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Tick distribution pattern in India and Overview on possible methods for their control

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Abstract
Ticks have a major impact on husbandry, productivity and welfare of domestic animals. They are responsible for substantial economic losses to the livestock industry directly through dermatitis, weight loss, loss of quality of hides, itching, irritation, anaemia and indirectly through transmitting viral, rickettsial, bacterial and protozoan diseases. The studies show that prevalence of ticks has a seasonal distribution, preferable host selection and also depends on rearing practices adopted by small holders and the rearers. Ticks have been controlled by using chemical acaricides since past several decades, but, the method has been posing several deleterious effects including environmental pollution and resistance development. Therefore, focus is given on several alternative methods to control the ticks. The present paper deals with the distribution pattern of ticks in India and possible factors that affect their prevalence. The paper also discusses several strategies (conventional and alternatives) for tick control.

Keywords: Ticks, prevalence, tick control strategies etc

Introduction

India's livestock sector is one of the largest in the world and plays an important role in country's economy. The major constraints in the livestock sector are the parasitic infections, out of which the ectoparasitic infestation is among the serious veterinary problems [1, 2]. The ectoparasites are known to cause heavy economic losses to livestock industry due to their usual habit of blood sucking, which adversely affects the economic production [3]. Among the arthropod ectoparasites, ticks are the important and the most common ectoparasites of mammals, birds and reptiles worldwide [4].

Ticks belong to phylum Arthropoda and order Acarina. There are 899 tick species that parasitize the vertebrates including Argasidae (185 species), Ixodidae (713 species) and Nuttalliellidae (1 species) [5]. Argasidae ticks are soft ticks while Ixodidae are hard ticks. Hard ticks feed for extended periods of time on their hosts, varying from several days to weeks, depending on such factors as life stage, host type, and species of tick. The outside surface, or cuticle, of hard ticks actually grows to accommodate the large volume of blood ingested, which, in adult ticks, may be anywhere from 200 to 600 times their unfed body weight [6].The economically most important ixodid ticks of livestock in tropical regions belong to the genera of Hyalomma, Boophilus, Rhipicephalus and Amblyomma [7].

Prevalence of ticks in India

Despite their high medical and veterinary importance, ixodid ticks remained an unstudied group in India till 1928. The pioneering work of Sharif (1928) had resulted in the publication of an identification key to ixodid ticks, which later on formed the baseline for further studies on various aspects of Indian tick fauna [8]. Checklists of Indian ticks, based on collection of ticks from different parts of India were prepared and documented by different workers [9-12]. The distribution and abundance of ticks species infesting cattle and other animals in India vary greatly from one area to another. The incidence and prevalence of ixodid ticks were reported from different parts of the country viz. Gujarat, Haryana, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal [13-24]. The detail of the tick species found in different animals studied in different states in India is shown in Table1.

Table 1: Tick species found in different animals studied in different states investigates so far in India

S.No	Name of the State	Tick Species Found	Animal Studied	References
1.	Gujarat	Rhipicephalus sanguineus,	Dog	[14]
2.	Haryana	Hyalomma anatolicum anatolicum, H. anatolicum excavatum, Rhipicephalus sanguineus, R. (Boophilus) microplus, R.(Boophilus) decoloratus and Dermacentor spp.	Cattle and Buffalo	[21]
3.	Kerala	Haemaphysalis bispinosa, H. intermedia, H. turturis, H. aculeata, H. cuspidata, H. spinigera, H. knobigera sp., Rhipicephalus haemaphysaloides, R. sanguineus, R. (Boophilus) annulatus, R. (B.) microplus, R. (B.) decoloratus, Hyalomma marginatum isaaci, H. anatolicum anatolicum, H. hussaini, Nosomma monstrosum, N. keralensis sp. and Amblyomma integrum	Cow, Buffalo, Goat, Pig, Dog, Cat Domestic Fowl, Duck, Sheep, and Pigeon	[17]
4.	Maharashtra	Rhipicephalus spp., Hyalomma spp., Amblyomma spp.	Cattle and Buffallo	[19]
5.	Punjab	Hyalomma anatolicum anatolicum and Rhipicephalus (Boophilus) microplus	Cattle	[20]
6.	Rajasthan	Amblyomma clypeolatum, A. javanense Boophilus microplus, Haemaphysalis indica,H. kutchensis, Hyalomma antolicum anatolicum H. detritum, H.	Cattle, Small Mammal, Camel, Dog, Lizard,	[13]

		romedarii, H. hussaini, H. kumari, H. marginatum isaaci, Hyalomma sp., Rhipicephalus haemaphysaloides R. ramachandrai, R. sanguineus, R. turanicus, Ixodes vespertilionis	Tortoise, Python, Hare	
7.	Tamil Nadu	Hyalomma anatolicum anatolicum, H. marginatum isaaci, Rhipicephalus haemophysaloides and Haemophysalis bispinosa	Sheep and Goat	[15], [16]
8.	Uttarakhand	Rhipicephalus (Boophilus) microplus, Rhipicephalus sanguineus, Rhipicephalus Haemaphysaloides, Hyalomma anatolicum anatolicum and Hyalomma marginatum isaaci	Cattle and Buffalo	[18]
9.	Uttar Pradesh	Rhipicephalus (Boophilus) microplus, Haemaphysalis bispinosa, Hyalomma anatolicum anatolicum	Cattle and Buffalo	[23], [24]
10.	West Bengal	Hyalomma anatolicum anatolicum, H. brevipunctata,Haemaphysalis bisponosa, H. darjeeling, H. aborensis, H. aponommoides and H. ramachandrai, Boophilus microplus, Dermacentor auratus	Cattle, Dog, Goat, Man, Fox, Deer	[22]

Distribution of various tick species in three countries *viz.* India, Bangladesh and Pakistan has been reported [25]. A total of 105 tick species were reported by them from India alone. Out of these 105 tick species, 87 species belonged to family Ixodidae (hard ticks) and 18 tick species belonged to family Argasidae (soft ticks). The ixodid ticks reported from India included *Amblyomma* (12 species), *Dermacentor* (3 species), *Haemaphysalis* (44 species), *Hyalomma* (8 species), *Ixodes* (11 species), *Nosomma* (1 species), *Rhipicephalus (*8 species).

Medical, veterinary and economic importance of ticks

Ticks have been recognised as important ectoparasites of livestock. They are known to be voracious blood suckers, causing heavy blood losses, toxicosis, hide damage, irritation, and weight loss resulting in lower productivity [26] as well as mortality [27]. Ticks have been found to affect the appetite, body condition, blood composition and respiratory rate of the animals, besides spreading tick-borne diseases like theleriosis, babesiosis etc. [28]. A review was done on the effect of tick infestation on the productivity of all breeds of cattle, it is reported that on an average, each engorging tick was found responsible for the loss of 1.37 ±0.25 g body weight in *B. taurus* and 1.18 ± 0.21 g in *B. taurus* X *B. indicus* cattle [29]. Severe tick infestation has been reported to cause tick induced anaemia and even death in cattle [30], [31]. In addition, the ticks may cause immune suppression in the host which may facilitate the attack of other microorganism; causing further diseases [32, 33]. Several studies have reported that although tick burden was not found directly associated with the reproductive efficiency, but, there was a trend that the time between parturition to first ovulation and the conception has shown to increase with an increase in tick burden [34]. Thus ticks contribute significant loss of production to the livestock, dairy and leather industries due to their multifarious effects on the host animal [35]. The potential of ticks as a vector in transmitting diseases have been reported for *Boophilus* (bovine babesiosis and anaplasmosis), *Haemaphysalis* (theileriosis and babesiosis in sheep and goats), *Hyalomma* (bovine tropical theileriosis, equine babesiosis), *Rhipicephalus* (canine babesiosis, ehrlichiosis and equine babesiosis), and *Argas* (aegyptianellosis, spirochaetosis in birds). Ticks are reported to transmit variety of pathogens that cause human diseases as well such as lyme diseases, ehrliciosis, babesiosis, rocky mountain spotted fever, Kyasanur Forest disease (KFD), Indian Tick typhus (ITT), Crieman Congo Haemorrhagic fever (CCHF), tularemia and tick borne relapsing fever [36, 37].

In India, tick and tick borne diseases causes loss of US $498.7 million (more than 2000 crores) per annum [38]. Over the past two decades, the incidence of tick borne diseases has increased and poses a major public and animal health problem. The recent report of increasing number of tick borne diseases (KFD, ITT and CCHF) essentially underlines the need for strategic and effective tick control methods, as in neglected and untreated animals death could occur [39]. Farmers in high risk areas consider tick worry to be an important constraint as the most common combined effect of TTBDs in Indian dairy system is a reduction in milk yield. Loss of 14% of the lactation would therefore result in a significant reduction in income and would be particularly serious for the livestock dependent system [40]. Some of the important tick-borne diseases of human and livestock in India has been shown in Table 2.

Table 2: Important tick-borne diseases of human and livestock in India

S.No	Tick Borne Diseases	Pathogen/Parasites	Tick Vector	Host
1.	Kyasanur Forest Diseases	Kfd Virus	Haemaphysalis spinigera	Man
2.	Crimean Congo Hemorrhagic Fever (CCHF)	Cchf virus	Hyalomma spp	Man
3.	Indian Tick Typhus (ITT)	Rickettsia conorii	Rhipicephalus sanguineus	Man
4.	Bovine Tropical Theileriosis	Theileria annulata	Hyalomma anatolicum anatolicum	Cattle
5.	Babesiosis	Babesia bigemina B. motasi B. canis B. ovis B. equi	Boophilus microplus Haemaphysalis sp R. sanguineus Rhiphicephalus sp Hyalomma sp	Cattle/Buffalo Goat Dog Sheep Horse
6.	Anaplasmosis	Anaplasma marginale	B. microplus	Cattle, Buffalo, Sheep
7.	Ehrlichiosis	Ehrlichia bovis, E. canis	Hyalomma sp R. sanguineus	Cattle Dog

***Source*:** Ghosh *et al., J Vect Borne Dis* 44, June 2007, pp. 79–89 [38]

The lack of accurate data on the epidemiology of TTBDs in India makes it difficult to determine their impact. However, since each of the TBDs is Vectored by particular tick species, the potential distribution of each disease can be estimated from the distribution of its vectors.

Factors affecting prevalence of ticks

A number of factors affect the percentage of tick infestation that include climatic conditions of the area, susceptibility of breed, age of the host and predilection site etc. Some are discussed below:

Season

Ixodid ticks have been reported to show higher prevalence in animals during the rainy season and it has been documented by several workers [41-45]. A study in Bangladesh has reported high tick prevalence in summer season [46]. However, in Paraguay the highest tick prevalence recorded in late autumn [47]. The difference in the studies may be attributed to changes in the seasonal activity of the ticks due to abiotic conditions of the area [48]. The contrasting results of various studies can also be explained by the fact of variations of geographical location of experimental area, topography, the composition of soil, type, and humidity of the area under study. Ticks at higher altitudes may be limited by delayed development of ticks due to colder temperature and desiccation [49]. However, the global warming has resulted in the establishment of ticks even at higher altitudes [50].

Host Breed

Breed has been considered as an important determinant in the susceptibility of animals to tick infestation. No breed is completely resistant to ticks and all the breed at the same time adversely affected by parasites [51]. It was also reported that due to high tick infestation, the productivity of *Bos taurus* has been affected while there is little effect on *Bos indicus*. The degree of tick resistance has been found a highly heritable trait in *Bos indicus* cattle and their crosses [28]. A comparative study on relative tick infestation was done in *Bos indicus* (Zebu) and its cross bred (*Bos indicus* X *Bos taurus*) and it was found that the tick burden of pure zebu cattle was less as compared to zebu-taurine cross under identical field conditions [52]. Serum complement levels were found to be negatively associated with the tick burden, being higher ($P<0.001$) in pure zebu cattle than in the cross bred [35]. The tick resistance in Boron, Friesian and Arsi breeds of cattle against ixodid ticks was also investigated and it was observed that the local Arsi breed has proven to be more resistant to ixodid ticks in comparison to the exotic Boron and Friesian exotic breeds [53]. The rapid rate of turning of dairy farming from indigenous to exotic breeds is also making livestock sector more prone to tick infestation [54].

Host Age

The age of the host animals has an important role on the infestation pattern of tick species [55]. In an epidemiological in different agro- climatic zones of Punjab state, it was found that among the various age groups significantly higher tick infestation was recorded in calves of less than 6 months followed by 6 months -1 year age group and least in >1year age group [20]. However, other reported that calves (below one year) were the most susceptible followed by grown up and adult cattle [18]. The possible reason behind this trend may be the lack of immunity in young cattle against the ecto-parasites [18]. In addition to low immune defence in the calves, another reason might be that the softer and thinner tissue of the young calves also facilitated the penetration of tick mouth parts into the host for successful feeding. The resistance in the animals build up as the age advanced and the animals became more adaptable with older age than in younger state irrespective of the farm species [55]. However, in another study prevalence of ectoparasites was reported significantly higher ($p<0.05$) in older animals aged followed by in adult aged > 2- 8 years and lowest in young animals [46, 56].

Predilection Site

The study on the attachment of tick on different body part of cattle is an important aspect of epidemiological studies. The predilection site of tick infestation may vary, both with the tick species and with the animal host. In different studies on predilection sites, it was observed that adult *Rhipicephalus appendiculatus* adults preferred feeding on the ears, and *Amblyomma variegatum* adults on the dewlap, axillae, udder and groin, *Rhipicephalus (Boophilus) decoloratus* or *Rhipicephalus (Boophilus) microplus* generally on the shoulders, dewlap and belly; while *Hyalomma truncatum* adults were mostly found around the anus [57-60]. It is also reported that larvae of *Rhipicephalus (Boophilus) microplus* prefer sparser and shorter hair as found on flank, axillae and dewlap in summer, and densely haired parts such as back and neck in winter [61]. Generally, most of the ticks have been reported to infest the sites with thinner skins and shorter hair. This predilection is suitable for ticks because it allows easy penetration of their mouth parts into the blood vessels for feeding. Moreover, the predilection for the groin area and external genitals is also because they are richly supplied with blood vessels. No association of coat colour with the prevalence of tick infestation has been reported so far, however in a study it was reported that cattle with brown coat colour have less infestation as compared to white or black or spotted coat [19].

Tick Control

Chemical control

Use of arsenic was the first effective method for controlling ticks in South Africa [62]. It was inexpensive, stable, and water soluble, and proved to be most effective agent. Unfortunately, arsenic has a very short residual effectiveness (less than one to two days), and in most areas of the world *Boophilus* ticks have become resistant to arsenic [63]. Organochlorine insecticides were the first synthetic organic insecticides to be marketed and many of them were formulated for the control of ticks on cattle. DDT and benzenehexachloride (BHC) were the first of this group of chemicals to be used as acaricides [64, 65]. The organophosphates are generally the most toxic of all pesticides to vertebrates [66]. The development of organophosphate acaricides was primarily for the control of organochlorine resistant *Boophilus* ticks [67]. Ethion, chlorpyrifos, chlorfenvinphos and coumaphos are four of the most widely used organophosphates for the treatment of tick-infested cattle. The formamidines, chlordimeform, clenpyrin, chlormethiuron and amitraz are members of a small group of chemicals that are effective against ticks. Synthetic pyrethroids e.g. permethrin and fenvalerate, were the first of these materials available for control of ticks on cattle [66]. Two classes of macrocyclic lactones with acaricidal activity are ivermectin and milbemycins. They are very active at low doses for controlling ticks. The subcutaneous injections of ivermectin, doramectin and moxidectin are efficacious for the control of ticks on cattle

[68]. Another class of pesticide is the spinosyns for eg. spinosad, a fermentation metabolite of the actinomycete *Saccharopolyspora spinosa*. Spinosad provides about 90% control of *Boophilus microplus* on cattle infested with all the three parasitic stages *i.e.* larvae, nymph and adults [69]. Synthetic acaricides are the mainstay of tick control world-wide. Despite being the preferred choice for tick control, indiscriminate use of acaricides has contributed to the development of resistance in the ticks [70]. Large scale resistance to Organophosphate (OP) compound, diazinon, has experimentally validated in Indian isolates of *Rhipicephalus (Boophilus) microplus* [71]. The resistance levels against cypermethrin and deltamethrin, the most commonly used synthetic pyrethroids (SP), in *Rhipicephalus (Boophilus) microplus* using adult immersion test was experimentally validated on the basis of the data generated on variables (mortality, egg mass weight, reproductive index and percentage inhibition of oviposition), they categorized the different levels of the resistance [72].

Vaccination

Vaccination is an environment friendly and effective strategy for tick control. It can reduce vector capacity to transmit pathogens. Due to concerted research efforts in this field, two recombinant vaccines (Gavac TM and Tick GARDPLUS) against *Rhipicephalus (Boophilus) microplus* are available commercially. Both the vaccines are based on the concealed tick midgut protein, Bm86 [38]. In India, much of the earlier work was focused on immunization of animals using crude and partially purified antigens to develop a protective immune response against ticks. Several immunodominant antigens were identified from the crude larval and nymphal extracts of *Hyalomma anatolicum* and *Rhipicephalus (Boophilus) microplus* with varied efficacy against challenge infestations. However, none of the studies have reached to the development of immune-prophylactic measure against the target tick species.

Pasture Burning and Rotation

Other methods like pasture burning have also been considered for tick control [73-75]. Burning pasture is a named component of the Cuban government directed integrated tick management program [76]. Regular monitoring of burning pasture is necessary for controlling all stages of ticks because ticks recolonize burnt areas [77]. However, the burning of pastures on a routine basis may be difficult for the resource-poor livestock raisers in the developing countries. Pasture alternation and/or rotation management approach consists of keeping grazing areas free of cattle until the larvae die. Pasture alternation and/or rotation combined with applications of chemical acaricides has been proved as an effective way for the control of cattle ticks [78]. Pasture rotation combined with acaricide applications or habitat conversion was the most economically feasible IPM strategy in reducing tick burden ranging from 77% to 89% [79]. In contrast to pasture burning method, rotation and/or alternation of pastures can also be adopted by the resource-poor farmers.

Ethno-veterinary Practices (EVP)

Ethno-veterinary practices (EVP) are still a very much important method of treatment of livestock illness and pests especially in developing countries. Farmers and indigenous people have a long history of relying on a system of curing and treatment of animals which is basically based on folk beliefs, traditional knowledge, skills, methods, practices and use of medicinal plants as its integral component [80,81]. This practice is typically community-based and, as a result, the plant species used for such purposes may vary from one community to another. Furthermore, knowledge of such practices is orally transferred from one generation to another.

The use of plants or plant-based products for the control of arthropod ectoparasites on livestock is widespread among small scale livestock keepers in India as well as in other developing countries. Plants/plant parts and their extracts have been used in many parts of the world to kill or repel insects [82]. More than 2400 plant species have been reported to have some pest control properties [83].The ingredients of plants and herbs are known to possess insecticidal, growth inhibiting, anti-molting and repellent activities [84]. Approximately 80% of the people in developing countries rely even today mainly on traditional medicines. An estimated 14–28% of the 422,000 plants occurring on Earth have been used by human cultures for medicinal purposes at one time or another [85].

The low cost of the medicinal plants is particularly appealing to farmers, although seasonal availability, harvesting timing vis-a-vis application time, variable efficacy, uncertainty over dosages and standardization may be the drawbacks [86]. Several plants have been documented by workers which are used in EVP for the control of ticks in different parts of the country. These plants/parts include root decoction of *Lagerstroemia microcarpa* and leaf decoction of *Cleistanthus collinius* [87], roots of *Jatropha curcas* [88], leaf of *Nicotiana tabacum* [89,90], seed and leaf of *Annona squamosa* [89], [90], leaf of *Senna occidentalis* [90], bulb of *Allium cepa* [91], and seeds of *Brassica campestris* [92] among many more.

Research on Phytoextracts for Tick Control

Research on plants for use in tick control has been developed in an attempt to find extracts with acaricidal properties that can be used in association with or even as replacements for synthetic compounds. One advantage from the use of these compounds is that resistance develops slowly as there is usually a mixture of different active agents with different mechanisms of action [93, 94].

A number of studies have so far been conducted to validate the use of plants for tick control. Some plants have been tested and were proved to be capable of causing tick mortality [73] tick repellent [95] and/or tick immobilization [73]. Many workers have reported botanical products that kill parasites or inhibit oviposition [96-99].

Acaricidal activity of custard seed oil (*Annona squamosa),* neem oil (Azadirachta indica) and pyrethrins against three tick species Boophilus microplus, Hyalomma anatolicum and Rhipicephalus haemaphysalis, both in vitro and in vivo [100]. Oils of citronella, lavender, lily of the valley and peppermint found to have similar repellent effects as the commercially traded DEET (N, N-diethyl-m-tuluamide) [101].

Adulticidal and larvicidal effect of indigenous plant extracts against the adult cattle tick Haemaphysalis bispinosa Neumann, 1897 (Acarina: Ixodidae), sheep fluke Paramphistomum cervi Zeder, 1790 (Digenea: Paramphistomatidae), fourth instar larvae of malaria vector, *Anopheles subpictus grassi* and Japanese encephalitis vector, *Culex tritaeniorhynchus* Giles (Diptera: Culicidae). The study reported that indigenous plants have potency to control ticks and other parasites [102,103]. Similarly, anti-tick properties of the root extracts of *Senna italica* subsp. a*rachoides* against adults of *Hyalomma marginatum rufipes*. Of the hexane, chloroform, dichloromethane, ethyl acetate and methanol extracts tested, only ethyl acetate extracts proved to be potent against adults of *H. marginatum rufipes*. The acaricidal activity of the ethyl acetate root extract of *S. italica* subsp. *arachoides* increased significantly ($P < 0.05$) with concentration when tested against *H. marginatum rufipes* [104].

Literature survey shows that although many plant species have been used to control ticks by the rural people/ small holder farmers, still their scientific validation has not yet been widely established. Studies to evaluate anti-tick property of different plants has been carried out by various workers, but the field is still in nascent stages and still more research needs to be done in the area to explore more and more plants and plant products with the aim to develop a low-cost, effective and potent acaricide with little or no side-effects.

Conclusion

It is observed from the previous studies that ticks have a seasonal distribution and preferable host selection. The prevalence of ticks also depends on rearing practices adopted by small holders and the rearers. More systematic study on tick distribution on different host is required which may contribute to the increased understanding of epidemiology of ticks. The distribution of ticks is determined by a complex interaction of factors such as host density, host susceptibility, grazing habits, and pasture-herd management. Therefore, effective tick control program should be formulated and implemented, based on the distribution pattern of ticks and factors responsible for their distribution. It is of utmost need to control the indiscriminate and frequent use of chemical acaricide so that the chances of development of resistance should be checked. Therefore, a sustainable approach like integrated tick control strategy is highly required which involve variety of tick control methods like brushing of the animal at regular intervals, use of chemical acaricides, vaccination as well as herbal treatment of livestock for the removal of ticks.

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