Rhipicephalus Tick in Southeast Asia

Subjects: Parasitology

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Rhipicephalus species are distributed globally with a notifiable presence in Southeast Asia (SEA) within animal and human populations. The *Rhipicephalus* species are highly adaptive and have established successful coexistence within human dwellings and are known to be active all year round, predominantly in tropical and subtropical climates existing in SEA.

Keywords: Southeast Asia ; Rhipicephalus tick ; Tick and tick-borne diseases ; Susceptibility Host Responses ; Host Range ; Economical impacts

1. Background

Southeast Asia (SEA) covers about 4.5 million km^2 of landmass, with a human population hovering around 670 million [1]. This region comprises 11 countries, and it is a vast Asian region situated east of the Indian subcontinent and South of China (**Figure 1**). All 11 countries fall within the tropical and subtropical climatic zones. The enormous variety of landscapes and climatic complexities have given rise to a considerable diversity of animals throughout the region, including ticks. With the consistent growth in the average annual gross domestic product (GDP), the concurrent expansion of SEA's livestock sector naturally occurred [2]. Several adverse effects have accompanied this spectacular change in—the "Livestock Revolution"—the phenomenal rise in demand for foods of animal origin in society [3]. Examples include the existing threats of outbreaks of zoonotic diseases that can compromise both animal and human health [4][5], cause economic losses due to diseases [6], and result in environmental pollutions from the usage of disease control drugs and pesticides [7][8]. Small-scale livestock farming (i.e., backyard and village farms) remain the predominant practice in most low-income countries in SEA [9]. This practice requires intensive contact between livestock and farmers, which creates ideal conditions for cross-transfer of pathogens associated with potential zoonosis, in addition to ticks [10].

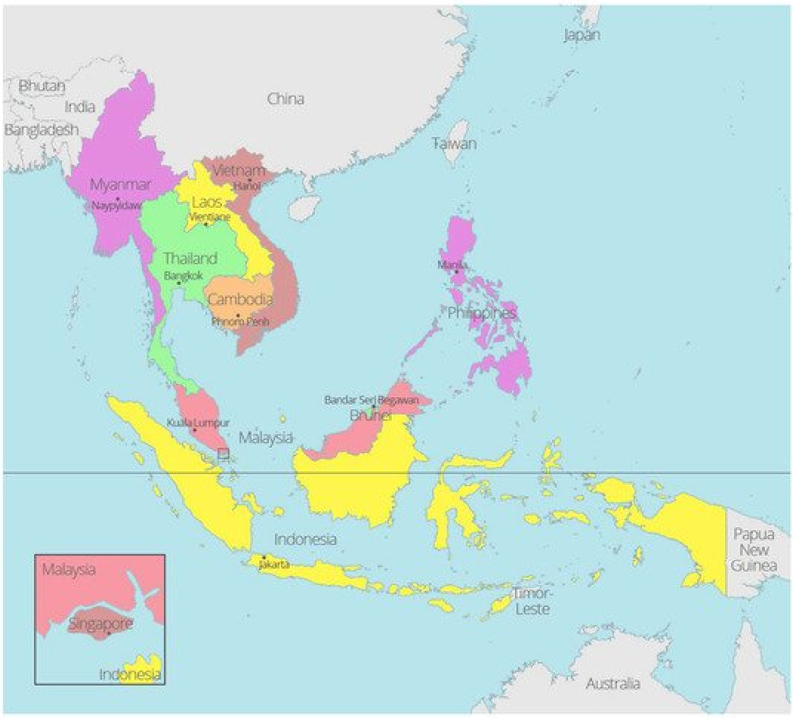

Figure 1. Geographic depiction of Southeast Asia: SEA comprises countries within the Indo-Chinese peninsula of continental Asia, including Myanmar (Burma), Laos, Vietnam, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Timor-Leste, Brunei and the Philippines (https://aseanup.com/free-maps-asean-southeast-asia/, accessed on 4 January 2021).

Ticks are second only to mosquitoes as vectors of disease of medical and veterinary importance. They transmit the widest variety of pathogens for any known arthropod vector, viz. viruses, bacteria, rickettsia, protozoa, or even certain helminths (microfilaria) [11][12]. Rhipicephalus. Being the genus most frequently associated with both human and domesticated animals, *Rhipicephalus* is thus the utmost studied genus.

2. Genus *Rhipicephalus* and Its Common Species in Southeast Asia

Ixodidae, also known as hard ticks, are exclusively parasitic arthropods. *Rhipicephalus* is one of the 12 extant genera of Ixodidae and comprises 84 described species [13][14]. *Rhipicephalus* falls under the subfamily of Rhipicephalinae (Metastriata) (**Figure 2**).

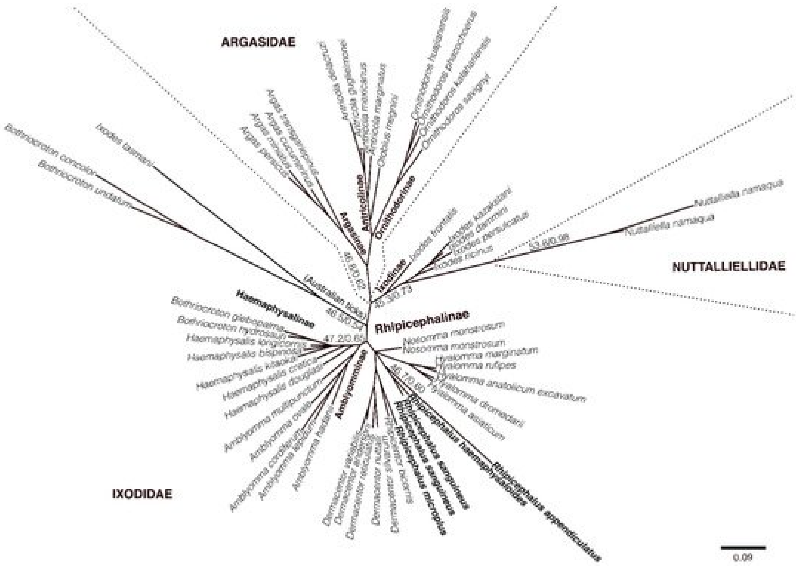

Figure 2. Phylogenetic tree based on maximum-likelihood analysis of the subfamilies of ticks from a 16S ribosomal RNA gene sequence alignment dataset. Branch support value on nodes indicates the bootstrap values of maximum-likelihood and Bayesian posterior probabilities. The highlighted names are *Rhipicephalus spp.* tick sequences from several countries.

Tick species under this genus are found globally even in regions they may not be necessarily 'indigenous' to. Animal trade across the SEA region and other parts of the world enhances the rapid distribution and establishment of tick species such as *Rhipicephalus*. *Rhipicephalus* species are associated with the infestation of livestock or domesticated animals, primarily cattle and dogs [15][16][17][18] imported into or exported out of the SEA region. They are mainly two- and three-host ticks (*Rhipicephalus*) or one host ticks for all the five species under Boophilus.

Morphology-based taxonomic classification of *R. microplus* and *R. sanguineus* s.l. has been challenging even for the most experienced taxonomists. The intra-species variations within the *R. microplus* species complex led to the description of multiple sub-species. However, many were later considered synonyms to *R. microplus* or *R. australis* [19]. In recent years, molecular-based phylogenetic analyses added a great deal of insight into the species diversity within the *R. microplus* species complex. Based on studies of mitochondrial cytochrome c oxidase subunit I (COI) gene marker, there are five different phylogenetic clades within the *R. microplus* species complex viz. *R. annulatus*, *R. australis* and three *R. microplus* sensu stricto (s.s.) clades [18][19][20]. These species are not possible to be differentiated based on morphology alone. *Rhipicephalus sanguineus* s.l. on the other hand was shown to have two major phylogenetic clades, the northern (tropical) and southern (temperate) lineages [21]. Besides, several other phylogenetic clades, or operational taxonomic units (OTUs), also exist, representing separate species and needs to be confirmed in further genetic characterization [21].

Rhipicephalus microplus has been reported to occur in Cambodia [22], Laos [22][23], Myanmar [19], Vietnam [24][25], Thailand [26][27], Malaysia [18], the Philippines [28][29] and Indonesia [30][22]. *Rhipicephalus microplus* is frequently found on livestock animals such as cattle [30], water buffaloes [29] and goats [18]. *Rhipicephalus microplus* is widely researched as it is a significant pest of cattle with substantial economic impact [31]. *Rhipicephalus sanguineus* s.l. refers to a group of closely related species associated with dogs worldwide [32]. In SEA, it has been recorded in Laos [23][33], Myanmar [34], Vietnam [35], Thailand [36], Malaysia [37][38], the Philippines [39] and Indonesia [40]. So far, the *R. sanguineus* s.l. identified in SEA fall within the tropical lineage [37]. Nevertheless, the genetic diversity of *R. microplus* and *R. sanguineus* s.l. ticks in SEA is still largely unexplored. Not to mention that there are other species of *Rhipicephalus* whose molecular work are comparatively lesser than *R. microplus* and *R. sanguineus* s.l. *Rhipicephalus pilans*. For instance, only one nucleotide result was available in the gene bank after research on the evolution and ecological niches of *Rhipicephalus* was published in the year 2021 [41].

3. Host Range of *Rhipicephalus* Species in Southeast Asia

The host specificity of *Rhipicephalus* in SEA can be narrowed down based on previous incidences and findings. They are mainly associated with several types of livestock and companion animals (**Table 1**).

Table 1. Host-tick list of *Rhipicephalus* hard tick in Southeast Asia.

Host Type	Country	Tick Species	Host	Reference
Livestock	Cambodia	*Rhipicephalus microplus*	Unknown	[22]
		Rhipicephalus australis	Unknown	[42]
	Indonesia	*Rhipicephalus australis*	Unknown	[42]
		Rhipicephalus haemaphysaloides	*Bos taurus* *Bubalus bubalis* *Capra aegagrus hircus*	[43]
		Rhipicephalus microplus	*Bos taurus* *Bubalus bubalis* *Capra aegagrus hircus* *Equus caballus* *Sus scrofa*	[30][43][44]
		Rhipicephalus pilans	*Bos taurus* *Bubalus bubalis* *Capra aegagrus hircus* *Equus caballus* *Ovis aries*	[30][43][44]
		Rhipicephalus sanguineus s.l.	*Bos taurus* *Bubalus bubalis* *Gallus gallus domesticus* *Sus scrofa domesticus*	[44]
	Laos	*Rhipicephalus haemaphysaloides*	*Bos sp.*	[23]
		Rhipicephalus microplus	*Bos sp.*	[23]
		Rhipicephalus australis	Unknown	[42]
	Malaysia	*Rhipicephalus microplus*	*Bos taurus*	[18][45]
		Rhipicephalus microplus	*Bos sp.*	[19]
	Myanmar	*Rhipicephalus microplus*	*Bos sp.* *Sus scrofa*	[46]
	Singapore	*Rhipicephalus microplus*	*Bos sp. and Bos taurus*	[27][47][48]
	Thailand	*Rhipicephalus australis*	Unknown	[42]
	The Philippines	*Rhipicephalus microplus*	*Bos sp. and Bos indicus* *Bubalus bubalis* *Capra aegagrus hircus*	[28][29][49]
		Rhipicephalus haemaphysaloides	*Bos sp.*	[50]
	Timor-Leste	*Rhipicephalus microplus*	*Bos sp.* *Capra aegagrus hircus*	[50]
		Rhipicephalus sanguineus s.l.	*Bos taurus*	[50]
		Rhipicephalus annulatus	*Bos sp.*	[51]
	Vietnam	*Rhipicephalus microplus*	*Bos sp.*	[24]
		Rhipicephalus sanguineus s.l.	*Bos sp.*	[52]
		Rhipicephalus haemaphysaloides	*Canis lupus familiaris*	[43]

Host Type	Country	Tick Species	Host	Reference
Companion animals	Indonesia	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris* *Felis catus*	[53][43][54]
		Rhipicephalus haemaphysaloides	*Canis lupus familiaris*	[23]
	Laos	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris*	[33][55]
		Rhipicephalus sanguineus s.l.	*Canis lupus familiaris*	[37][56][57][58][59][60][61][62]
	Malaysia	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris*	[34]
	Myanmar	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris* *Felis catus*	[53][62][63]
	Singapore	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris*	[21][36][62]
	Thailand	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris* *Felis catus*	[53][29][62]
	The Philippines	*Rhipicephalus haemaphysaloides*	*Canis lupus familiaris*	[52]
	Vietnam	*Rhipicephalus sanguineus* s.l.	*Canis lupus familiaris*	[21][35][52][62]
Rodents	Indonesia	*Rhipicephalus haemaphysaloides*	*Forest rats **	[43]
		Rhipicephalus microplus	*Rattus exulans* *Rattus hoffmanni* *Rattus rattus*	[44]
		Rhipicephalus pilans	*Niviventer fulvescens* *Rattus argentiventer* *Rattus exulans* *Rattus rattus* *Rattus tiomanicus*	[43][44][64]
		Rhipicephalus sp.	*Sundamys muelleri*	[65]
	Malaysia	*Rhipicephalus haemaphysaloides*	*Pteropus vampirus* *Rusa unicolor* *Helarctos malayanus* *Panthera tigris* *Varanus salvator* *Sus scrofa* *Hylomys suillus*	[43][66]
Wild animals	Indonesia	*Rhipicephalus microplus*	*Bos javanicus* *Manis javanica* *Rusa timorensis* *Rusa unicolor*	[43][44]
		Rhipicephalus pilans	*Crocidura nigripes* *Hylomys suillus* *Rusa timorensis* *Suncus murinus* *Sus scrofa*	[43][67]
		Rhipicephalus sanguineus s.l.	*Bos javanicus* *Rusa unicolor*	[43]
	Thailand	*Rhipicephalus haemaphysaloides*	*Arctictis binturong* *Cuon alpinus* *Martes flavigula* *Neofelis nebulosi*	[68]
		Rhipicephalus microplus	-	[44]
Human	Indonesia	*Rhipicephalus pilans*	-	[44][64]
		Rhipicephalus sanguineus s.l.	-	[43]
		Rhipicephalus microplus	-	[68]
	Thailand	*Rhipicephalus sanguineus* s.l.	-	[69]

* Not being explicitly mentioned on the species in the original article.

4. The Impacts of Ticks and Tick-Borne Diseases

Tick-borne diseases transmitted by *Rhipicephalus* ticks affect cattle production worldwide, including SEA countries [70][71][72]. Studies have shown the potentially devastating impact of *R. microplus* infestation on developing countries' livestock economies [31]. These losses are bothered by developing countries' inability to control and monitor the diseases; hence, it impairs the livestock economy [73]. The distribution and prevalence of these diseases across the SEA geopolitical area appear to be quite eco-oriented. Important Rhipicephalus-borne diseases in SEA are babesiosis, anaplasmosis, theileriosis, and ehrlichiosis. Some other pathogens transmitted by *R. sanguineus* s.l. include Hepatozoon canis [39][60][74] and Coxiella burnetti [59], which causes hepatozoonosis and Q-fever, respectively. The host range for these diseases is reasonably consistent, although outliers to the known host range for some tick-borne diseases have also been reported in the SEA. For instance, rare infections in a previously unknown host for Babesia canis, such as in wild rodents, have been reported [75] in Thailand. Similarly, Lim et al. [76] reported a rare occurrence of human babesiosis (caused by Babesia microti) exported from the USA into Singapore.

Babesiosis affects most warm-blooded animals with high economic and health consequences. *Babesia caballi* and *Theileria equi* collectively cause equine piroplasmosis characterized by fever and jaundice, mainly in horses and other Equidae in SEA [77][78]. Anaplasma that causes anaplasmosis is a tropical to subtropical rickettsial disease of ruminants and companion animals. Anaplasma marginale and *A. centrale* are the notable species in cattle and buffaloes across SEA [79], while *A. platys* occur in dogs [74][80].

Currently, tick-borne protozoal and rickettsial diseases are invariably endemic in SEA. Concurrent infectious diseases with Babesia, Theileria, *Anaplasma* and *Ehrlichia spp.* are increasingly reported. The theory of increasing sensitivity of pathogens detection with the help of molecular work could logically fit this scenario. However, it remains unclear why such co-morbidities are consistently challenging to treat, and the ticks are difficult to control in the environment. Hence, an elaborate effort is required to identify the epidemiological patterns of *Rhipicephalus*, the pathogens they transmitted and the rising incidence of resistance to control drugs of this tick in SEA. Molecular detection of the presence of pathogens in squashed ticks is more direct in understanding the host-parasite dynamics for TBDs should be extended further to involve more host species of *Rhipicephalus* in the region. It remains crucial to determine the extent to which *Rhipicephalus* species act as biological, mechanical vectors or both for pathogens of interest.

Tick-borne protozoan diseases cause substantial economic loss in Thailand's dairy and beef industries [81]. High mortality rates were noticed in the 50 million USD imported exotic breed of cattle due to tick-borne diseases. The Department also expended over 20 million USD to diagnose, treat and control diseases of animals. However, the exact economic impacts of ticks and tick-borne diseases in SEA are not available due to the lack of farm economic impact study compared to the European and African regions [82].

5. Resistant and Susceptibility Host Responses

The complex interaction, mainly due to the host's diverse immune mechanisms and non-immune structural components, has contributed to various responses towards tick feeding [83]. Most mammals mount an immunological response to a feeding tick bite. It is often more vital to the host's species with little or no evolutionary experience. Some species or breed appear to be better adapted to the tick bite; for instance, Bos indicus cattle breeds are more resistant to *R. microplus* than *B. taurus* breeds, although considerable variation in resistance exists between and within breeds [84]. The pattern of host resistance to ticks in the SEA region is not necessarily different from other parts of the world. Such resistance is often dependent on the commonality of the several species. Resistance is generally believed to be under genetic control [85]; thus, highly resistant animals can be selected to progress genetic improvement in tick resistance within a herd.

Overall, resistance to *R. microplus* infestation in cattle has many effector mechanisms. Although some of the mechanisms and modulating factors have been identified and quantified, much remains to be explained. Studying the genetic resistance to ticks among different breeds of cattle can contribute to alternative control methods. Investigations have intensified the crossing of these two groups, aiming to obtain more resistant animals to the conditions found in tropical countries and are also good meat producers. Regarding SEA, in addition, the host-range resistant factors should be expanded to include companion animals, wild animals, and livestock to understand the phenomenon. For future research, potential research of wild cattle in SEA such as Banteng (*Bos javanicus*), Gaur (*Bos gaurus*) and water buffalo (*Bubalus bubalis*) can be explored for conservation and genetic diversification purposes.

6. Controlling and Acaricides Resistance

Rhipicephalus ticks' control mainly depends on conventional acaricides. However, the exhaustive use of these chemicals has resulted in tick populations developing resistance to major acaricide chemical classes [86]. Ivermectin, a macrocyclic lactone, is used as an endo-ectoparasiticide. It is used as an acaricide and anthelmintic in goat and sheep farms in Malaysia [87], Indonesia [88], and Thailand [89]. Although there is currently no report of acaricide-resistant *Rhipicephalus* ticks in the SEA region, we cannot discount the possibility of this event. Thus, the application of alternative tick control approaches, including the rotation of acaricide, sterile hybrid ticks, pasture rotation, anti-tick vaccine, development of host resistance to ticks and the use of plant extracts, should be explored in SEA.

The alternation of the use of two or more acaricide with different modes of action could be an advantageous tick control method as well as a measure to prevent cross-resistance [86].

The success of mosquito control using genetic control methods [90] rekindled interest in using this method to control *Rhipicephalus* ticks. Osburn and Knipling [91] demonstrated sterile males' production and fertile females through the mating between R. annulatus and R. microplus. The backcrossing of fertile female progenies also produces sterile males and fertile females [91].

The per capita consumption of livestock products among SEA countries is projected to increase in the years to come [92] significantly. The increase in demand for livestock products has intensified the race to acquire agricultural land between the livestock and crop farmers. Integrating both cash crop plantations with ruminant cultivation is very much encouraged [93].

Since the excessive use of acaricides has been shown to cause the accumulation of chemical residues in milk, meat, and the environment, safer methods have arisen. Vaccination or immunological control is touted as the most promising, environmentally friendly, and sustainable strategy for the management of *Rhipicephalus* infestation [94].

Plant extracts or secondary metabolites, including flavonoids, terpenes, spilanthol and coumarins, have been studied comprehensively for their potential to control ticks [95].

In essence, livestock farmers in SEA are the most burdened by problems associated with R. microplus infestation. However, due to the structural issues plaguing the SEA livestock industry (such as the high cost of animal feeds, lack of quality breeds, inefficient coordination of agricultural policies and limited industry linkages [96][97][98][99], most smallholder farmers resort to using acaricide as it is the most cost-effective method to control tick infestation. Hence, in addition to structural reforms to the agriculture policies by the respective governments, farmers must be educated on sustainable agricultural practices and shown the impact of such practices in improving income levels [100]. Besides, there should be more university-industry-farm partnerships for the pilot-testing of newer technologies such as the application of Internet-of-Things and artificial intelligence to improve aspects of livestock farming [96].

7. Conclusions

The *Rhipicephalus* species is abundant and widely distributed in SEA. There seems to be no propensity for certain *Rhipicephalus* species in one SEA country over another because of the uniformity in environmental parameters. Thus far, the host range for *Rhipicephalus* is within those animal species of domestic reach (from food animals to companion animals to rodents). The presence and host range of *Rhipicephalus* species in the wild is yet to be studied and understood. There is a realm of unknown ecodynamics for this species. Nevertheless, *Rhipicephalus* pilans were found in some wild animals in Borneo. The distribution in other countries and domestic animals need crucial investigation to factor in this species in the epidemiology of tick-borne diseases in the region. The occurrence of ticks and tick-borne diseases in SEA follows a trend of the countries' affinity for specific domestic species and outbreak incidence. Those with a higher buffalo population, such as Thailand and Cambodia, would have a higher report of *Rhipicephalus* and TBDs prevalence associated with buffaloes, and vice versa for countries that farm cattle or small ruminants more.

Tick-borne diseases in SEA remain poorly characterized, mainly due to limited expertise and insufficient research interest. Base on the works collected from this review paper, we found that the knowledge of *Rhipicephalus* ticks in this region is still somewhat restricted. Reports and studies of these ticks focused primarily on the occurrence and the diseases associated with this parasite. Even though this genus of ticks consists of the two most economically important species, the data on their impacts in both the livestock and pet industry in SEA countries are not available. In some countries, there are absolutely no reports. Therefore, concerted efforts must be mounted to establish a rapporteur system for tick and TBDs in SEA. Babesiosis, anaplasmosis, and theileriosis are the most reported tick-borne disease of animals in SEA. Diagnosis is usually based on clinical signs of anemia, jaundice, fever, and laboratory findings, while treatments range from antibiotics to antiprotozoals. The roles the *Rhipicephalus* plays in the potential mechanical transmission of these diseases remains unclear even as the biological vector status is established.

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