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Priyanka Patoliya
Dairy Production Section, ICAR- National Dairy Research Institute, Bengaluru, Karnataka, India

Kathan Raval
Dairy Production Section, ICAR- National Dairy Research Institute, Bengaluru, Karnataka, India

Vishwaranjan Upadhyaya
Division of Animal Physiology, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Raju Kumar Dewry
Artificial Breeding Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Sanjit Maiti
Division of Dairy Extension, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Gautam Mondal
Division of Animal Nutrition, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Tushar Kumar Mohanty
Artificial Breeding Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Mukesh Bhakat
Artificial Breeding Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Corresponding Author
Mukesh Bhakat
Artificial Breeding Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Tick infestation and its herbal treatment approach in India: A review

Priyanka Patoliya, Kathan Raval, Vishwaranjan Upadhyaya, Raju Kumar Dewry, Sanjit Maiti, Gautam Mondal, Tushar Kumar Mohanty and Mukesh Bhakat

Abstract
Ticks are blood-sucking ectoparasites, a significant impediment to the dairy sector and implicated in diseases such as Babesiosis, Theileriosis, Anaplasmosis, etc., and deteriorate animal's health associated with welfare issues which have a drastic impact on the dairy farm economy and livestock productivity. Researchers's understanding of possible health threats and environmental damage caused by the excessive use of synthetic acaricides stirred the need to adopt an alternative approach in controlling the tick infestation. As a biodiverse country, India has a diverse group of medicinal herbs that can be used as a safe, effective alternative to chemical acaricides against cattle ticks. Identifying the acaricidal properties of herbal plants and their specific active components can help reduce pollution and the spread of resistance among target tick populations. The use of the herbal formulation as a tick control measure discussed in the review certainly impacts future livestock production. This article reviewed the current prevalence of tick population and infestation rate in dairy animals across the country, the variables that cause it, and their impact on animal health and production. In addition, this article includes thorough information about herbal treatments and formulations that may be used to control ticks.

Keywords: Formulations, herbal, infestation, prevalence, ticks

Introduction
In today's world of livestock production, there is no longer any debate about the relevance of producing animals in the global economy and food security. For an animal to be productive, it must be in good health (Singh *et al.*, 2021) [161]. Production loss of dairy animals is multifactorial, but endo and ectoparasites infestation and related diseases are major obstacles in animals' health and performance (Jadhao *et al.*, 2021) [73]. Ticks are only second to mosquitoes as carriers of infectious diseases in people and animals globally (Singh and Rath, 2013) [169]. As a result of infestation and associated anemia and immunosuppression, the animal is stressed, which impacts its behaviour, output, and wellbeing (Hurtado and Giraldo-Rios, 2018) [70]. In cattle, various protozoan diseases like Babesiosis, Theileriosis, Anaplasmosis and Heartwater disease are transmitted by ticks (Ghosh *et al.*, 2007) [55]. The mortality incidence is less associated with tick infestation, but growth and production-related losses are more evident (Marcelino *et al.*, 2012) [111], making the small dairy farmers economically more vulnerable. Worldwide, ticks are considered the most damaging pests of livestocks economically and exist in 931 different species (Nava *et al.*, 2017) [127]. The problems of ticks and tick-borne diseases are more common in tropical and subtropical countries like India (Minjauw and McLeod, 2003) [117], where the climatic conditions are more conducive for their growth. Ticks are blood-sucking ectoparasites belonging to the class Arachnida, Order Acari. In India, the tick genus *Rhipicephalus* and *Hyalomma* are the most common. The species *Rhipicephalus microplus* and *Hyalomma anatolicum* have have been found in 24 and 20 Indian states, respectively (Ghosh and Nagar, 2014) [56].

The most commonly used method for controlling tick infestation is to treat the host with synthetic acaricides to kill the associated larvae, nymphs, and adults. Although this has limitations because environmental pollution and parasite reoccurrence is widespread. In such recurrent conditions, introducing new chemical compounds becomes necessary due to the quick development of resistance in the tick population (Kumar *et al.*, 2021) [103]. This is one of the main challenges to the long-term viability of the livestock management system, and it must be addressed in a cost-effective and long-term manner. Herbal acaricidal formulations are one such approach that is now being used owing to their efficacy, safety, and environmental friendliness (Nimabalker *et al.*, 2020) [129]. Various plants with acaricidal, insecticidal, growth-inhibiting, anti-molting, and repelling properties are available in the traditional knowledge system (Jain *et al.*, 2020a) [77].

Most importantly, these herbs or plants are holistic in action (Martin *et al.*, 2001) [112] and, therefore, have many positive values to offer to rural livestock farmers (Odindo, 1991) [133]. Advantages of phyto acaricides include quick disintegration, lack of persistence, and absence of bioaccumulation in the environment, which have been common issues in using synthetic chemicals (Jain *et al.*, 2020b) [78]. Testing of several plant extracts against *R.(B.) microplus* revealed acaricidal properties, which might provide a viable replacement for synthetic acaricides (Morais-Urano *et al.*, 2012) [121]. With these considerations, the purpose of this review is to emphasize the prevalence of tick species in dairy animals in India and their impact on health and production, with a particular focus on the application of herbal medicinal practices in tick control and management strategies. This review constitutes a combined list of previously used plants or herbs and their formulations with acaricidal properties reported in various peer and non-peer-reviewed publications.

Tick species in India and their distribution

India is an agricultural country, and livestock is an integral part of the farming community, providing milk, meat, wool, hide, and other farm products and supporting other farming operations. In India, the awareness of the economic loss associated with tick infestation is less. Still, globally, ticks and tick-borne diseases are among the most critical bottlenecks in livestock rearing (Minjauw and McLeod, 2003) [117]. Several tick species are extensively spread throughout the country, and several studies have documented their distribution and abundance. India approximately reported 106 species of ticks, belonging to the families Ixodidae and Argasidae infesting domestic, wild, and other animals and few of them have been acting as the principal vectors of pathogens (Geevarghese *et al.*, 1997; Ghosh *et al.*, 2007) [53, 55]. The common ticks species found in India among cattle, buffalo, sheep, and goats are *Amblyomma testudinarium*, *Dermacentor auratus*, *Haemaphysalis bispinosa*, *H. spinigera, H. intermedia*, *Hyalomma anatolicum anatolicum*, *H. marginatumisaaci*, *H. hussaini*, *H. detritum*, *H. kumari*, *Rhipicephalus (Boophilus) microplus*, *Ixodes acutitarsus*, *I. ovatus*, *Nosomma monstrosum*, *R. haemaphysaloides*, and *R. turanicus* (Ghosh *et al.*, 2006) [54].

Among them, *B. microplus*, (Soulsby, 1982) [173], presently known as *R. (B.) microplus* (CFSPH, 2007) [23], is the world's most crucial cow tick, responsible for the spread of protozoans such as *Babesiabigemina*, *B. bovis* and *Anaplasmamarginale* (Abbas *et al.*, 2014) [1]. Likewise, in India, it is widely prevalent in different agro-climatic zones affecting the various age groups of animals in cattle, horse, sheep, goat, and deer (Ghosh *et al.*, 2007) [55]. Since it has the enormous spreading capacity, vector capacity, blood-sucking tendencies, and the number of cattle it affects, it has the most significant economic impact (Benavides and Romero, 2001 [16]; Garcia *et al.*, 2016 [50]). Similarly, ticks of genus *Rhipicephalus*have been reported worldwide, including India, because of their high adaptability and reproductive powers. Other tick genuses like *H. a. anatolicum*, *H. marginatumisaaci*, *B. microplus*, *R. haemaphysaloides* etc. are equally reported from almost all the states of India infesting livestock population (Ghosh *et al.*, 2006) [54]. The prevalence of various tick species across multiple states of India in dairy animals has been presented in Table 1.

Table 1: Prevalence rate of ticks in livestock in various states of India

State	Species of animal	Species of tick	Overall prevalence of ticks infestation	Reference
Andhra Pradesh (East Godavari)	Buffalo	*Haemaphysalis spp.*	29.52%	Chennuru *et al.*, 2019 [26]
Andhra Pradesh	Cattle Buffalo	*Rhipicephalus spp. Hyalomma spp.* and *Haemaphysalis spp.*	82.41% 73.26%	Anish *et al.*, 2020 [8]
Assam (Indo-Bhutan Border Districts)	Local and Crossbred Cattle	*R. microplus* (23.45%), *H. bispinosa* (15.75%) and mixed infection (10.69%)	49.90%	Mushahary *et al.*, 2019 [123]
Chhattisgarh (Bastar plateau)	Zebu Cattle (Kosli)	*R. microplus* (89.39%), *H. bispinosa* (8.83%) and mixed infestation (40.47%)	Intensity of infestation @ 7-24 ticks per animal	Jadhao *et al.*, 2018 [74]
Chhattisgarh (plain)	Cattle	*H. a. anatolicum* (68.38%), *R. microplus* (30.40%) and mixed infection (63.82%)	Intensity of infestation @ 6 to 65 ticks per animal	Jadhao *et al.*, 2020 [75]
Gujarat (Patan)	Buffalo	*Hyalommaexcavatum*	30.66%	Oza *et al.*, 2020 [134]
Gujarat South	Cattle Buffalo	*R. microplus* (57.80%), *Hyalomma spp.* (13.05), *Haemaphysalis spp.* (20.32%) and mixed infection (8.83%)	67.4% in cattle and 32.26% in buffalo	Patel *et al.*, 2019 [138]
Haryana	Cattle Buffalo	*H. a. anatolicum, H. a. excavatum, R. (B.) microplus, R. decoloratus* and *Dermacentor spp.*	55.26% 46.67%	Chillar *et al.*, 2014
Himachal Pradesh	Cattle	*R. (B.) microplus* (68.4%), *R. annulatus* (30.85%), and *H. a. anatolicum* (0.74%)	66.4%	Sharma *et al.*, 2021 [103]
Jammu	Cattle Buffalo	*R. (B.) microplus*	47.08 % 37.29 %	Khajuria *et al.*, 2015 [94]
Jammu	Cattle	*R. (B.) microplus*	40.18%	Godara *et al.*, 2018 [60]
Jhakhand	Cattle	*R. (B.) microplus* (54.68%), *H. a. anatolicum* (20.72%), *H. bispinosa* (16.29%) and Multiple species of ticks (8.30%)	41.18	Shekhar *et al.*, 2020 [163]
Karnataka	Cattle	*Haemaphysalis, Hyalomma*, and*Rhipicephalus species*	88.3%	Krishnamoorthy *et al.*, 2021 [100]
Karnataka (Tumkur)	Holstein Friesian	*Haemaphysalis spp.* and *Rhiphicephalus (Boophilus)*	88.8%	Vidya, 2021 [186]

	Jersey	*spp.*	11.1%	
Kashmir valley	Cattle Sheep Goat	*Haemaphysalis spp*. only in cattle, *Haemaphysalis spp*. (73.68%) and *Ornithodoros spp.* (26.32%) in sheep and *Haemaphysalis spp*. (85.74%) and *Rhipicephalus spp.* (14.26%) in goat	24.59% in cattle, 52.61% in sheep and 54.28% in goat	Tramboo *et al*., 2018 [181]
Kerala (Western Ghats)	Cattle	*R. microplus* (52.71%), *H. bispinosa* (16.9%), *R. decoloratus* (15.77%), *H. turturis* (11.42%), *R. sanguineus* (1.32%), *A. integrum* (1.15%) and *H. spinigera* (0.71%)	86.15%	Balasubramanian *et al*., 2019 [14]
Kerala	Crossbred Holstein Friesian, crossbred Jersey, Kasaragod Dwarf, and Vechur	*R. annulatus* (43.40%), *H. bispinosa* (32.06%), *R. haemaphysaloides* (1.89%), *Amblyomma sp.* (1.89%), *R. microplus* (15.09%), and *Rhipicephalus sp.* (5.66%)	30.8%	Akhil *et al*., 2021 [6]
Kerala	Cattle	*Haemaphysalis*, *Hyalomma*, and *Rhipicephalus species*	82.5%	Krishnamoorthy *et al*., 2021 [100]
Madhya Pradesh (Indore)	Cattle	*R. (B.) microplu* (24.07%), *H. anatolicum* (5.6%) and Mixed infection (1.7%)	58.87%	Jayraw *et al*., 2016 [82]
Madhya Pradesh (Jabalpur)	Bovines	*R. microplus* and *H. a. anatolicum*	55.83%	Katuri *et al*., 2017 [91]
Maharashtra (Nashik)	Cattle Buffalo	*Boophilus spp*. (67.28), *Amblyomma spp*. (12.09) and *Hyalomma spp*. (10.28)	62% 28.20%	Jawale *et al*.,2012 [81]
Mizoram	Cattle	*R. microplus*	63.39%	Ghosh *et al*., 2018 [58]
Odisha	Cattle	*R. (B.) microplus* (42.89%), *H. anatolicum* (11.82%) and *R. sanguineus* (4.16%)	40.27%	Dehuri *et al*., 2017 [34]
Punjab	Cattle	*R. microplus* (50.16%), *H. a. anatolicum* (11.34%) and mixed infestation (3.45%)	58.06%,	Singh and Rath, 2013 [169]
South India	Cattle Buffalo Goat	*Haemaphysalis spp*., *Boophilus spp*., *Hyalomma spp*., *Amblyomma spp*., and *Rhipicephalus spp*.	35.11% in cattle 58.06% in buffalo 41.94 in goat	Shobana *et al*., 2013 [164]
Tamil Nadu State (Nilgiri Hills and Adjoining Areas)	Cattle Buffalo Goat Sheep	*R. microplus*, *Amblyomma spp*., *Hyalomma spp*., *Haemaphysalis spp*., *Rhipicephalus spp*. And *Ornithodoros spp*.	46.51% in cattle, 12.82% in buffalo, 39% in goat and 35% in sheep	Kumar *et al*., 2014 [102]
Tamilnadu(Madurai)	Cattle	*Amblyomma spp*., *Haemaphysalis spp*., *Hyalomma spp*., *Rhiphicephalus (Boophilus) spp.*	27.34%	Ranganathan *et al*., 2021 [149]
Uttarakhand	Cattle Buffalo	Ixodid ticks *R. (B.) microplus*, *R. (B.) microplus* (96.44%), *R. sanguineus* (1.98%), *R. haemaphysaloides* (1.96%) and *Hyalomma spp.* (0.003%)	66.32% 40.67% 35.78%	Negi and Arunachalam, 2020 [128] Vatsya *et al*., 2007 [183] Vatsya *et al*., 2008 [184]
Uttar Pradesh (Mathura)	Zebu cattle Buffalo	*R. (B.) microplus*and *H. a. anatolicum Hyalomma spp*. (46.29%), *Boophilus spp*. (13.23%) and mixed infection (7.71%)	60.07 % 51.81%	Patel *et al*.,2013 [137] Patel *et al*., 2015 [139]
Uttar Pradesh (Lucknow)	Cattle Buffalo	*R. microplus* (59.74%) *H. a. anatolicum* (26.80%) and *H. bispinosa* (18.80%) *Hyalomma* and *Rhipicephalus spp*.	59.11% 53.33%	Kaur *et al*., 2017 [93] Poonam and Suman, 2017 [144]
Uttar Pradesh (Gangetic plain)	Cattle	*H. anatolicum, H. excavatum, H. hussaini, H. brevipunctata, R. microplus, R. decoloratus and H. bispinosa*	65%	Singh *et al*., 2021 [161]
Uttar Pradesh (Eastern part)	Buffalo	*R. (B.) microplus H. a. anatolicum*	59.8%	Naseem *et al*., 2020 [125]
West Bengal	Cattle	*Rhipicephalus spp*. (32.25%) *Hyalomma spp*. (12.58%) and *Haemaphysalis spp*. (3.22%) Mixed infection (6.12%)	41.93%	Debbarma *et al*., 2017 [33]

Factors affecting the prevalence of tick infestation in dairy animals

Although ticks are widely prevalent in all agro-ecological zones (Ghosh *et al.*, 2007) [55], their prevalence varies in different areas. This is attributed to various factors like geo-climatic conditions, association and management of other species of animals, age, breed, and sex of an animal, and farm management practices (Khan *et al*., 1993) [95]. For example, *B. microplus* infection rates are more significant in cattle than in buffalo because of cattle's thicker hair coat and buffalo have access to mud for wallowing, which might lead to tick dropping (Patel *et al.*, 2013) [137]. Compared to crossbred cattle, epidemiological investigations using sero-surveillance in animals revealed that indigenous breeds are more resistant to some infections even without any management methods and are less sensitive to protozoan illnesses (Ghosh *et al.*, 2020) [57]. The incidence of tick infestation and disease was shown to be greater in old and sick cattle (Ponnudurai *et al.*,

2017) [143]. Some other factors which affect the infestation rate of ticks in animals were:

Age of animal

It was observed that the age of the host depicts tick infestation pattern (Manan *et al.,* 2007) [110] and reportedly had a significant (p< 0.01) influence on the prevalence of tick and other ectoparasite infestation (Kabir *et al.,* 2011) [87]. Age-wise, tick infestation was observed to be highest in age group >1 year (76.5%) [Odds ratio (OR)]: 6.37; 3.32–12.21) followed by age group >6 months to 1 year (38.8%) (OR: 9.09; 4.67–17.69) and the lowest in ≤6months age (29.3%) (Sharma *et al.,* 2021) [162]. Mooring and Harte (2000) [119] explained that young animals' tick avoidance might be assisted due to possession of innate and cell-mediated immunity in their body. Gopalkrishnan *et al.* (2020) [63] also found that adults had a greater rate of tick infection (80.14%) than calves (19.86%). In contrast, Naseem *et al.* (2020) [125] observed a higher prevalence of tick infestation of buffalo in an age of 1–12 months (97.2%) as compared to the age of >24 months (24.3%) (OR: 4.2; P < 0.05) with the explanation that young buffaloes may not receive a sufficient amount of acaricidal treatment compared to the older animals.

Sex of animal

The female cattle were found to be more infested with ticks (Bilkis *et al.,* 2011 [19]; Mamun *et al.,* 2010 [109]) with a prevalence rate of 71.6% compared to 23.4% in male cattle (Sharma *et al.,* 2021) [103]. This greater prevalence rate than male cattle possibly due to hormonal influences (Bilkis *et al.,* 2011 [19]; Kabir *et al.,* 2011 [87]; Mamun *et al.,* 2010 [109]) i.e., high levels of prolactin and progesterone hormone makes them more prone to any infection (Kaur *et al.,* 2015) [92]. Moreover, female cattle bear higher stress than males due to pregnancy, lactation, and production, making them disposed to infection (Mamun *et al.,* 2010) [109]. In particular, the female group of crossbreds had the highest tick infestation (95.03%) and disease incidence (94.59%) (Gopalkrishnan *et al.,* 2020) [63]. However, some studies had also reported a higher prevalence of tick infestation in male cattle (Atif *et al.,* 2012 [10]; Singh and Rath, 2013 [169]; Wasihun and Doda, 2013) [189] may be the reason for higher prevalence was due to the lack of care shown by dairy farmers to their male animals (Wasihun and Doda, 2013) [189] especially after the popularization of artificial insemination (Singh and Rath, 2013) [169]. Naseem *et al.* (2020) [125] also observed a higher prevalence of tick infestation of in male buffaloes (78.5%) as compared to females (51.8%) (OR: 1.68; P < 0.05) attributed to the fact that females are given greater attention on the farm since they are more economically advantageous.

Breed of animal

Variation in the tick infestation rate among different cattle breeds under the same environmental conditions has been well known for many years (FAO, 2011) [45]. There is a positive correlation between the prevalence, production system and breed of cattle (Yacob *et al.,* 2008). It is established that the tick infestation rate was high in exotic cattle breeds followed by crossbreeds and local breeds (Kaur *et al.,* 2017) [93]. Reportedly the local breed, *B. indicus* (Brahman) cattle are highly resistant to tick infection with inconsiderable sensitivity (3.61%) than crossbreeds (96.39%) (Gopalkrishnan *et al.,* 2020) [63]. Tick infestation was highest in cross-bred Jersey cattle (69.8%) (OR: 3.51; 1.59–7.76), followed by cross-bred Holstein Friesian cattle (69.6%) (OR: 0.95; 0.51–1.75), and lowest in indigenous cattle (OR: 0.95; 0.51–1.75). (45.0 %) (Sharma *et al.*, 2021) [162]. The least tick burden in indigenous breeds is attributed to the greater concentration of serum complements than exotic cows, making them more resistant to ticks (Wambura *et al.,* 1998) [188]. Moreover, breed difference is attributable to breed's capacity to express tick resistance through morphological adaptations such as skin thickness, light coat colour, short dense hair, and immune-biochemical reactions in their skin (Franzin *et al.,* 2017 [46]; Shyma *et al.,* 2015).

Management practices

There was a higher infection rate of ixodid ticks in the intensively reared cattle compared to those raised in semi-intensive or extensive systems Kaur *et al.* (2017) [93]. This is because ticks may be fed by a crow or other birds from the body of cattle that are raised semi-intensively or extensively, which increases the odds of tick removal. However, some workers have also reported a higher infection rate in cattle that are kept under an extensive production system (Kabir *et al.*, 2011 [87]; Tiki and Addis, 2011 [179]), which substantiates the importance of managemental conditions. The risk factors related to management practices revealed that the prevalence of ixodid ticks was significantly less when the animals were kept in pucca sheds with acaricide application done both on the body and shed with reapplication in 3 months (Sharma *et al.*, 2021) [103]. The animals kept in pucca sheds with good ventilation and drainage facility with low humidity have less tick prevalence than the animals in kutcha sheds, where ticks can easily hide in cracks and crevices to lay eggs. Body condition is another determining factor of rate of tick infestation, and it was observed that animals with poor body condition (43.37%) showed significantly higher tick infestation than cattle with normal body condition (38.87%) (Dehuri *et al.*, 2017) [34]. The animals in poor physical condition were less resistant to tick infection and cannot establish resistance, whereas animals in good physical condition could fight the infestation effectively (Manan *et al.*, 2007) [110].

Season

Diverse geographical locations, terrain, soil type, and fluctuations in temperature and humidity might all contribute to variations in tick infection rates. The seasonal variations in tick infestation were reported by several workers from different parts of the world and found the higher prevalence of tick infestation in the rainy season (Atif *et al.*, 2012 [10]; Rony *et al.*, 2010 [158]; Vatsya *et al.*, 2007) [183]. This suggests that humidity is a macroclimatic factor influencing the infestation rate of ticks (Vatsya *et al.*, 2008) [184]. Monsoon season (74.9%) (OR: 1.25; 0.65–1.86) had the highest prevalence, followed by summer (65.3%) and winter (59.4%) (OR: 0.64; 0.26–0.79) (Sharma *et al.*, 2021) [162]. Favorable environmental conditions, such as ambient temperature and atmospheric humidity, as well as the conditions of grazing lands, which are ideal for tick feeding, breeding, growth, and development, uphold higher tick infestation rates in the monsoon than in other seasons (Godara *et al.*, 2018 [60]; Vatsya *et al.*, 2008) [184]. On the contrary, the survival rate of larvae, nymph, engorged females, and unfed adults becomes very low during cold and dry weather conditions and generally, they hide in cracks and crevices to pass the winter season leading to low infestation (Gray, 1991 [64]; Singh and

Rath, 2013) [169]. According to Singh *et al.* (2021) [103], tick infection prevalence in Haryana cattle was 21.75, 16.25, and 27.50 % in the summer, winter, and rainy seasons, respectively. Gopalkrishnan *et al.* (2020) [63] also revealed in a recent study that the monsoon season (38.60%) had the most tick infestation. In contrast, some studies also reported a higher tick prevalence in the summer (Kabir *et al*., 2011) [87] and winter (Mamun *et al*., 2010) [109] season.

Predilection site

The predilection site of tick infestation may vary with tick species and host. Ticks may infest any part of the host's body, but they prefer an area with soft skin in general. Typically, most ticks have been reported to infest the sites with the thinner skins and shorter hairs and the area richly supplied with blood as it allows easy penetration into the skin (Vidya, 2021) [186]. Additionally, the infestation of ticks to the cattle varies in the different anatomical regions due to the presence or absence of other alternative ectoparasites present in the particular environmental condition. Ticks prefer warm, moist, concealed places with a solid vascular supply and thin skin, making external genitalia and udder more prone to infestation (Muchenje *et al*., 2008) [122]. According to Katuri *et al.* (2013) [90], the most infested areas of the animal were the udder or scrotum (32.4%), anno-vulva (21.9%), perineum (18.77%), dewlap (16.7%), and brisket (3.1%). Dehuri *et al.* (2017) [34] revealed that with regards to tick predilection site on host body, udder (35.03%) was the highest infested site, followed by inner thighs (27.55%), perineum (8.58%), neck (8.41%), legs (7.73%), ear (7.05%), belly (5.69%) and tail (3.48%) in cattle. In contrast to this, Vidya (2021) [186] observed that the infestation level in Holstein Friesian cattle was high in the head region (508), followed by abdomen (299), leg (220), teat (100), back (33), and tail (22). However, the infestation level in jersey was high in the teat region (70), followed by the head (38), leg (25), abdomen (9), tail (6), and back (5).

Tick detection methods

Ticks cause significant economic losses both as a blood-sucking parasite and a vector of various diseases' pathogens (Grisi *et al*., 2014) [65]. The infestation must be measured to maximize the efficacy of management strategies. Various on-host sampling approaches have been utilized to acquire measurements of parasitic tick loads on domestic animals. The most common method for counting ticks is to count engorged females with a length of 4 to 8 mm by palpation on one side of the animal, and then extrapolate the result to the other side of the body by multiplying by two (Cortivo *et al*., 2016) [29]. MacIvor *et al.* (1987) [108] reported that general live sampling of ticks involves a quick but careful search of all body areas above the fetlock and gave particular attention to the muzzle, ear, belly, groin, peri-anal region and tail. This method, although well established, has some shortcomings like first, the process is slow and tiresome, second, it is subject to psychophysical and optical phenomena (Barbedo *et al*., 2017) [15], and the animals often have to be restrained (Cortivo *et al*., 2016) [29]. Later, patch sampling has been suggested for obtaining measures of relative tick burden that are comparatively quick and easy to perform on livestock animals in a field situation whereby only specific predilection sites are sampled (Baker and Ducasse, 1967) [13]. The number of ticks collected offers an indicator of the relative degree of the infestation, and patch sampling is based on the well-known fact that ticks prefer to concentrate on particular predilection regions of the host body surface (Rechav, 1982) [153]. When measures of relative tick load are sufficient, at that specific time patch sampling can provide reliable information on relative tick burdens which are positively and substantially correlated with the total tick burden (larvae, nymphs, and adults) (Kaiser *et al*., 1982; Mooring and McKenzie, 1995) [88, 120].

One of the modern technologies that can replace the traditional manual method is infrared thermography (IRT), which is a non-invasive technique that measures emitted infrared radiation and presents an image signifying the apparent temperature of an object (Alsaaod *et al*., 2015) [7]. Infrared pictures were used to identify and count ticks and horn flies in Holstein cows (Cortivo *et al*., 2016) [29]. According to Barbedo *et al*. (2017) [15], the colour transformations and mathematical morphological operations-based approach are particularly successful in identifying ticks present in pictures, even when the background contrast is low, making it simple to detect and count.

Pathophysiology and impact of tick infestation

Ticks have a drastic influence on animal production and health, either directly through their bites or indirectly by the infectious agents they transfer (Eskezia and Desta, 2016) [42], including viruses, bacteria, rickettsiae, and protozoa (Taylor *et al*., 2016) [176]. These ectoparasites affect animal production in multiple ways; some are direct i.e., production loss, anemia and by prompting disease incidence and indirectly through effects on feed intake, reproduction and growth (Hurtado and Giraldo-Ríos, 2018) [70]. Retarded development and decreased production are directly associated with the animal's lowered feed intake due to irritation caused by tick bites, altered metabolism and through the mediation of tick toxin. Besides, it is indirectly intensified due to modified physiology and homeostasis viz. changes in digestion, immunosuppression, increased abortion and lowered pregnancy rates (Mondal *et al*., 2013) [118]. Ticks being hematophagous arthropods, rely solely on blood for nutrition (Galay *et al*., 2014) [48], thus can induce anaemia and the immunosuppressive effects increase the chances of tick-borne diseases in hosts (Ferreira and Silva, 1998 [43]; Inokuma *et al*., 1993 [72]). Ticks can cause skin irritation, hair loss, lyme disease, heartwater, gall sickness and an assortment of other diseases in animals posing various problems in the dairy herd. Various tick-associated diseases in cattle reported in India have been tabulated in Table 2.

Table 2: Tick-associated diseases in Cattle reported in India

Disease	Pathogen or causative agent	Tick vector	References
Tropical theileriosis	*Theileriaannulata T. orientalis*	*Hyalommaanatolicumanatolicum*	Jongejan and Uilenberg, 2004 [83]
Bovine theileriosis	*T. buffeli T. lestoquardi*	*Hyal. anatolicumanatolicum*	Ghosh *et al*., 2006 [54]
Babesiosis	*Babesiabigemina B. bovis*	*B. microplus*	Mondal, 2013 [118]
Anaplasmosis	*Anaplasmamarginale*	*Rhipicephalus spp., Hyalomma spp., and Boophilus spp.*	Garg *et al*., 2004 [51]
Ehrlichiosis	*Ehrlichiabovis E. phagocytophilum*	*Rhipicephalus spp.*	Sreekumar *et al*., 2000 [174]

Ticks and tick-borne diseases infest over 80% of the world's cattle herd, resulting in an estimated annual economic loss of US$22 to US$30 billion (Lew-Tabor and Valle, 2016) [106] due to production loss, disease transmission and reduction in the value of hide (Garcia, 2003). Hurtado and Giraldo-Rios (2018) [70], reported that tick-infested animals consume less food (4.37 kg) which significantly hampers their growth and production than animals who are not exposed to ticks (5.66 kg). In young animals, tick infestation has serious effects as development gets compromised at an early age resulting in a long-term negative impact on its productivity and reproductive potential. On average, each tick was responsible for losing 1.37 ± 0.25g body weight in cattle (Holroyd and Dunster, 1978 [69]; Jonsson, 2006 [85]). An animal with an average of 40 ticks per day could lose weight equivalent to 20 kg per year (Frisch *et al*., 2000) [47]. In India alone, tick and tick-borne diseases cause an estimated loss of more than 26.88 US$ per annum (Ghosh *et al*., 2007) [55]. Total losses for control of babesiosis in India costs 57.2 million US$ annually (McLeod and Kristjanson, 1999) [114], while theileriosis infects around 33 million crossbred cattle and 105 million buffaloes in India, resulting in an estimated annual loss of 239.5 million US$ (Minjauw and McLeod, 2003) [117].

When ticks bite their hosts, they cause irritation, inflammation, or hypersensitivity in the skin tissue (Gashaw and Mersha, 2013) [52], potentially leading to dermatitis, secondary bacterial infections, or myiasis (Reck *et al*., 2014) [154]. As a consequence of the damage to their skin, there may be the acquisition of new diseases, and infection can become significant enough to cause death in some animals (Eskezia and Desta, 2016 [42]; Jonsson *et al*., 1998 [84]; Narladkar, 2018 [124]; Rocha *et al*., 2019 [156]). Tick-borne infections are spread by the saliva of ticks, a process known as saliva-assisted transmission (Nuttall, 2019) [132]. Tick saliva also contains a neurotoxin that can cause host paralysis (Diaz, 2015; Kwak and Madden, 2017; Pienaar *et al*., 2018; Wikel, 2018) [36, 105, 142, 191]. Tick bites degrade the quality of hides and skins, hence the leather value. This deterioration in quality is because of the bites of the ticks, which cause leather to become hard, opaque, punctured, and rough (Chaudhry *et al*., 2011 [25]; Lima *et al*., 2018 [107]). Predicted that an engorged female tick cause 8.9 mL of milk production losses, a decrease in one-gram live weight gain per dairy cow (Jonsson *et al*., 1998) [84], and sometimes a 50% reduction in total milk production (Rodrigues and Leite, 2013) [157]. According to (Ayadi *et al*., 2016) [12], theileriosis in cattle causes a drop in milk output of 2.76 L/day/cow, equating to 31.92 percent of the total milk supply. Consequently, ticks and tick-borne illnesses have a global impact on animal health. Tick infestation is also associated with alterations in host physiology viz. increase in serum urea nitrogen, serum gamma globulin, rectal temperature, water intake, urine volume, and decrease in packed cell volume, serum iron content, serum esterified cholesterol, serum free cholesterol, serum phospholipids, albumin content, serum alkaline phosphate, serum amylase and dry matter digestibility (El-Deeb and Younis, 2009; Wikel, 2018) [41, 191]. Usually haematological parameters like haemoglobin, packed cell volume (PCV), total leucocyte count (TLC), and platelets are reduced significantly in tick infestation (Kaur *et al*., 2017 [93]; Khan *et al*., 2021; Raut *et al*., 2008) [96, 151] due blood-sucking activity of the ticks engorged in the animal body. The IgG level was also increased significantly in the blood of infested animals (Khan *et al*., 2021) [96]. The overall effect of tick infestation in cattle has shown in Figure 1.

Phytomedicine approach to control tick infestation

Apart from the periodical application of chemical acaricides in India, other measures are practiced to control and treat tick infestation (Kumar *et al*., 2021) [103]. These measures vary depending on the species of livestock and types of farmers. Arsenic trioxide, organochlorines, organophosphates, carbamates, amidines, pyrethroids and ivermectins etc. are the common synthetic acaricides used across the country and world. These acaricides kill attached larvae, nymphs, and adult ticks (Ghosh and Nagar, 2014) [56]. The real challenge is that ticks develop resistance to several existing chemical acaricides, and newer acaricide classes are more expensive. The use of chemicals in agriculture operations and livestock industry is a potential environmental hazard, and their presence in the food chain is growing further concern. The development of new anti-tick compounds is expensive and time-consuming; therefore, the focus has been shifted towards developing an integrated eco-friendly approach with multiple modes of action (Ghosh and Nagar, 2014 [56]; Khare *et al*., 2019 [97]; Kumar *et al*., 2021 [103]). To address the issues associated with the use of chemical acaricides, researchers have focused on the development of herbal acaricides (phytoacaricides), which are safe for animals to use and have a lower risk of developing resistance(Adenubi *et al*., 2016; 2020) [3, 4].

Medicinal plants have been recognized and utilized in traditional medicine worldwide since the dawn of civilization (Adhikari and Paul, 2018) [5]. About 2000 plant species have been effectively employed in Ayurveda, India's famed conventional medicinal system. For example, the classic ancient herb is *Azadirachta indica* (Neem). This wonder herb has been used in folkloric medicine for centuries, but whose utility as a natural pesticide and acaricide was only identified around 26 years ago (Kumar and Navaratnam, 2013) [104]. In India, the rich biodiversity of 15,000–20,000 plant species with proven medicinal value can be explored (Parasuraman *et al*., 2014) [136]. The majority of these herbal plants are adaptable, holistic in action, user and environment-friendly, and aid in developing community-driven tick control programmes that are well-suited to local conditions and specific to various livestock populations (Mondal *et al*., 2013) [118]. Herbal preparations in rural areas are widespread because of their local availability, cost-effectiveness, and potent therapeutic value (Adenubi *et al*., 2016) [3]. The active compounds in the medicinal plant can serve as insecticides, acaricides, growth inhibitors, anti-molting agents, and repellents, interrupting insect's biological processes during their life cycle (Adenubi *et al*., 2016; 2020 [3, 4]; Kumar *et al*., 2021 [103]; Jain *et al*., 2020a [77]; 2021a [79]; Nimbalkar *et al*., 2020 [129]). Besides, herbal products also have some downsides in practical application; one such is their availability in ready-to-use form (Adenubi *et al.* 2020 [4]; Mondal *et al*., 2013 [118]). As a result, medicinal plants found in India should be further explored and embalmed for acaricidal properties, as these plants can play a crucial role in primary health care.

Acaricidal plants and their active phytochemical compounds

According to various studies, acaricidal activity may be found in a variety of herbs and medicinal plants (Attia *et al*., 2012 [11]; Krishna *et al*., 2014 [99]; Miao *et al*., 2012 [115]; Miguel *et* *al*., 2013 [116]; Yang *et al*., 2014 [192]; Yang and Lee, 2013a; Yang and Lee, 2013b [193]). More than 200 plant species with tick-repellent or acaricidal characteristics have been identified worldwide (Adenubi *et al*., 2016) [3]. Plant extracts include a variety of bioactive chemicals with varying polarity; thus, separating these molecules always remains a significant challenge in the discovery and characterization of bioactive substances (Ingle *et al*., 2017) [71]. Qualitative phytochemical screening is carried out using biochemical assays to investigate the different classes of active chemicals found in the extract, such as tannins, glycosides, essential oils, flavonoids, alkaloids, ester, fatty acids, etc. (Hikal *et al*., 2017) [68]. The principal kinds of plant-based compounds exhibiting biocidal properties in a tick are essential oils, extracts, or pure allelochemicals. Various methods used for obtaining above mentioned compounds include steam distillation (Gomes *et al*., 2012) [62], hydrodistillation (Dolan *et al*., 2009) [39], ethanolic and aqueous extraction (Costa-Júnior *et al*., 2016) [30], methanolic extraction and spilanthol (Cabezas-Cruz *et al*., 2018) [20], hexane, ethyl, and acetate extractions (Cruz *et al*.,2016 [31]; Conceicao *et al*., 2017 [28]). Some of these herbs and medicinal plants have been been tabulated in Table 3.

Table 3: Hebs or medicinal plants having acaricidal activity

Plant	Common name	Tick species	Active Phytochemical	References
Aegle marmelos	Bael	*H. bispinosa* *R.(B.) microplus*	Aeglemarmelosine, alkaloids, coumarins	Elango and Rahuman, 2011 [40]
Allium sativum	Garlic	*R. (B.) microplus*	Allicin, terpenoids, steroids	Aboelhadid *et al*., 2013 [2]; Shyma *et al*., 2014 [166]
Andrographi spaniculata	Creat	*H. bispinosa* *R.(B.) microplus*	Tannins, flavonoids, carbohydrates and proteins	Elango and Rahuman, 2011 [40]
Anisomele smalabarica	Kala bhangra	*H. bispinosa*	Alkaloids, saponins, protein, gum, mucilage	Nisha and Packialakshmi, 2014 [130]
Annona squamosa	Custard apple	*R. (B.) microplus*	Squamocin (annonin)	Pavela, 2016 [140]
Artemisia absinthium	Wormwood	*Hyalomma anatolicum* *R. sanguineus*	Cis-epoxyocimene, sesquiterpenes	Godara *et al*., 2014 [61]
Azadirachta indica	Neem	*R.(B.) microplus*	Azadirachtin	Shyma *et al*., 2012 [167]; Srivastava *et al*., 2008 [175]
Carica papaya L.	Papaya	*R. (B.) microplus*	Alkaloids, glycosides, phenols and tannins	Shyma *et al*., 2014 [166]
Curcuma longa	Turmeric	*R. (B.) microplus*	Curcumin	Chabban *et al*., 2019
Cymbopogon winterianus	Lemon grass	*R. (B.) microplus*	Geraniol, citronellal, citronellol	Singh *et al*., 2014 [171]
Datura stramonium	Datura	*R. B. microplus*	Alkaloids, atropine, scopolamine, tannin, proteins	Shyma *et al*., 2014 [166]
Jatropha curcas	Ratanjot	*R. annulatus*	Stigmasterol, β-sitosterol, campesterol	Juliet *et al*., 2012 [86]
Leucas sps.	Thungai	*R. annulatus*	Nicotine, diterpenes, lignans, flavonoids Flavones, diterpenes	Ravindran *et al*., 2011 [152]; Divya *et al*., 2014 [37]
Ocimum basilicum	Basil	*R. (B.) microplus*	Linalool, (Z)-cinnamic acid methyl ester, cyclohexene	Zhang *et al*., 2009 [195]; Veeramani *et al*., 2014 [185]
Ricinus communis	Castor	*R. (B.) microplus*	Quercetin, gallic acid, flavone, kaempferol	Ghosh *et al*. 2013 [59]
Solanum trilobatum	Red Pea Eggplant	*Hyalomma anatolicum* (a.) *anatolicum Koch*	Carbohydrates, saponins, phytosterols, tannins	Sahu *et al*., 2013 [160]; Rajakumar *et al*., 2014 [148]
Tagetes erecta	African Marigold	*R.* (B.) *microplus* *H. bispinosa*	Thiophenes, flavonoids, carotenoids, triterpenoids	Elango and Rahuman, 2011 [40]; Vijay *et al*., 2013 [187]
Vitex negundo	Nirgundi	*R. (B.) microplus*	Flavonoids, flavones, glycosides, triterpenes, tannins	Singh *et al*., 2014 [171]
Withania somnifera	Ashwagandha	*R. (B.) microplus*	Steroids, alkaloids, salts, flavonoids	Singh *et al*., 2014 [171]

Adenubi *et al.* (2020) [4] extensively reviewed the various isolated compounds found in different plant species having acaricidal properties like precocene I and precocene II in *A. conyzoides*, azadirachtin in *A. indica*, elimicin, catechol, chlorogenic acid, quercetin in *C. citratus*, 1-8 cineole, spathulenol in *E. globulus*, nicotine, solanesol, 1-quinic in *N. tobacum*, thymol, eugenol, terpen-4-ol in *O. gratissimum* and quercetin, ellagic acid in *R. communis*. Extracts of tobacco plant (*Nicotiana tobacum*) have potent acaricidal properties. Neem has also been used in acaricide trials. Azadirachtin is the pure component of neem oils that has been studied the most. In adult female ticks, treatment with the aqueous extracts of neem leaf at 10% and 20% results in morphological changes during oocyte development (Denardi *et al*., 2010) [35]. The number of eggs deposited and the larval hatching rate in *R. microplus* was affected by water-soluble tannins in fresh and dried *Aloe arborescens* extracts (De Matos *et al*., 2017) [32]. Clove essential oil has eugenol as the main constituent (Ferreira *et al*., 2018) [44], which reportedly decreases egg production index (EPI) and hatching considerably. Acaricidal activity was discovered in *Petiveriaalliacea* root and stem extracts containing benzyltrisulfide (BTS) and benzyldisulfide (BDS) metabolites (Rosado-Aguilar *et al*., 2010) [159]. Cadina-4, 10 (15)-dien-3one derived from *Hyptisverticillata* leaves and stems reportedly hinder the oviposition and hatching of *R. (B.) microplus* eggs (Porter *et al*., 1995) [145]. The methanolic extract of *Calotropisprocera*has acaricidal property against *R. microplus* due to presence of active compounds like 3-Isopropoxy-1,1,1,7,7,7-hex,Naphthalene, 1,6-dimethyl-4,Cyclohexane and 2-(2',4',6',8',8'-Hept (Bhaskar *et al*., 2021) [17].

Acaricidal action of plant based acaricides

Many plant-derived chemicals used for tick control have a poorly known mechanism of action. Similarly, the specific mechanism of many plant essential oils' actions is unknown, and little research has been done to investigate how these naturally occurring molecules affect ticks. According to Khare *et al*. (2019) [97], Herbal acaricides can decrease egg development, have antifeedant effects, have antagonistic effects on regulating hormones, disrupt sexual communication and mating, and function as a repellent, and prevent chitin synthesis. Some essential oils have neurotoxic properties, such as acetylcholinesterase (AChE) inhibition, antagonism with octopamine neurotransmitter receptors, or chloride channel closure by gamma-aminobutyric acid (GABA) (Camilo *et al*., 2017) [21]. Through *in vitro* test, it was investigated that essential oil components interact with Tyramine receptor, thus it can be a possible mode of action for pulegone, carvacrol, isoeugenol, 1,4-cineole, and piperonyl alcohol (Gross *et al*., 2017) [66]. Further research in this direction speculated that the impact of herbal acaricidal medications may be due to a rise in AChE concentration in tick synganglion (neurons), leading to excessive salivation, lacrimation, paralysis, and, eventually, tick mortality (Jain *et al*., 2020b) [78].

The main bioactive compound found in *Nicotianatabacum* is the alkaloid nicotine, which exhibits its action by mimicking the excitatory neurotransmitter acetylcholine (Ujvary, 2010) [182]. Similarly, Azadiractinan active component of *Azadirachtaindica* stimulates chemoreceptors on restrictive cells and blocks the firing of phagostimulatory receptors on feeding stimulatory cells of ticks (Koul, 2008) [98]. It also inhibits protein synthesis in various tissues of the tick's body, such as the midgut, thereby impairing food protein digestion (Ujvary, 2010) [182]. Exposure of neem oil to the ticks results in significant morpho-physiological modifications resulting in functional impairment of the reproductive system (Remedio *et al*., 2015) [155]. Monoterpenoids such as eucalyptol, linalool, and citral, are extracted from various plants, which exert their effects by reversibly inhibiting acetylcholinesterase (Picollo *et al*., 2008; Siramon *et al*., 2009) [141, 172]. Thymol and 1,8-cineole are the active compounds present in *O. gratissimum*, affects the GABA receptors (Priestley *et al*., 2003; Tong and Coats, 2010) [146, 180], and are effective against *R.(B.) microplus* (Castro *et al*., 2018) [22]. However, the specific mechanism of action of other components of plant extracts and essential oils impacting tick biology is still unknown, and in this aspect more research is needed (Quadros *et al*., 2020) [147].

Various herbal formulations for the control of ticks

The complete eradication of ticks from the dairy farm is challenging as many factors can culminate in their recurrence, and ill management is one of the significant factors (Jain *et al*., 2020b [78]; Kumar *et al*., 2021 [103]). Although it is challenging to replace chemical acaricides completely, herbal treatments can be used to reduce their use if thoroughly exploited and investigated (Nimbalkar *et al*., 2020) [129]. Phytochemicals of essential oils from the plants are proven acaricidal agents and have comprehensive spectrum action against insect, moths and mites (Djebir *et al*., 2019) [38]. Commercially, some herbal formulations were available for control of ticks like Zerokeet Liquid developed by Ayurvet Limited, having the extracts of plants Deodar (*Cedrusdeodara*), Karanj (*Pongamiaglabra*), Neem (*A. indica*), Nilgiri (*E. globulus*) and Sweetflag (*A. calamus*) recommended for the control of ticks, fleas, lice and mites. Another formulation was Keetguard developed by Ayurvet Limited having extracts of Deodar(*C. deodara*), Nilgiri(*E. globulus*), Pine (*Pinuslongifolia*) and Karanj(*P. glabra*) recommended to be applied on animal's body for 18-24 hrs before giving bath after diluting it with water in 1:40 ratio. Some of the documented herbal preparations having acaricidal property have been tabulated below in Table 4.

Table 4: Various herbal preparations having acaricidal properties

Formulations	Local Name	Botanical name	Method of preparation	Dose and method of administration	Reference
Pestoban	Deodar Neem Bidang	*C. deodara* *A. indica and* *Embeliaribes*	Bathed once in 20% solution and allow to dry on their bodies.	Used @ 1:10 dilution as spray solution and 2nd application on the following day.	Nooruddin *et al*., 1990 [131]; Maske *et al*., 1995 [113]
Medicated soap	Floss flower	*Ageratum houstonianum*	2kg of dried leaves were soaked in 6L of water and boiled for 10h in modified Clevenger Vendor and evaporate was collected in an open mouth bottle and filtered through an anhydrous sodium sulphatecolumn as essential oil and stored in the dark at room temperature.	19.0, 23.75 and 28.50ml of the essential oil were added to 950 g of palm oil based liquid soap and poured the solution into molds and allow to solidify.	Pamo *et al*., 2005 [135]
Extract spray	Neem oil or Neem seed extract	*A. indica*	Minimum concentration required to be effective against ticks is 1% (10 ml of Neem Oil per litre of water to be dissolved). Or 30ml of neem oil is mixed in 5L of water, with a few drops of mild soap to emulsify the oil.	Spray it on the animals every 2-3 weeks.Application should always be done against the direction of the hair and should cover the entire body, especially underbelly and legs.	Srivastava *et al*., 2008 [175]
Herbal extract	Neem Tobacco Aak Ajwain	*A. indica A Juss,* *Nicotianatabacum,* *C.* Kaiser and *Trachyspermumammi*	5kg of each plant material were soaked together in 50L distilled water. Suspension was shaken vigorously every 72 h. After 30	45% (w/v) suspension using distilled deionized water was prepared. Topically appliedon the tick-	Zaman *et al*., 2012 [194]

			days, the suspension was heated (not exceeding 50°C) till an extract in the form of a paste weighing 10 kg was achieved.	infested body parts, twice and continued for 6 days.	
NIF's Poly Herbal Medication	Neem Monks pepper	*A. indica A Juss* *V. negundo L*	2.5kg fresh leaves of neem and 1.0kg fresh leaves of monks pepper collected and dissolved in 4L and 2L luke warm water respectively overnight. 300ml supernatant fluid from neem crude extract and 100ml of monks pepper crude extract mixed in 3600ml of water (3:1 ratio) to make 4L preparation.	The 400ml preparation was mixed in 3,600 ml of fresh water. Topically applied over affected site of animal two times daily for three days.	Thakur *et al*., 2016 [178]
Clear Ticks (Poly herbal spray)	Lemon grass Tulsi Pine Aak Dhatura Bael Castor Neem Garlic Papaya Custard apple Karanj	*Andropogon citrates Cymbopogoncitratus, Ocimum sanctum, P. longifolia, Calotropisprocera, Daturastramonium, Aegle marmelos, Ricinuscommunis, A. indica, Allium sativum, Carica papaya, Annona squamosa* and *P. glabra*	Extracts	Uniformly sprayed once over the body of animals for 7 days.	Bhikane *et al*., 2018 [18]; Jadhav *et al*., 2018 [18]
Herbal acaricide product	Neem Karanj Nilgiri Lemon grass Kapur	*A. indica* *P. glabra* *E. globulus* *C. martini* *Cinnamomumcamphora*	100ml of water soluble herbal acaricide contains: 5ml Lemon grass, 5ml Eucalyptus oil, 3ml Neem oil, 3 ml Karanj oil and 2ml KapurBase: q.s.	Used @ 2-5 ml/100 ml water.	Rao *et al*., 2018 [150]
Essential Oils	Nilgiri Lavender Oregano Rosemary Thyme	*Eucalyptus globulus* *Lavandulastoechas* *Origanumfloribundum Munby* *Rosmarinusofficinalis* *Thymus capitatus*	Extraction of essential oils from plant parts was carried out by hydrodistillation for 3 hr using a Clevenger-type hydrodistillation apparatus.	Essential oils were serially diluted in 2% Tween 80 to obtain 12.5µl/ml concentrations.	Djebir *et al*., 2019 [38]
Plant extract spray	Cotton	*Gossypium spp.*	Cottonseeds were heated in hot air oven (150 °C for 30min) with frequent agitation. Seeds were pressed using cold press machine (40 rpm speed and 23 °C). The obtained oil was centrifuged (12 min at 6895×g) and supernatant was used.	Used @ 10% and 12.5% diluted with water in the ratio of 1:5. Topically sprayed over affected site of animal twice a day.	Jain *et al*., 2020a [77]
Medicinal plants	Pirandai (Veld grape)	*Cissusquandrangularis L.*	200gm stem crush aerial parts, mix with water.	Pasted over the affected part.	Kamatchi and Parvathi, 2020 [89]
Medicinal plants	Castor bean	*R. communis L.*	100gm mature seeds crush and mixed with curcuma powder.	1 table spoon paste was pasted over the affected part once a day.	Kamatchi and Parvathi, 2020 [89]
Medicinal plants	Sozina (Moringa) Saini	*Moringa oleifera* *Calcium Hydroxide*	Root part of Moringais crushed to extract juice. Calcium Hydroxide mixes with water to make paste form.	Externally apply over affected part of the body until gets cured.	Kumar *et al*., 2020 [101]
Herbal extract suspension	Garlic Hemp	*A. sativum* *Cannabis sativa*	50gm leaf powder of each dissolved in 100mL of methanol and filtrate was placed in a rotary evaporator to yield a powder.	15, 35 and 45% concentration was used by diluting in distilled water. Topically applied over the infected area twice for six consecutive days.	Nasreen *et al*., 2020 [126]
F-1	Gulvel Chibad Neem Nirgudi Sweetflag	*Tinosporacordifolia* *Cucumissativus forma hardwickii Azadirachtaindica* *Vitexnegundo* *Acoruscalamus*	150g Gulvel stem, 500g Chibadfruit, 100g Kadunimb bark, 130g Nirgudi leaves and 25g Vekhand rhizome. Crush all to get fine paste and keep in 10L of water overnight and filter the juice.	Spray the medicine once, using spray pump.	Nimbalkar *et al*., 2020 [129]
F-2	Chibad	*C. sativus forma hardwickii*	500g of Chibad fresh fruits and 250g of salt. Crush these two and add this to 1L water and mix	Apply on the entire animal body, especially affected areas once in a day and	Nimbalkar *et al*., 2020 [129]

			properly.	continue same after a week.	
F-3	Chibad Mahua	*C. sativus forma hardwickii Madhucaindica*	100g of Chibad fruit and 250g of common salt mix together and then crush it properly to make smooth paste by adding water and the liquid paste is rubbed on the skin. 300mL of long stored Mahua oil.	Apply on the body surface and massage with Mahua oil after 4 hr of application. Repeat same after a week. (After oil application animal should be kept in shade for a day).	Nimbalkar *et al.*, 2020 [129]
Poly-herbal Acaricidal Medication	Drek Banha or Mala	*Melia azedarach* *V. negundo L.*	To prepare the crude extract2.5 kg fresh leaves of Drek and 2.0 kg fresh leaves of Banha or Mala were soaked in 4 and 1 litres of lukewarm water, respectively and kept overnight.	300ml supernatant fluid from Drek and 100 ml of Banhaor Mala were mixed in 3.6L of water. Topically applied over affected site of animal two times daily for 3 days.	Thakur *et al.*, 2020 [177]
Thymol- and thymol-eucalyptus-combinations	Clove basil Nilgiri	*Ocimumgratissimum* *E. globulus*	5% Thymol and 5% Thymol eucalyptus suspension.	Animals were sprayed twice with a two-week interval.	Arafa *et al.*, 2021 [9]
Emulsifiable concentrate of arecoline hydrobromide	Betel nut	*Areca catechu*	12.5 mg/mL	Topically applied on animals skin using polysorbate-80 as a surfactant.	Jain *et al.*, 2021a [79]
Antiticknatural formulation	Chick weed	*Azeratumconyzoides*	Grinded powdered plant was soaked in 95% ethanol (30–35°C), with 4 changes of ethanol overnight (18 h). Extract was decanted, filtered and concentrated under reduced pressure using rotary vacuum evaporator.	6–12% (w/v) concentrations was used.	Kumar *et al.*, 2021 [103]
Antitick natural formulation	Chick weed	*Ageratum conyzoides*	Solvent guided extraction without partitioning method was used to prepare the phyto extract	8, 10, 12 and 14% concentration of 95% ethanol extract was used. Topically applied on infested animals.	Shanmuganath *et al.*, 2021 [161]

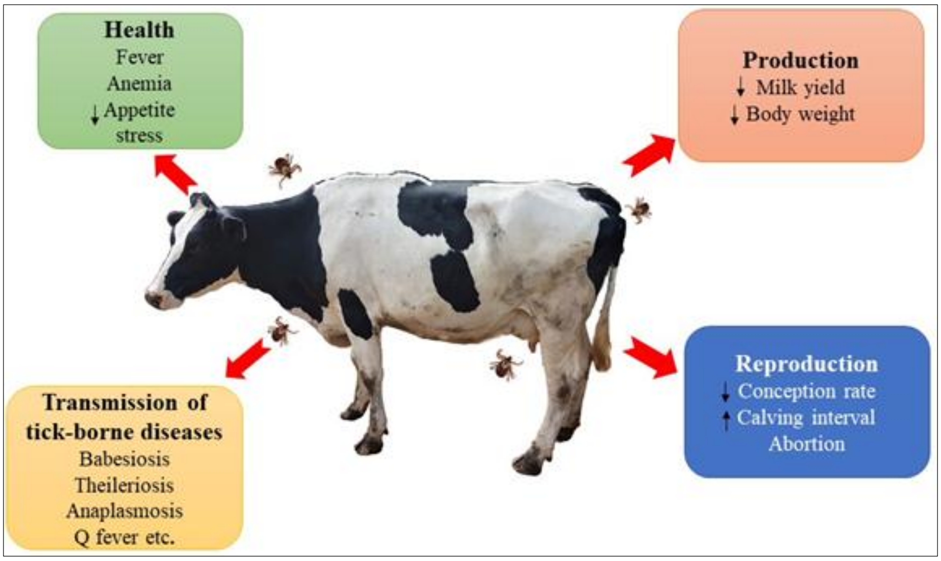

Fig 1: Effect of tick infestation on animal health and production

Conclusions and future perspectives

Tick infestation and its repercussions cause significant economic losses to the global cattle industry, amounting to several billions of dollars. It is associated with the loss of health, growth, production, and severe anemia can also cost a life. Chemical acaricides are the most commonly used agent for controlling tick infestation throughout the world. Still, the growing concern of environmental hazards, development of resistance in ticks, and presence in food chains are pushing the development of more effective plant-based acaricides. Although it is challenging to replace the chemical acaricides, herbal medications in a polyherbal formulation offer great potential in tick control programmes and management strategies. The repellent, anti-ovipositional, and other acaricidal properties of the various extracts of herbal plants may make them a valuable prospect in developing a sustainable tick control strategy. The tick burden in different breeds at diverse locations might be attributed to the variation in other managemental systems, the effect of supplementary feeding, and the adoption of various tick control measures.

Therefore, quantitative data on host tick loads and resistive capacity of different breeds of diverse geographical locations is critical for developing control methods and effectively managing animal populations. Thus, there is a need to establish field-oriented, cost-effective, and readily available quality herbal acaricides along with quick, efficient, and accurate methods for counting ticks. Government implementation of short- and long-term policy and control measures may make it easier for dairy farmers to respond to issues.

Disclosure statement

The authors reported no possible conflicts of interest.

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