of different agroclimatic zones of Sikkim and reported 27.48% infections with a mean EPG of 86.037 [18]. The rate of infestation was found to be more in subtropical and high humid zone (32.52%) followed by temperate humid (22.19%) and sub-alpine low humid zone (9.59%). Strongyles (21.65%), *Strongyloides* (10.58%), *Toxocara vitulorum* (5.07%), *Moniezia* sp. (4.47%) and *Trichuris* sp. (1.10%) were recorded. Again Pal et al. reported 20.13% G.I. parasitic infections in cattle from Sikkim [19]. The incidence was significantly lower in Government cattle farm (11.42%) than that of privately managed farms (22.75%). The most prevalent G.I. parasites were Strongyles (18.81%), *Moniezia* sp. (11.22%), *Ascaris* sp. (8.25%), *Strongyloides* sp. (6.6%), *Trichuris* sp. (2.31%), *Nematodirus* sp. (1.66%) and amphistome (1.65%). The seasonal distribution of G.I. parasitism indicated a higher percentage of infection during summer (29.11%) followed by spring (22.22%) and autumn (19.22%).

The infection rate was significantly lower in winter (10.0%). In Meghalaya Bandyopadhyay et al. conducted a systematic study during 1997-1999 to assess the economic impact after controlling the G.I. parasitic infections in cattle using strategic anthelmintic treatment (mebendazole at 5 g/cow) along with fortification using mineral mixture (nutrimilk at 25 g/cow) [10]. They observed that productivity of cattle in terms of milk yield was estimated to be considerably higher (3715, 3590 and 3154 L) due to strategic anthelmintic treatment as compared to control group (2928 L). Bandyopadhyay et al. also observed that occurrence of Strongyle infection is 50% dependent on rainfall in Meghalaya. 1% increase in rainfall predicts 0.03% increase in Strongyle infection [20]. Minimum and maximum temperature contribute only 20% occurrence of the disease. Laha et al. reported 28.25% G.I. parasitic infections in cattle of Meghalaya [21]. The eggs of *Strongyle* sp. were predominant (65.96%) followed by *Strongyloides* sp. (25.13%), *Trichuris sp.* (13.08%), *Moniezia* sp. (10.47%) and *Nematodirus helvetianus* (2.61%). Chamuah and Borkotoky form Nagaland reported prevalence of Strongyle parasites *viz. Trichostrongylus, Haemonchus*, *Oesophagostomum* and *Cooperia* species in both Tho-Tho cattle and cross bred cattle [22]. *Moniezia benedeni* was recorded in Tho-Tho while *Moniezia expansa* was recorded in cross bred cattle.

Though, G.I. helminths are generally considered to cause harmful effect to the hosts which subsequently are responsible for economic losses to the livestock owner. But interestingly, one of the G.I. helminths of cattle has been found to cause beneficial effect to human being. A section of people living in Meghalaya have the practice of eating rumen flukes of cattle [23]. They reported that flukes (*Cotylophoron, Paramphistomum, Calicophoron, Gastrothylax* and *Fischoederius*) contain 12.60% total protein, 0.78% fat and 0.87% ash on fresh weight basis. High prevalence of flukes, easy visualization in rumen, their bulk collection, and presence of nutritive value, absence of any ill effect and lack of imminent danger of transmissibility are believed to be the rationales influencing their consumption by people.

Coccidiosis: Coccidiosis is also one of the most pathogenic intestinal diseases caused by different species of *Eimeria* belonging to phylum-apicomplexa [24]. The disease is particularly a problem of confined animals kept under intensive husbandry practices and is more common in housed animals than in those on pastures. In associations with other enteropathogens, coccidia have been indicated as an important cause of diarrhea in calves [25]. Borkakoty et al. from Kamrup district of Assam reported prevalence of *Eimeria bovis*, *E. zuernii*, *E. ellipsoidalis*, *E. subspherica*, *E. bukidnonensis*, *E. auburnensis* and *E. cylindrica* in calves and adult cattle [13]. Das et al. reported 11.97% *Eimeria* infection in dairy cattle of Guwahati, Assam [26]. Seven species of Eimeria were recorded *viz. E. bovis* (6.80%), *E. zuernii* (2.35%), *E. subspherica* (0.68%), *E. bukidnonensis* (0.94%), *E. auburnensis* (0.86%), *E. ellipsoidalis* (0.13%) and *E. alabamensis* (0.21%). Deka et al. from Mizoram reported *Eimeria bovis* infections in cattle [16]. From Sikkim, Rahman et al. and Pal et al. reported 5.91% and 3.96% coccidia infections in cattle, respectively [18,19]. Laha et al. reported *Eimeria sp.* (17.80%) infections in cattle of Meghalaya [21]. From Arunachal Pradesh, Tayo et al. identified different species of *Eimeria* in ruminants *viz. E. bovis*, *E. zuernii*, *E. bukidnonensis*, *E. auburnensis*, *E. ellipsoidalis*, *E. canadensis* and *E. cylindrica*. Out of these species *E. zuernii* and *E. bovis* were most predominant [27].

Zoonotic parasites of cattle in Northeast region

Factors such as poverty, lack of personal hygiene, defecation in open spaces, scarcity of potable water, abundance of stray animals and certain culinary habits are responsible for prevalence of zoonotic diseases. These factors have a direct bearing on the frequency of parasitic infections and consequently the prevalence of infection varies in different regions. According to Macpherson the behaviour of *Homo sapiens* has a pivotal role to play in the epidemiology of parasitic zoonoses [28]. Some of the zoonotic parasitic infections which are reported from NE region of India are given below

Cryptosporidiosis: *Cryptosporidium*, an ubiquitous intracellular extra-cytoplasmic apicomplexan protozoan parasites known to have multiple hosts such as humans, domestic animals, wild animals, birds, rodents and reptiles. In cattle *Cryptosporidium* infection was first reported in the early 1970's [29,30]. However, because of the association with other viral or bacterial enteropathogens, the role of *Cryptosporidium sp.* as primary enteropathogens was uncertain until 1980, when Tzipori et al. attributed an outbreak of neonatal diarrhea due to cryptosporidial infection alone [31]. Bovine cryptosporidiosis is a common disease affecting newborn calves and is characterized by acute gastrointestinal disturbances, mucoid or haemorrhagic watery diarrhea, fever, lethargy, anorexia and loss of condition leading to significant economic losses in farm animals and neonatal morbidity in cattle. The intensity of shedding has been found to be significantly higher in calves with diarrhea. *Cryptosporidium parvum* is also an emerging zoonotic protozoan parasite of calves, and is associated with diarrhea in children [32]. The rate of Cryptosporidium infection has been found to be significantly higher in urban slum areas [33] and in patients with diarrhea [34]. *Cryptosporidium parvum* has been reported to be the most common parasites observed in individuals positive for human immunodeficiency virus (HIV) [35]. From NE region of India, Das et al. reported for the first time *Cryptosporidium sp.* (16.43%) infections in cattle of Assam. Age-wise, 28.41% and 10.92% infections were recorded in calves (< 1 month) and adult cattle, respectively. *C. parvum* and *C. andersoni* in calves and adult cattle, respectively were identified by PCR-restriction fragment length polymorphism (RPLF) [36]. In Sheather's sucrose flotation, the oocysts

appeared as round or oval, refractile bodies with a thin cytoplasmic membrane. However, in modified Ziehl-Neelsen staining, the oocysts appear as spherical to ellipsoidal shaped pink to red stained bodies containing four sporozoites against a pale green background. Agewise, 28.41% and 10.92% infections were recorded in calves (< 1 month) and adult cattle, respectively.

Giardiosis: Giardiosis in dairy cattle is caused by the flagellate protozoa Giardia duodenalis (Syn. G. lamblia or G. intestinalis) which belongs to the Class-Mastigophora and Family-Hexamitidae. It is one of the most frequent enteroparasites worldwide and has been included in the WHO 'neglected disease initiative' [37]. The disease is most common in developing countries and other areas where sanitation and hygiene are poor. The parasite occurs in two morphologically distinct forms one being vegetative trophozoite and the other is thin walled cyst. Cyst is the infective stage and is encysted immediately when released into the feces. Giardia cysts can be transmitted directly between hosts, or on various fomites including contaminated water and food. Trophozoites are released from the ingested cysts in the small intestine, where they multiply. Giardia infection in cattle is often subclinical or asymptomatic, but sometime show symptoms such as anorexia, watery and foul-smelling diarrhea, reduced weight gain and ill thrift in young calves. Infections are associated with a decreased microvillus surface area, reduced intestinal enzyme activity and increased intestinal transit which ultimately result in malabsorptive diarrhea [38]. Das et al. for the first time from Assam reported 17.94% Giardia duodenalis infection in dairy cattle [39]. In zinc sulphate solution (33%), Giardia cyst appeared as oblique cyst with ventral concavity. Age-wise infection rate was 13.45% and 21.68% in calves and heifers, respectively.

Taeniasis: Taeniasis is the true zoonoses in which man is the definitive host and disseminator of infection while cattle act as intermediate host. Adult tape worm Taenia saginata lives in the small intestine of man measuring about 5-12 m in length. The eggs or gravid segments are passed out along with the feces on the ground. Cattle get infection by swallowing these eggs while grazing in the field and the larval stage *Cysticercus bovis* develops in the skeletal and cardiac muscles of cattle. Transmission from man to animals may be either direct or indirect though direct transmission is uncommon. It can also occur when the hands are contaminated with Taenia eggs and these are used for feeding and handling calves. But common mode of transmission is the indirect one through contamination of food, soil and sewage, and by birds or flies. Sewage is an important means of spreading Taenia infection between human and animals. Other factors such as human habits, behaviour, religion and beliefs as they influence the type of food being consumed and the manner in which it is cooked also influence the transmission between animals and man. It is more common in those areas where people are accustomed to eat insufficiently cooked or smoked meat or where people defecate in open. Deka et al. reported prevalence of Cysticercus bovis in cattle (5.3%) from Northeast region of India [40].

Echinococcosis (Hydatidosis): Echinococcosis/hydatidosis have been recognized as the most important helminth zoonosis with profound economic and public health significance in developing countries [41]. It is caused by a very small taeniid tapeworm of the genus *Echinococcus*. There are four species under the genus *Echinococcus viz. E. granulosus*, *E. multilocularies*, *E. oligarthrus* and *E. vogeli*. Their infective larval stages (metacestodes) are very large cyst; either hydatid or alveolar cysts and occur in number of mammals including man.

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Fasciolosis: It is caused by flukes *Fasciola hepatica* and *Fasciola gigantica* in mammalian hosts belonging to the families bovidae, cervidae, capridae, equidae etc. They are also capable of infecting humans. *F. hepatica* is found in most parts of the world having temperate climate while *F. gigantica* is found mostly in areas having tropical and subtropical climate. In India *F. gigantica* is mostly prevalent in cattle. From NE region of India, Narain et al. from Upper Assam reported *F. hepatica* infections in a seven year old girl having history of eating watercress regularly [43]. They observed that besides the presence of eggs in the stools, her liver was enlarged and tender. Ultrasonography revealed presence of adult fluke in gall bladder, and a marginal thickening of gall bladder wall.

Cattle tick: Hard ticks, particularly cattle tick Boophilus microplus is prevalent almost in all North Eastern states. Bite by *B. microplus* causes stress and weakness, decrease milk production and reduce weight gain in the infested cattle. They also transmit various tick borne diseases. Tick borne diseases are responsible for economic losses in terms of mortality and morbidity of livestock worldwide [44]. It has been observed that only 20 to 30 ticks could be able to cause significant harmful effect to cattle in terms of decreased milk production, reduced weight gain and susceptibility for diseases. One of the important impact of *B. microplus* is that they transmits parasitic diseases particularly *Babesia bigemina* infection in cattle. They can also transmit *Babesia bovis* and *Anaplasma marginale*. Laha et al. observed that 3.7% B. microplus ticks infected with *B. bigemina* infections in Meghalaya [45].

Haemoprotozoan parasites

Haemoprotozoan parasites are serious constraints for the improvement of livestock production. Trypanosomosis, Theileriosis, Babesiosis and Anaplasmosis are the major haemoprotozoan diseases of livestock in our country which causes severe economic loss to the livestock owner. Among these, Babesiosis, Theileriosis and Anaplasmosis are transmitted through ticks and known as tick borne diseases (TBD). These tick borne haemoprotozoan diseases have been found to exist in our country since long. But with the import of exotic breed of cattle for upgrading the indigenous stock to improve their milk yield, these diseases have gained greater significance in our

country. Losses due to these haemoprotozoan diseases include mortality, reduction in milk yield, loss of body weight, abortion, infertility, decrease draft power and the cost of treatment of affected animals. It has been observed that the total annual loss due to tick borne diseases (TBD) was estimated as 364 million USD, including an estimated mortality of 1.3 million cattle. Amongst these, theileriosis accounted for 68% of the total loss. Cost associated with mortality was estimated as 49%, cost associated with chemotherapy was 21% and cost associated with application of acaricide accounted for 14% of the total estimated annual losses due to TBD. Beside these losses 1%, 6% and 9% of the total annual loss were estimated due to infection and treatment method, loss of milk production and loss of body weight respectively [46]. The asymptomatic infection accounted a high proportion (50.8%) of these costs, which is important to note down. Sub-clinical infections with anaemia showed the highest losses in live weight, whereas disease cases were responsible for 23.64% of the losses with mortality as the most important element [47]. Some of the important haemoprotozoan diseases of cattle in NE region of India are given below.

Babesiosis: From NE region of India, Laha et al. reported 3.6% *B. bigemina* infections in cattle using PCR (Polemerase Chain Reaction) [48]. The infection has been reported from other NE states like Tripura [49], Assam [50], Manipur [51], Assam [51,52], Mizoram [53] and Arunachal Pradesh [27,51]. In a recent study, *B. bigemina* infection has been found in 64.91% cattle of Assam [54]. A clinical case of babesiosis caused by *B. bigemina* in crossbred cattle of Meghalaya has been reported [55]. The clinical symptoms of *B. bigemina* infection in cattle are high rise of temperature (106.40F), haemoglobinurea, anorexia, decrease milk production, anaemia and diarrhea. It has been observed that due to clinical babesiosis in crossbred cattle of Meghalaya decrease milk production could be noticed for 30 days and during this period total loss of 51.6 litre of milk has been estimated. Basic Local Alignment Search Tool (BLAST) analysis of B. bigemina sequences by Laha et al. revealed 99.2 to 99.7% identity at 18S rRNA gene nucleotide sequence level and were found to be closely related with the cognate gene nucleotide sequences of *B. bigemina* from Argentina and Kenya where 99.1 to 99.9% and 99.0 to 99.7% nucleotide identities were observed, respectively [55]. Distant relationship of these Indian organisms was observed with few cognate gene sequences from China where more than 7% divergence was observed in the distance matrix [45,56].

Oriental theileriosis: Oriental theileriosis is a tick-borne haemoprotozoan parasite of cattle caused by *Theileria orientalis*. The infection is widely distributed in tropical and subtropical countries of the world. Earlier *Theileria orientalis* was considered as non-pathogenic but presently receiving great importance due to emergence of pathogenic strains and for causing outbreaks [57]. The infection is transmitted through the ticks *Rhipicephalus* (Boophilus) *microplus* and was detected in 21.05% cattle of Assam by PCR [54]. A clinical case of *Theileria orientalis* infection in a 3 year aged indigenous heifer from Assam was reported by Kakati et al. [57]. The infected animal showed lateral recumbency with high body temperature (1070F), highly congested mucous membrane of the eyes, nasal discharge, head and neck pulled out more dorsally, anaemic conjunctiva, sticky and tarry colored dung and reddish mucoid vaginal discharge, intermittent bellowing with hyperesthesia, paddling of legs, anorexia, depression, dehydration, weakness and in severe cases there will be tarry colored dung.

Anaplasmosis: Anaplasmosis occurs in cattle by two species - *Anaplasma marginale* and *A. centrale*. The disease is characterized by high fever and progressive anaemia. Ticks of the Genus *Boophilus*, *Rhipicephalus* and *Hyalomma* are responsible to transmit the parasites. Besides, transmission by dipteran flies, transplacental transmission and infections through contaminated needle can also occur. Cattle of all ages may be infected but with the increase of age, severity of disease increases. Anaplasmosis in cattle have been reported from Assam [51], Arunachal Pradesh [27]. In a recent study, *A. marginale* infection has been found in 14.03% cattle of Assam [54].

Conclusions

Parasitism is a production problem severely limiting the animal productivity and growth along with zoonotic importance. Although, parasitic diseases are rarely fatal, the long term debilitating effects of these infections due to sub-clinical parasitism assume greater importance in terms of production losses to the infected animals. Many epidemiological factors are responsible for causing parasitic infections in cattle of this region. So, proper monitoring of parasitic infections in cattle of this region with modern techniques is urgently required for correct diagnosis, treatment and control of parasitic infections in cattle.

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