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A Review: An Insight into the Potential of Biological Control of Ticks in Domestic and Wild Animals

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Abstract

Ticks are hematophagous arthropods that transmit pathogens to humans, animals and poultry birds, mostly in tropical and subtropical regions globally, causing considerable economic and health losses by serving infectious vectors. In endemic locations of the world, tick-borne diseases have become a public health issue. Ticks biting causes anemia in animals and also impair their hide quality. Therefore, the current review article focused on the biological control of ticks. Ticks, like any other creature, are susceptible to various infectious agents (*Anaplasma phagocytophilum*, *Babesia bigemina, B. gibsoni, Hepatozoon canis, H. americanum, Theileria annulate, T. taurotragi etc*). Ticks can become infected with rickettsia, spirochetes, viruses, bacteria, and fungi. Some protozoans and worms infiltrate ticks and reproduce inside them, killing them. Fungus (*Metarhizium anisopliae, Verticiliium lecanii, Beauveria bassiana*), bacteria (Bacillus), nematodes (*Steinernema glaseri*, *S. carpocapsae*), and parasitoids (*Ixodiphagus* species.) have proved effective biological agents to control ticks. Insects are also a type of natural tick enemy. Ticks that are engorged with blood and while moulting are the most vulnerable to insect predation and eaten by spiders, ants, beetles, dragonflies, and wasps (Ixodiphagus). Ticks are also preyed upon by amphibians and reptiles. Birds such as yellow-billed oxpecker (*Buphagus africanus*), helmeted guineafowl and Galliformes are good predators of ticks. Biological agents affect only target pests (ticks), do not destroy beneficial natural enemies and are safer for the ecosystem and humans. By keeping in view, the significance of biological agents, we highly recommend them in integrated tick management program that could minimize the tick population.

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1. INTRODUCTION

The major source of livelihood for many farmers in Pakistan is the livestock industry, which plays an important role in the economy of the country. Approximately 30 to 35 million Pakistanis are engaged in livestock farming currently.[1] Due to a wide host range and climatic change, ticks as the primary ectoparasites pose the greatest danger to Pakistan's livestock economy, particularly goat and sheep production. The death rate is minimal. Tick pathogens that transmit zoonotic diseases to humans and animals, such as Lyme and CCHF, have resulted in colossal losses in output (wild and domestic). Theileriosis, babesiosis, and rickettsial diseases are transmitted by ticks throughout the world. Ticks and tick-borne diseases are the most significant health issues limiting or reducing goat and sheep production in the country (Pakistan). Ticks are blood-feeding ectoparasites of tropical and subtropical vertebrates, including humans, domesticated animals, wild animals, birds, and reptiles in Pakistan. Ticks are found throughout the world, although they tend to thrive more in countries with humid and warm climates, which provide ideal conditions for tick reproduction, growth, and development. Three genera, including Rhipicephalus, Amblyomma, and Hyalomma, are home to the most widely distributed species in the world, which are documented.

It has been observed that the interaction between ticks and their hosts has been considerably impacted by several factors, including climate changes such as temperature and humidity. These days, ticks have infested areas that were tick-free a year ago. The extensive distribution of ticks is caused by the mobility of humans and other animals, both domestic and wild. Animal health is significantly impacted by ticks, one of the most important groups of arthropods. The tick feeds on the blood of other animals to live and reproduce. [2, 3, 4,5]

By feeding on the host, they enslave it; they can cause paralysis and disorders of the immune system because of inoculated saliva, and they can transmit health-threatening pathogens. They can also act as a vector of various bacteria, viruses, and protozoans to domestic livestock, sylvatic, and humans [6, 7, 8].

1.1. Taxonomy/Classification and tick hosts

Ticks belong to order Acarina and class Arachnida. Ticks classify into three families i.e., Argasidae or Argasids, Ixodidae or Ixodid, and Nuttalliellidae [9]. According to Naval *et al.* [10], more than 879 tick species have been reported throughout the world including 692 and 186 species belong Ixodidae and Argasidae while the third family has only one tick species (*Nuttalliela namaqua*) [11, 12, 13]. Tick species reported around the globe especially in Pakistan with their hosts are given in Table 1.

Table 1. Globally reported tick species along with their hosts; domestic as well as wild animals

Tick Species	Host	References
Argas abdussalami	Poultry	Abbasi *et al.* [14]
A. persicus	Poultry	Abbasi *et al.* [14]
A. reflexus	Poultry	Ghosh *et al.* [15]
A. vespertilionis	Poultry	Rafique *et al.* [16]
A. japonicus	Buffalo, cattle	Kwak [17]
Ornithodoros thokozani	Poultry	Razzak and Shaikh [18]
O. capensis	Buffalo, cattle	Kwak [17]
O. sawaii	Buffalo, cattle	Kwak [17]
Amblyomma testudinarium	Buffalo, cattle	Kwak [17]
A. variegatum	Cattle, buffalo	Perveen [19]

A. geoemydae	Buffalo, cattle	Kwak [17]
A. nitidum	Buffalo, cattle	Kwak [17]
A. pomposum	Cattle, buffalo, goat, sheep	Rehman *et al.* [20]
Boophilus annulatus	Cattle, buffalo, goat, sheep	Riaz and Tasawar [21]
B. sharif	Cattle, buffalo	Ghosh *et al.* [15]
Dermacentor circumguttatus	Cattle, buffalo	Rehman *et al.* [20]
D. bellulus	Buffalo, cattle	Kwak [17]
D. andersoni	Sheep, cattle	Karim *et al.* [22]
D. raskimensis	Horse, cattle	Shah *et al.* [23]
D. marginatus	Horse, cattle, sheep, goat	Ghosh *et al.* [15]
D. rhinocerinus	Buffaloes, Cattle	Rehman *et al.* [20]
D. silvarum	Sheep, goat	Muhammad *et al.* [24]
Haemaphysalis punctata	Horse, sheep, goat, cattle	Ramzan *et al.* [8] Ramzan *et al.* [25]
Hae. aciculifer	Cattle, buffalo	Muhammad *et al.* [24]
Hae. formosensis	Buffalo, cattle	Kwak [17]
Hae. sulcate	Horse, sheep, goat, cattle	Ramzan *et al.* [8]
Hae. megalaimae	Buffalo, cattle	Kwak [17]
Hae. houyi	Cattle, buffalo	Ghosh *et al.* [15]
Hae. kashmirensis	Sheep	Rehman *et al.* [20]
Hae. flava	Sheep	Karim *et al.* [22]
Hae. parmata	Buffalo, cattle	Shah *et al.* [23]
Hae. bispinosa	Horse	Ghosh *et al.* [15]
Hae. spinulosa	Sheep, goat	Muhammad *et al.* [24]
Hyalomma anatolicum	Goat, buffalo, sheep, cattle	Ramzan *et al.* [8]
H. anatolicum anatolicum	Goat, buffalo, sheep, cattle	Ahmad *et al.* [26]
H. dromedarii	Goat, buffalo, sheep, cattle	Ramzan *et al.* [8]
H. aegyptium	Goat, buffalo, sheep, cattle	Ramzan *et al.* [8]
H. hussaini	Buffalo, cattle	Ghosh *et al.* [15]
H. detritum	Camel	Hornok *et al.* [27]
H. Isaaci	Buffalo, cattle	Ghosh *et al.* [15]

H. marginatum	Buffalo	Hornok *et al.* [27]
H. marginatum toranicum	Goat, buffalo, sheep, cattle	Ghosh *et al.* [15]
H. scupense	Goat, buffalo, sheep, cattle	Ghosh *et al.* [15]
H. rufipes	Goat, buffalo, sheep, cattle	Ghosh *et al.* [15]
H. turanicum	Goat, buffalo, sheep, cattle	Ghosh *et al.* [15]
H. schulzei	Camel	Ghosh *et al.* [15]
H. kumara	Buffalo, cattle	Hornok *et al.* [27]
H. impeltatum	Camel, cattle	Adil *et al.* [28]
H. excavatum	Buffalo	Adil *et al.* [28]
Rhipicephalus evertsi	Buffalo, cattle	Adil *et al.* [28]
R. arnoldi	Buffalo, cattle	Adil *et al.* [28]
R. longus	Buffalo, cattle	Razzak and Shaikh [18]
R. decoloratus	Buffalo, cattle	Adil *et al.* [28]
R. kochi	Buffalo, cattle	Adil *et al.* [28]
R. microplus	Camel, cattle	Karim *et al.* [22]
R. appendiculatus	Buffalo, cattle	Jamil *et al.* [6]
R. sanguineus	Horse, camel, goat, buffalo, sheep, cattle	Ramzan *et al.* [29]
R. haemaphysaloides	Cattle, goat, sheep	Irshad *et al.* [30]
R. pravus	Goat, sheep, camel	Adil *et al.* [28]
R. turanicus	Sheep, cattle	Hart [31]
Ixodes ricinus	Sheep, cattle	Iqbal *et al.* [32]
I. ovatus	Buffalo, cattle	Kwak [17]
I. simplex	Buffalo, cattle	Kwak [17]
I. monospinosus	Buffalo, cattle	Kwak [17]
I. melicola	Buffalo, cattle	Petney *et al.* [33]
I. vulpicola	Buffalo, cattle	Petney *et al.* [33]
I. vulpinus	Buffalo, cattle	Petney *et al.* [33]
I. sciuricola	Buffalo, cattle	Petney *et al.* [33]
I. barbarossae	Buffalo, cattle	Petney *et al.* [33]
Dermacentor marginatus	Wild boar	Angelini et al.[111]

Hyalomma marginatum	Wild boar	Angelini et al.[111]
Rhipicephalus bursa	Wild boar, Mouflons	Angelini et al.[111]
Haemaphysalis punctata	Mouflons, Deer	Angelini et al.[111]
Ixodes ricinus	Deer	Angelini et al.[111]

1.2. Distribution

This small creature is widely distributed throughout the whole world (especially found in tropical and subtropical regions) due to its high reproductive potential and migration. Tick species have been collected and identified from Afghanistan, Australia, Africa, China [34], Europe, North and South America [35], Iran [36], Saudi Arabia, Pakistan [6, 8], Brazil, Switzerland, Turkey, India, North-West Tunisia [37] and France [38]. The general life cycle of ticks is also shown in **Fig. 1.**

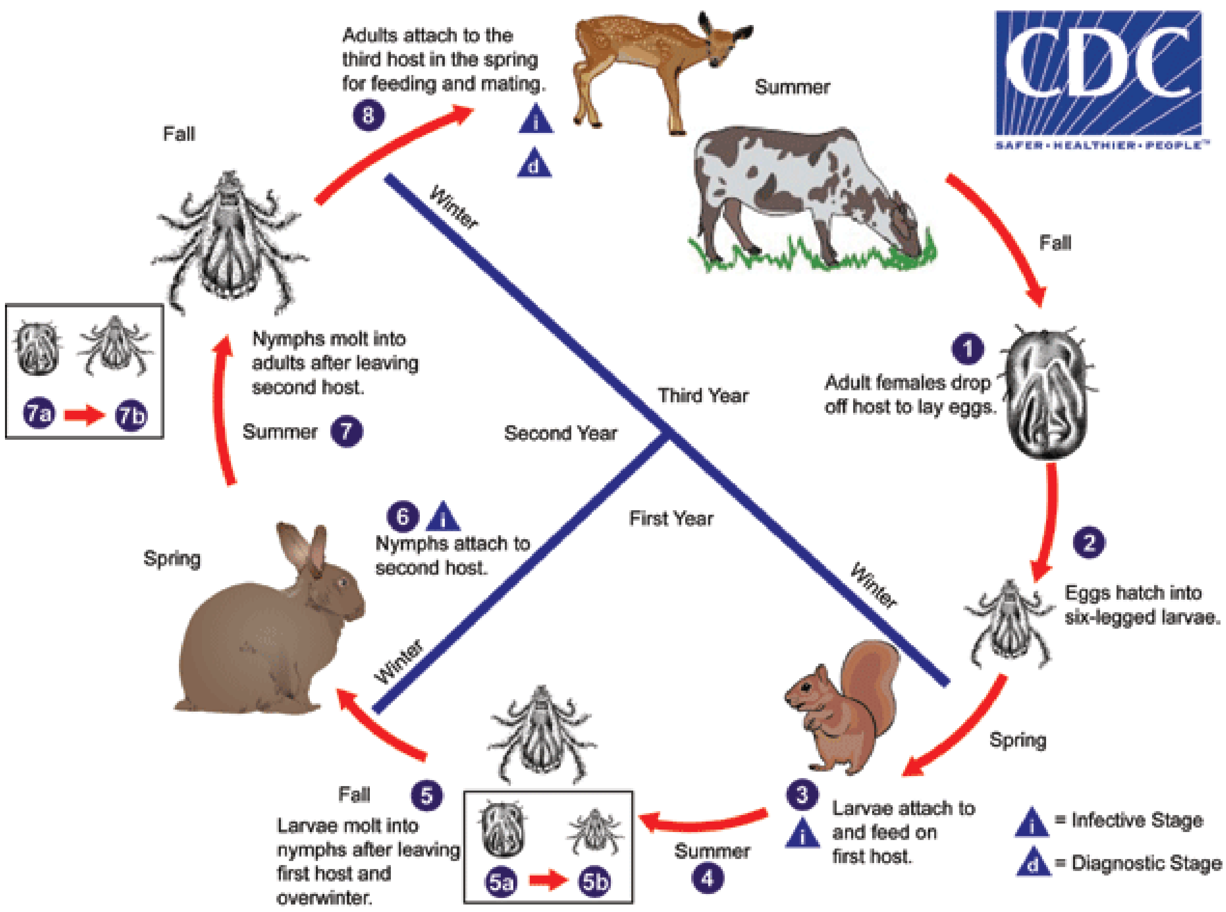

Figure 1: General Life cycle of ticks

1.1. Tick associated pathogens

Several tick-associated pathogens have been identified by many researchers in the world [49]. And almost all kinds of ticks serve as a vector for the transmission of pathogens. The diversity of microorganisms is shown in Fig. 2, showing the prevalence of microbes in various tick species [31].

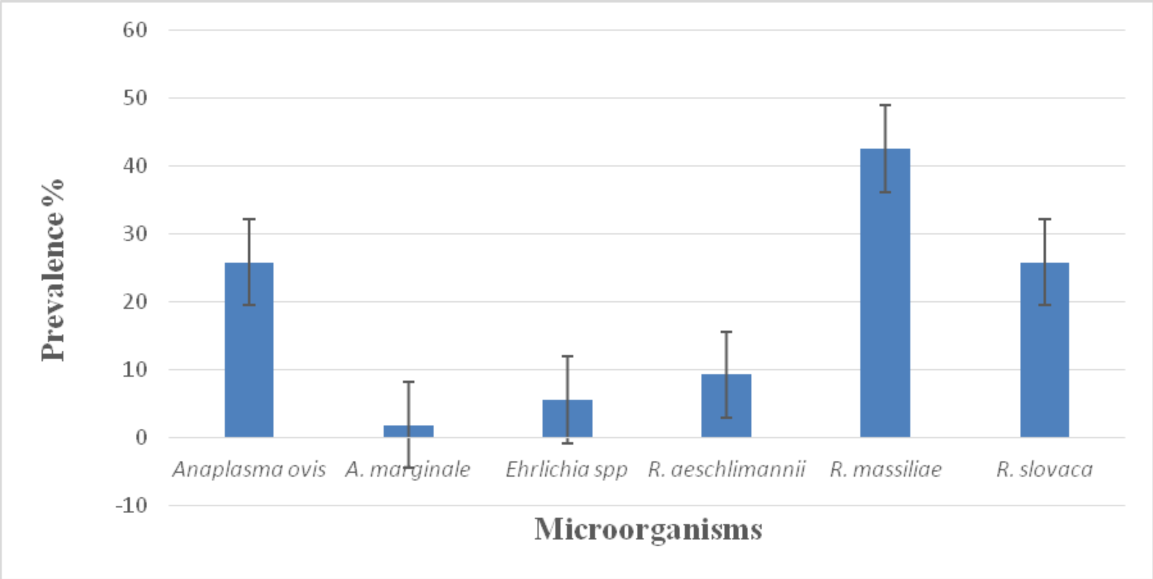

Fig. 2: Diversity of Microorganisms in Ticks

1.3.1 Zoonotic diseases transmitted to humans

The diseases which are transmitted from animals to human beings are termed zoonotic diseases. Ticks are potential vectors for various bacterial, rickettsial, viral and protozoal organisms and transmit these infectious agents from the host or reservoir animals to human beings,[50] exposing them to hazardous infections **(Table 2).**

Table 2. List of Tick-Borne Zoonotic Diseases

Diseases	Infectious agent	Vectors	Hosts	Regions	Citations
Meningo encephalitis	Tick-borne encephalitis virus (TBEV)	*I. ricinus*, I. scapularis and *I. persulcatus*	Human and rodents	Asia, Europe and Russia	Hollidge *et al.*, [39]
Alkhurma hemorrhagic fever	Alkhurma virus	*O. savignyi* and *H. dromedary*	Sheep and camel	Egypt and Saudi Arabia	Charrel *et al.*, [40]
Powassan disease	Powassan virus	*D. variabilis, I. marxi, I. cookei, I. spinipalpusm, I. scapularis* and *D. andersoni*	Mice and Human	Russia and America	Venugopal *et al.*, [41]
Nairobi sheep disease	Bunya viridae	*R. appendiculatus*	Goat and Sheep	India and Africa	Tarif *et al.*, [42]
Louping ill	Louping ill virus	*I. ricinus*	Human and Sheep	America and Scotland	Singh and Gajadhar [43]
Colorado tick fever	Colorado tick fever virus (CTFV)	*D. andersoni*	Deer and Human	Canada	Lin *et al.*, [44]

	Coltivirus				
Bourbon virus disease	Bourbon virus	*I. scapularis*	Deer	United States (US)	Devi *et al.*, [45]
Babesiosis	Babesia divergens, B. microti	*I. scapularis, I. Ricinus*	Human, Cattle	America, Europe	Piesman and Eisen [46]
Crimean–Congo hemorrhagic fever	Naiovirus	*A. variegatum, H. truncatum, H. anatolicum, H. punctata, H. marginatum, R. bursa*	Human, Cattle, Sheep, Buffaloes, Goat	Asia, Africa, Europe	Piesman and Eisen [46]
Rocky Mountain spotted fever	*Rickettsia rickettsii*	*A. americanum, A. cajennense, A. aureolatum, D. variabilis, D. andersoni, R. sanguineus*	Human	Asia, America	Breitschwerdt *et al.* [47]
Q fever	*Coxiella burnetii*	*A. americanum, A. cajennense, A. aureolatum, , D. variabilis, D. andersoni, R. sanguineus*	Human	Asia, America, Europe, Australia	Piesman and Eisen [46]
Lyme Disease	*Borrelia burgdorferi*	*Ixodes scapularis*	Human, mice, deer, raccoons, lizzards	Northeast, middle east and Asian countries including Pakistan	Hussain *et al.* [48]

1.2. Management strategies for ticks

Different management strategies adopted to control ticks and tick-borne diseases in the world. The most common tick management approaches adopted by researchers are cultural control [5, 51], chemical control [52] and biological control [53].

1.2.1. Biological control

The excessive use of acaricides on the animal body can cause serious problems for animals' health. The most important and alternative tick control method is biological control. Different bio-control agents as predators such as mites, birds, rodents, arthropods, beetles, fish, amphibians, etc., pathogens and parasites (parasitoids) such as bacteria, fungi, viruses, nematodes, and protozoa are ecofriendly and nontoxic to non-target organisms applied to control tick species. The chemical resistance could be minimized by applying a suitable and sustainable alternative biological or natural control method [25].

1.2.2. Pros and cons of Biocontrol

There are several pros and cons of biocontrol. It is eco-friendly, economical, safe for non-target, having no residual effects on hosts. The application of biocontrol is accessible in many cases, and the method is easily established. It is host specific. There are some disadvantages of the bio-control method. Some are given here. Biocontrol is very slow and takes a long time to give satisfactory results. It cannot give 100% results against hosts under field conditions. They cannot survive in harsh conditions such as high temperatures. The storage, application, manufacturing, preparation, and shipping techniques of biocontrol cannot be easy [54].

1.2.3. Microbial control/Pathogens

The most common or widely used pathogens are bacteria, viruses, protozoa, rickettsia, and fungi. These disease-causing microorganisms or pathogens are widely used against targeted vectors of medical, agricultural, and veterinary such as ticks and mosquitoes [55]. Bacterial strains have been isolated from dead tick species. For example, *Proteus mirabilis* is isolated from dead and sick *D. andersoni* [56]. Some other bacteria such as *Staphylococcus* sp. and *Pseudomonas* sp. were isolated from dead specimens of *B. decoloratus* under laboratory conditions [57]. Mwangi [58] isolated and identified some bacterial strains such as *Escherichia coli, Proteus mirabilis*, and *Serratia marcescens* from *R. appendiculatus* under field conditions while *Staphylococcus aureus* from *B. decoloratus*.

Some pathogens have been isolated from various tick species whose description is given in Fig. 1.

Bio-control agents or pathogens are necessary to reduce tick abundance because it is likely to remain the most effective method of preventing tick-borne diseases.

1.2.4. Entomopathogenic Fungus

Several strains of fungus have been applied against various arthropods such as ticks worldwide. *Metarhizium anisopliae* has been widely used entomopathogenic fungi as biological agents of tick species such as *Rhipicephalus annulatus*, *R. microplus*, *R. appendiculatus, A. variegatum* and *Ixodes scapularis* [59, 60, 61, 62]. *A. reflexus* knowns as the pigeon tick is a pathogen-transmitting soft tick that feeds on pigeons as well as humans. It can create serious problems in case of diseases on human and animal health.

A study was conducted by Tavassoli *et al*. [63] to check the efficacy of *Metarhizium anisopliae* strains such as V245, 715C, and 685 against different life stages (egg, larva, and adult) of *A. reflexus.* They showed that all fungal strains significantly reduced percentage hatchability, while among tested strains, strain V245 was recorded as the most effective strain given 100% larval mortality at the lowest concentration (10^3 conidia/ml) after 10 days of post-treatment. Many studies have been performed under laboratory conditions to check the pathogenicity of fungus against different stages of tick species, including hard and soft ticks [64, 65, 66]. Fernandes *et al*. [67] and Hornbostel *et al*. [61] reported that entomopathogenic fungi infect arthropods like ticks and can be epizootic in their host populations. Ticks are primarily controlled through chemical products/ acaricides, which have several adverse side effects, including toxicity to the livestock ecosystem, cause pollution, and the induction of chemical resistance in some tick populations. The season can highly affect the potential of fungus 93% of ticks died within one week in the summer while 62.2% died within six weeks in winter [68, 69].

1.2.5. Bacteria

Bacteria species play a key role in the reduction of the tick population. Various species have been reported in the world which attacks tick and minimizes their population among domestic and as well as wild animals. In Egypt, a study was conducted by Hassanain *et al.* [70] to check the toxicity of three different bacteria species such as *Bacillus thuringiensin* (*Bt.*), *B. thuringiensis* var. *kurstak*i (*Btk*) and *B. thuringiensis* var. *israeliensis* (*Bti*). A list of bacteria is given in Table 3.

Table 3. List of bacteria with infected tick hosts

Bacteria	Infected tick host	Reference
B. thuringiensis	*I. scapularis*	Ceraul *et al*. [71]

B. cereus	*B. decoloratus*	Jaworski *et al.* [72]
Proteus mirabilis	*D. andersoni, A. hebraeum, H. marginatum*	Brum and Teixeira [73]
Cedecea lapagei	*B. microplus*	Brum and Teixeira [73]
Bt. kurstaki	*A. persicus, H. dromedarii*	Hassanain *et al*. [70]
Bt. israelensis	*A. persicus, H. dromedarii*	Hassanain *et al*. [70]
Wolbachia pipientis	*I. scapularis*	Songur *et al*. [74]

1.2.6. Protozoa

Entomopathogenic protozoans also play a key role in controlling the tick population. Nosema, Haemogregarina, Theileria, and Babesia are important protozoan [75].

1.2.7. Viruses

The Bio-Pesticide Manual [76] offers 96 marketed microorganism-based active chemicals. These are based on bacteria in 33 cases, fungus in 36 cases, and entomopathogenic nematodes in eight cases. Potential tick bio-control agents are found in all three of these classes. Although viruses have not yet been utilized to manage ticks, Assenga *et al*. [77] recently created a recombinant Baculovirus with a tick chitinase gene. Supernatant from an insect cell culture expressing the chitinase enzyme killed *Hae longicornis*, indicating a possible route for future bio-control studies.

1.2.8. Nematodes

Steinernema glaseri and *S. carpocapsae* have also been proven to be effective against engorged females of several other ticks that fall to the ground [78, 79, 80]. A study was performed to investigate the toxicity of different nematodes such as *S. carpocapsae, Heterorhabditis bacteriophora*, and *S. feltiae* under laboratory conditions against fed and unfed female and nymph of *I. ricinus* [81]. *S. carpocapsae* showed maximum toxicity against ticks than other nematode isolates. Some scientists reported resistance of nematodes against *A. variegatum* and *B. microplus* [82], while *B. annulatus* found most susceptible to nematodes [83].

1.2.9. Predators

1.2.9.1. Birds as a Bio-control agent

Birds are considered important predators of various arthropods such as insect pests, spiders, and especially ticks. The birds keep wild and domesticated animals (deer, lion, rabbit, cat, dog and cattle, goat, sheep, buffaloes) tick free, which attack them. Birds are natural predators of animal ticks and are used as part of an integrated tick control plan [84]. In Southern Africa, the yellow-billed oxpecker *Buphagus africanus* and the red-billed oxpecker *Buphagus erythrorhynchus* have been tested against tick species. These predators feed on the parasitic stages of ticks. The cattle egret *Ardeola ibis* is reported tick-eating bird which consumed a large population of ticks [85, 86]. Esther *et al*. [87] had given the same view about bird potential. Many other birds have been reported as important predators of tick species worldwide. The most important and widely used birds are the magpie (*Pica pica*) in Canada [88], the starling (*Sturnus vulgaris*) [89] in Australia, the Indian myna *Acridotheres tristis* [90] and pee wee (*Grallina cyanoleuca*) in Australia. According to an investigation by Wilkinson [91], the American robin *Turdus migratorius*, the superb starling *Spreo superbus,* and the African pied wagtail *Motacilia agwimp* had recorded predators of *R. appendiculatus* [58].

Williams *et al*. [92] also suggested that chickens can control the tick population to some extent and predate a large population of ticks in the morning time as compared to the evening time. These poultry birds can become part of integrated pest management (IPM) which minimize the pest (tick) population. Parola and Raoult [93] had also given the same recommendations in Zimbabwe. They reported that chickens proved very effective predators of *R. evertsi*, *A. hebraeum*, *B. decoloratus* and Hyalomma species. While Barre *et al*. [94] resulted that the maximum population of *R. appendiculatus* was predated or consumed followed by *A.*

variegatum B. decoloratus and *R. evertsi evertsi*. Dreyer *et al*. [95] also studied the mechanism of predation of chicken on ticks.

1.2.9.2. Ants as a biocontrol agent

The ants *Iridomyrmex delectus*, *Aphaenogaster longiceps,* and *Pheidole megacephala* have been reported to prey on cattle ticks (*B. microplus*) [96]. These ants reduced 50% the tick population. It has been reported that the fire-ant *Solenopsis invicta* eats away the *A. americanum* [97]. Butler *et al*. [98] reported that *S. geminata* had preyed 63% of gravid females of *B. microplus* in Mexico. *P. megacephala* feed on *A. cajennense* and *R. appendiculatus* in Cuba and Kenya [58].

1.2.9.3. Parasitoids

The order Hymenoptera is home to most parasitoids utilized in the biological control of plant-insect pests. Over two-thirds of effective biological pest management instances have used hymenopteran parasites, although only a few species are known to harm ticks [99]. The most important parasitoids applied to control tick species are given in Table 4. According to Larson [100], 49% of nymphs of *A. variegatum* parasitized through the release of *I. hookeri* on cattle in Africa while Lopes *et al*. [101] reported parasitism of Amblyomma species. and *Rhipicephalus sanguineus* by *I. texanus* and *I. hookeri* in Brazil.

Table 4. List of parasitoids along with their stages and hosts

Parasitoid	Stage	Host	Reference
Ixodiphagus texanus		*D. variabilis, Hae. leporispalustris, I. dentatus*	Gahan [102]
I. texanus	Nymph	*A. vahagatum*	Mwangi [58]
I. hookeri	Nymph, larva	*A. variegatum*	Takasu and Nakamura [103]
I. hirtus		*I. biroi, I. persulcatus*	Ostfeld *et al*. [54]
1. mysorensis		*Ornithodoros* species, *Amblyomma* species.	Ostfeld *et al*. [54]
Ixodiphagus hirtus		*Ornithodoros* species, *Amblyomma* species.	Ostfeld *et al*. [54]
Ixodiphagus biroi		*Ornithodoros* species, *Amblyomma* species.	Ostfeld *et al*. [54]
I. sagarensis		*Ornithodoros* species., *Amblyomma* species, *Dermacentor* species.	Ostfeld *et al*. [54]
Hunterellus hookeri		*R. sanguineus, I. dammini*	Howard [104] Gaye *et al*. [105]
H. theilerae	Nymph	*H. transiens*	Smith and Cole [106]
H. sagarensis		*Hae. bispinosa, Hae. Longicornis*	Geevarghese [107]

1.3. Why are biocontrol agents necessary for integrated tick management?

Nowadays, biocontrol is becoming the most eminent method that replaces chemical pesticides. It is eco-friendly and minimizes using chemicals to control ticks and other pests. This method can reduce pesticide resistance. Biocontrol is often more expensive than chemical pesticides because of the need for frequent reapplications (*i.e.,* bio-pesticide applications) [108, 109, 110].

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1.4. Limitations of Biological Control for ticks

The primary limitation and barrier to the biocontrol of ticks is the incapacity of the indigenous natural enemy to suppress the pest without regular supplementation. In other words, if the pest and control agent coexist naturally, yet the pest (by definition) is not generally controlled by the agent, the efficacy of the control agent appears to be questionable. However, low natural contact rates between the control agent and the target can result in poor control under normal (unaugmented) conditions. Changing the amount or distribution of the control agent to enhance contact rates with the target species is a fundamental problem for augmentative biocontrol.[54]

4. CONCLUSIONS

Ticks as ectoparasites are becoming a severe threat to humans and livestock in the whole world. These act as vectors for several infectious diseases such as babesiosis and anaplasmosis in humans and animals. Tick invades different hosts, including humans, and causes severe economic losses, even death. A diversity of biological agents is found in nature to control tick populations below an economic threshold level. Tick-controlling techniques such as grazing management, vaccination and biological control methods could be applied, which could be a successful method in the future. Biological agents such as fungi, bacteria and nematodes should be promoted against tick species in the world. Area-wide tick management by using biological agents should be recommended and applied.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Economic survey, 2020-21. Ministry of Finance, Government of Pakistan.
2. Jamil M. Tick collection and infestation on buffaloes at Dera Ismail Khan, KPK, Pakistan. Bioscience Research. 2022;19(1):665-70.
3. Jamil M, Bhatti AH, Zia R, Shabana K, Kashif M, Ullah N, Ali M, Jabeen N, Bilal M, Amin A, Khan I. Collection, prevalence and identifying hard tick species among small ruminants in Southern Khyber Pakhtunkhwa, Pakistan. Bioscience Research. 2022;19(2):893-8.
4. Jamil M, Idrees A, Khan S, Alwaili MA, Al-Qahtani WS, Qadir ZA, Kashif M, Afzal A, Ullah H, Khan I, Morsy K. Distribution and identification of tick species infesting donkeys, in district Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. Systematic and Applied Acarology. 2022;27(8):1518-24.
5. Jamil M, Idrees A, Qadir ZA, Elahi ME, Imran F, Qasim M, Khan MS, Aziz H, Iqbal Z, Qazi IM, Sadia BI. Medical and Veterinary Ectoparasites' Importance: An Insight on Alternative Control. Pakistan Journal of Medical and health sciences. 2022;16 (01):667.
6. Jamil M, Kashif M, Mubeen M, Jelani G, Ullah N, Tariq A, Rasheed M, Hussain A, Ali M. Identification of tick species infesting livestock in Dera Ismail Khan Pakistan. Systematic and Applied Acarology. 2021;26(12):2247-52.
7. Jamil M, Khan A, Zeeshan M, Hasan SM. Collection and Identification of Tick Species on Goats and Sheep in Dera Ismail Khan, Pakistan. Annals of the Romanian Society for Cell Biology. 2021;25(6):18389-94.
8. Ramzan M, Naeem-Ullah U, Saba S, Iqbal N, Saeed S. Prevalence and identification of tick species (Ixodidae) on domestic animals in district Multan, Punjab Pakistan. International Journal of Acarology. 2020;46(2):83-7.
9. Norton RA, Behan-Pelletier V. Chapter 15, Oribatida—In: Krantz GW, Walter DE (Eds.). A Manual of Acarology 3rd Edition. Lubbock: Texas Technology. 2009.
10. Nava S, Guglielmone AA, Mangold AJ. An overview of systematics and evolution of ticks. Frontiers in Bioscience-Landmark. 2009;14(8):2857-77.
11. Keve G, Sándor A, Hornok S. Hard ticks (Acari: Ixodidae) associated with birds in Europe: Review of literature data. Frontiers in Veterinary Science. 2022;9.
12. Rahman A, Kashif M, Nasir A, Idrees A, Jamil M, Ehsan M, Elahi Za, Qasim M, Khan I, Aziz H, Qazi I. A Review of Tick and Tick Control Strategies in Pakistan. Pakistan Journal Of Medical And Health Sciences. 2022;16(1):652-5.

13. Ullah N, Jamil M, Ramzan M, Arshad A, ul Haq MZ. Identification and new record of tick species on livestock from district Dera Ismail Khan, Pakistan. Persian Journal of Acarology. 2022;11(1):159-62.
14. Abbasi F, Abbasi IH, Nissa TF, Bhutto ZA, Arain MA, Soomro RN, Siyal FA, Fazlani SA. Epidemiological study of tick infestation in buffalo of various regions of district Khairpur, Pakistan. Veterinary World. 2017;10(6):688.
15. Ghosh S, Bansal GC, Gupta SC, Ray D, Khan MQ, Irshad H, Shahiduzzaman MD, Seitzer U, Ahmed JS. Status of tick distribution in Bangladesh, India and Pakistan. Parasitology Research. 2007;101(2):207-16.
16. Rafique N, Kakar A, Iqbal A, Masood Z, Razzaq W, Iqbal F. Impact assessment of tick species, Rhipicephalus (Boophilus) microplus on the milk productions of cattle's in the Quetta City of Province Balochistan, Pakistan. Global Veterinaria. 2015;15:19-23.
17. Kwak ML. A checklist of the ticks (Acari: Argasidae, Ixodidae) of Japan. Experimental and Applied Acarology. 2018;75(2):263-7.
18. Razzak A, Shaikh H. A survey on the prevalence of ticks on cattle in East Pakistan. Pakistan Journal of Veterinary Science. 1969;3:54-60.
19. Perveen F. Distribution and identification of ixodid tick species on livestock in northern Pakistan. Journal of Agricultural Science and Technology. 2011;1:73-81.
20. Rehman WU, Khan IA, Qureshi AH, Hussain S. Prevalence of different species of ixodidae (hard ticks) in Rawalpindi and Islamabad. Pakistan Journal of Medical Science. 2004;43:42-6.
21. Riaz M, Tasawar Z. A study on molecular diagnosis of Theileria species infection by PCR amplification in sheep and goats in Multan, Pakistan. Biological Sciences-PJSIR. 2017;60(1):36-45.
22. Karim S, Budachetri K, Mukherjee N, Williams J, Kausar A, Hassan MJ, Adamson S, Dowd SE, Apanskevich D, Arijo A, Sindhu ZU. A study of ticks and tick-borne livestock pathogens in Pakistan. Plos Neglected Tropical Diseases. 2017;11(6):e0005681.
23. Shah A, Shah SR, Rafi MA, Noorrahim MS, Mitra A. Identification of the prevalent ticks (Ixodid) in goats and sheep in Peshawar, Pakistan. Journal of Entomology and Zoology Studies. 2015;3:11-4.
24. Muhammad G, Naureen A, Firyal S, Saqib M. Tick control strategies in dairy production medicine. Pakistan Veterinary Journal. 2008;28(1):43.
25. Ramzan M, Murtaza G, Sattar A, Munawar N, Ullah A, Ejaz A, Ayaz F, Anwar S, Jameel K, Kamran F. Techniques for managing ticks and tick-borne diseases under changing climate; A review. Egyptian Academic Journal of Biological Sciences. 2021;13(1):117-28.
26. Ahmed S, Numan M, Manzoor AW, Ali FA. Investigations into Ixodidae ticks in cattle in Lahore, Pakistan. Veterinaria Italiana. 2012;48:185-91.
27. Hornok S, Kováts D, Horváth G, Kontschán J, Farkas R. Checklist of the hard tick (Acari: Ixodidae) fauna of Hungary with emphasis on host-associations and the emergence of Rhipicephalus sanguineus. Experimental and Applied Acarology. 2020;80(3):311-28.
28. Adil MM, Parveen A, Asif M, Farooq M, Iqbal F. Prevalence and identification of tick species on large ruminants from district Rajanpur in Punjab Pakistan. International Journal of Acarology. 2021;47(7):633-7.
29. Ramzan M, Naeem-Ullah U, Abbas H, Adnan M, Rasheed Z, Khan S. Diversity of hard ticks in goats and sheep in Multan, Punjab, Pakistan. International Journal of Agriculture and Biological Research. 2019;35:7-9.
30. Irshad N, Qayyum M, Hussain M, Khan MQ. Prevalence of tick infestation and theileriosis in sheep and goats. Pakistan Veterinary Journal 2010;30(3):178-80.
31. Hart BL. Role of grooming in biological control of ticks. Annals of the New York Academy of Sciences. 2000;916(1):565-9.
32. Iqbal A, Sajid MS, Khan MN, Muhammad G. Epizootiology of Ectoparasitic Fauna Infesting Selected Domestic Cattle Population of Punjab, Pakistan. International Journal of Agriculture and Biology. 2014;16(2).
33. Petney TN, Pfaeffle MP, Skuballa JD. An annotated checklist of the ticks (Acari: Ixodida) of Germany. Systematic and Applied Acarology. 2012;17(2):115-70.
34. Duan DY, Liu GH, Cheng TY. Microbiome analysis of the saliva and midgut from partially or fully engorged female adult Dermacentor silvarum ticks in China. Experimental and Applied Acarology. 2020;80(4):543-58.

35. Zhou S, Liu B, Han Y, Wang Y, Chen L, Wu Z, Yang J. ZOVER: the database of zoonotic and vector-borne viruses. Nucleic Acids Research. 2022;50(D1):D943-9.
36. Sarani M, Telmadarraiy Z, Moghaddam AS, Azam K, Sedaghat MM. Distribution of ticks (Acari: Ixodidae) infesting domestic ruminants in mountainous areas of Golestan Province, Iran. Asian Pacific Journal of Tropical Biomedicine. 2014;4:S246-51.
37. Rjeibi MR, Gharbi M, Mhadhbi M, Mabrouk W, Ayari B, Nasfi I, Jedidi M, Sassi L, Rekik M, Darghouth MA. Prevalence of piroplasms in small ruminants in North-West Tunisia and the first genetic characterisation of Babesia ovis in Africa. Parasite. 2014;21.
38. Michelet L, Joncour G, Devillers E, Torina A, Vayssier-Taussat M, Bonnet SI, Moutailler S. Tick species, tick-borne pathogens and symbionts in an insular environment off the coast of Western France. Ticks and Tick-borne Diseases. 2016;7(6):1109-15.
39. Hollidge BS, Weiss SR, Soldan SS. The role of interferon antagonist, non-structural proteins in the pathogenesis and emergence of arboviruses. Viruses. 2011;3(6):629-58.
40. Charrel RN, Fagbo S, Moureau G, Alqahtani MH, Temmam S, De Lamballerie X. Alkhurma hemorrhagic fever virus in Ornithodoros savignyi ticks. Emerging Infectious Diseases. 2007;13(1):153.
41. Venugopal K, Gritsun T, Lashkevich VA, Gould EA. Analysis of the structural protein gene sequence shows Kyasanur Forest disease virus as a distinct member in the tick-borne encephalitis virus serocomplex. Journal of General Virology. 1994;75(1):227-32.
42. Tarif AB, Lasecka L, Holzer B, Baron MD. Ganjam virus/Nairobi sheep disease virus induces a pro-inflammatory response in infected sheep. Veterinary Research. 2012;43(1):1-2.
43. Singh BB, Gajadhar AA. Role of India's wildlife in the emergence and re-emergence of zoonotic pathogens, risk factors and public health implications. Acta Tropica. 2014;138:67-77.
44. Lin D, Li L, Dick D, Shope RE, Feldmann H, Barrett AD, Holbrook MR. Analysis of the complete genome of the tick-borne flavivirus Omsk hemorrhagic fever virus. Virology. 2003;313(1):81-90.
45. Devi K. Bourbon virus: a newly described emerging infectious agent. Indian Journal of Microbial Research. 2015;2:1-6.
46. Piesman J, Eisen L. Prevention of tick-borne diseases. Annual Review of Entomology. 2008;53(1):323-43.
47. Breitschwerdt EB, Hegarty BC, Maggi RG, Lantos PM, Aslett DM, Bradley JM. Rickettsia rickettsii transmission by a lone star tick, North Carolina. Emerging Infectious Diseases. 2011;17(5):873-5.
48. Hussain S, Hussain A, Ho J, Li J, George D, Rehman A, Zeb J, Sparagano O. An epidemiological survey regarding ticks and tick-borne diseases among livestock owners in Punjab, Pakistan: A one health context. Pathogens. 2021;10(3):361.
49. Patel R, Singh R, Gupta B, Rai A, Dubey S, Dhakad BM, Soni D. Tick Borne Viral Zoonotic Diseases: A Review. Journal of Entomology and Zoological Studies. 2020;8:2034-41.
50. Hussain S, Hussain A, Ho J, Li J, George D, Rehman A, Zeb J, Sparagano O. An epidemiological survey regarding ticks and tick-borne diseases among livestock owners in Punjab, Pakistan: A one health context. Pathogens. 2021;10:361.
51. Fahimullah. Taxonomic identification of ticks found in domestic animals in arid zone area of Khyber Pakhtunkhwa, Pakistan. Bioscience Research. 2022;19(3):1386-1389.
52. Rodríguez-Vivas RI, Pérez-Cogollo LC, Rosado-Aguilar JA, Ojeda-Chi MM, Trinidad-Martinez I, Miller RJ, Li AY, de León AP, Guerrero F, Klafke G. Rhipicephalus (Boophilus) microplus resistant to acaricides and ivermectin in cattle farms of Mexico. Revista Brasileira de Parasitologia Veterinária. 2014;23:113-22.
53. Sullivan CF, Parker BL, Skinner M. A Review of Commercial Metarhizium-and Beauveria-Based Biopesticides for the Biological Control of Ticks in the USA. Insects. 2022;13(3):260.
54. Ostfeld RS, Price A, Hornbostel VL, Benjamin MA, Keesing F. Controlling ticks and tick-borne zoonoses with biological and chemical agents. Bioscience. 2006;56(5):383-94.
55. Carlberg G. Bacillus thuringiensis and microbial control of flies. MIRCEN Journal of Applied Microbiology and Biotechnology. 1986;2(2):267-74.
56. Brown RS, Reichelderfer CF, Anderson WR. An endemic disease among laboratory populations of Dermacentor andersoni (= D. venustus)(Acarina: Ixodidae). Journal of Invertebrate Pathology. 1970;16(1):142-3.

57. Hendry DA, Rechav Y. Acaricidal bacteria infecting laboratory colonies of the tick Boophilus decoloratus (Acarina: Ixodidae). Journal of Invertebrate Pathology. 1981;38(1):149-51.
58. Mwangi EN. The ecology of free-living stages of R. appendiculatus Neumann and other livestock ticks, and the role of predators, parasitoids and pathogens in the regulation of natural populations (Doctoral dissertation, PhD thesis. Kenyatta University, Nairobi, Kenya. 1990.
59. Alonso-Díaz MA, García L, Galindo-Velasco E, Lezama-Gutierrez R, Angel-Sahagún CA, Rodríguez-Vivas RI, Fragoso-Sánchez H. Evaluation of Metarhizium anisopliae (Hyphomycetes) for the control of Boophilus microplus (Acari: Ixodidae) on naturally infested cattle in the Mexican tropics. Veterinary Parasitology. 2007;147(3-4):336-40.
60. Pirali-Kheirabadi K, Haddadzadeh H, Razzaghi-Abyaneh M, Bokaie S, Zare R, Ghazavi M, Shams-Ghahfarokhi M. Biological control of Rhipicephalus (Boophilus) annulatus by different strains of Metarhizium anisopliae, Beauveria bassiana and Lecanicillium psalliotae fungi. Parasitology Research. 2007;100(6):1297-302.
61. Hornbostel VL, Ostfeld RS, Benjamin MA. Effectiveness of Metarhizium anisopliae (Deuteromycetes) against Ixodes scapularis (Acari: Ixodidae) engorging on Peromyscus leucopus. Journal of Vector Ecology. 2005;30(1):91.
62. Frazzon AP, Junior ID, Masuda A, Schrank A, Vainstein MH. In vitro assessment of Metarhizium anisopliae isolates to control the cattle tick Boophilus microplus. Veterinary Parasitology. 2000;94(1-2):117-25.
63. Tavassoli M, Pourseyed SH, Ownagh A, Bernousi I, Mardani K. Biocontrol of pigeon tick Argas reflexus (Acari: Argasidae) by entomopathogenic fungus Metarhizium anisopliae (Ascomycota: Hypocreales). Brazilian Journal of Microbiology. 2011;42:1445-52.
64. Manjunathachar HV, Saravanan BC, Kesavan M, Karthik K, Rathod P, Gopi M, Tamilmahan P, Balaraju BL. Economic importance of ticks and their effective control strategies. Asian Pacific Journal of Tropical Disease. 2014;4:S770-9.
65. Tavassoli M, Ownag A, Pourseyed SH, Mardani K. Laboratory evaluation of three strains of the entomopathogenic fungus Metarhizium anisopliae for controlling Dermanyssus gallinae. Avian Pathology. 2008;37(3):259-63.
66. Pourseyed SH, Tavassoli M, Bernousi I, Mardani K. Metarhizium anisopliae (Ascomycota: Hypocreales): an effective alternative to chemical acaricides against different developmental stages of fowl tick Argas persicus (Acari: Argasidae). Veterinary Parasitology. 2010;172(3-4):305-10.
67. Fernandes ÉK, Bittencourt VR, Roberts DW. Perspectives on the potential of entomopathogenic fungi in biological control of ticks. Experimental Parasitology. 2012;130(3):300-5.
68. Samish M, Rot A, Ment D, Barel S, Glazer I, Gindin G. Efficacy of the entomopathogenic fungus Metarhizium brunneum in controlling the tick Rhipicephalus annulatus under field conditions. Veterinary Parasitology. 2014;206(3-4):258-66.
69. Mesquita E, Marciano AF, Corval AR, Fiorotti J, Corrêa TA, Quinelato S, Bittencourt VR, Golo PS. Efficacy of a native isolate of the entomopathogenic fungus Metarhizium anisopliae against larval tick outbreaks under semifield conditions. BioControl. 2020;65(3):353-62.
70. Hassanain MA, Garhy ME, Abdel-Ghaffar FA, El-Sharaby A, Megeed KN. Biological control studies of soft and hard ticks in Egypt. Parasitology Research. 1997;83(3):209-13.
71. Ceraul SM, Sonenshine DE, Hynes WL. Resistance of the tick Dermacentor variabilis (Acari: Ixodidae) following challenge with the bacterium Escherichia coli (Enterobacteriales: Enterobacteriaceae). Journal of Medical Entomology. 2002;39(2):376-83.
72. Jaworski DC, Zou Z, Bowen CJ, Wasala NB, Madden R, Wang Y, Kocan KM, Jiang H, Dillwith JW. Pyrosequencing and characterization of immune response genes from the American dog tick, Dermacentor variabilis (L.). Insect Molecular Biology. 2010;19(5):617-30.
73. Brum JG, Teixeira MO. Acaricidal activity of Cedecea lapagei on engorged females of Boophilus microplus exposed to the environment. Arquivo Brasileriro de Medicina Veterinaria e Zootecnia. 1992:543-4.
74. Songür N, Basim HN, Şeşen H. Örgütsel vatandaşlık davranışında adalet algısının öncüllük rolü. Amme İdaresi Dergisi. 2008;41(4):79-100.
75. Rajput ZI, Hu SH, Chen WJ, Arijo AG, Xiao CW. Importance of ticks and their chemical and immunological control in livestock. Journal of Zhejiang University Science. 2006;7(11):912-21.

76. Almazan C, Tipacamu GA, Rodriguez S, Mosqueda J, de Leon AP. Immunological control of ticks and tick-borne diseases that impact cattle health and production. Frontiers in Bioscience-Landmark. 2018;23(8):1535-51.
77. Assenga SP, You M, Shy CH, Yamagishi J, Sakaguchi T, Zhou J, Kibe MK, Xuan X, Fujisaki K. The use of a recombinant baculovirus expressing a chitinase from the hard tick Haemaphysalis longicornis and its potential application as a bioacaricide for tick control. Parasitology Research. 2006;98(2):111-8.
78. Zhioua E, Lebrun RA, Ginsberg HS, Aeschlimann A. Pathogenicity of Steinernema carpocapsae and S. glaseri (nematoda: steinernematidae) to Ixodes scapularis (Acari: Ixodidae). Journal of Medical Entomology. 1995;32(6):900-5.
79. Samish M, Glazer I, Alekseev EA. The susceptibility of the development stages of ticks (Ixodidae) to entomopathogenic nematodes. Acarology IX. 1996;30:121-3.
80. Kocan KM, Pidherney MS, Blouin EF, Claypool PL, Samish M, Glazer I. Interaction of entomopathogenic nematodes (Steinernematidae) with selected species of ixodid ticks (Acari: Ixodidae). Journal of Medical Entomology. 1998;35(4):514-20.
81. Hartelt K, Wurst E, Collatz J, Zimmermann G, Kleespies RG, Oehme RM, Kimmig P, Steidle JL, Mackenstedt U. Biological control of the tick Ixodes ricinus with entomopathogenic fungi and nematodes: Preliminary results from laboratory experiments. International Journal of Medical Microbiology. 2008;298:314-20.
82. Mauléon H, Barré N, Panoma S. Pathogenicity of 17 isolates of entomophagous nematodes (Steinernematidae and Heterorhabditidae) for the ticks Amblyomma variegatum (Fabricius), Boophilus microplus (Canestrini) and Boophilus annulatus (Say). Experimental and Applied Acarology. 1993;17(11):831-8.
83. Samish M, Ginsberg H, Glazer I. Biological control of ticks. Parasitology. 2004;129(S1):S389-403.
84. Hassan SM, Dipeolu OO, Munyinyi DM. Influence of exposure period and management methods on the effectiveness of chickens as predators of ticks infesting cattle. Veterinary Parasitology. 1992;43(3-4):301-9.
85. McKilligan NG. The food and feeding ecology of the cattle egret, Ardeola ibis, when nesting in south-east Queensland. Wildlife Research. 1984;11(1):133-44.
86. Rothschild M, Clay T. Fleas, flukes and cuckoos. A study of bird parasites. Fleas, flukes and cuckoos. A Study of Bird Parasites. 1957.
87. Esther NM, Olusegun OD, Robin MN, Godwin PK, Shwagi MH. Predators, parasitoids and pathogens of ticks: A review. Biocontrol Science and Technology. 1991; 1(3):147-156.
88. Stelfox D. A note on magpies and Rocky Mountain sheep. Canadian Field Naturalist 1968;82:234.
89. Legg J. Some observations on the life history of the cattle tick (Boophilus australis). In Proceedings of the Royal Society of Queensland Brisbane. 1930;41(8).
90. Page N, Oatley TB. Indian mynas feeding on ticks. Lammergeyer. 1979;27:50.
91. Wilkinson PR. A preliminary note on predation on free-living engorged female rocky mountain wood ticks. Journal of Medical Entomology. 1970;7(4):493-6.
92. Williams GR, Rudge MR. A population study of feral goats (Capra hircus L.), from Macauley Island, New Zealand. InProceedings (New Zealand Ecological Society) 1969 (pp. 17-28). New Zealand Ecological Society (Inc.).
93. Parola P, Raoult D. Ticks and tickborne bacterial diseases in humans: an emerging infectious threat. Clinical Infectious Diseases. 2001;32(6):897-928.
94. Barré N, Mauléon H, Garris GI, Kermarrec A. Predators of the tickAmblyomma variegatum (Acari: Ixodidae) in Guadeloupe, French West Indies. Experimental and Applied Acarology. 1991;12(3):163-70.
95. Dreyer KA, Fourie LJ, Kok DJ. Predation of livestock ticks by chickens as a tick-control method in a resource-poor urban environment. Onderstepoort Journal of Veterinary. 1997;64(4):273-6.
96. Bruyne MD. Chemical stimuli in the mating behaviour of the cattle tick Boophilus microplus=: Stimuli chimiques dans le comportement sexuel de la tique du bétail Boophilus microplus (Doctoral dissertation, Université de Neuchâtel). 1996.
97. Harris WG, Burns EC. Predation on the lone star tick by the imported fire ant. Environmental Entomology. 1972;1(3):362-5.

98. Butler JF, Camino ML, Perez TO. Boophilus microplus and the fire ant Solenopsis geminata. New York: Academic Press. 1979.
99. Hajek AE, Eilenberg J. Natural enemies: an introduction to biological control. Cambridge University Press. 2018.
100. Larson CL. The Tick Parasite Ixodiphagus texanus in Nymphs and Larvae of Haemaphysalis leporis-palustris in Minnesota. The Journal of Parasitology 1937;23(5):496-8.
101. Lopes AJ, Nascimento–Júnior JR, Silva CG, Prado ÂP, Labruna MB, Costa–Júnior LM. Parasitism by Ixodiphagus wasps (Hymenoptera: Encyrtidae) in Rhipicephalus sanguineus and Amblyomma ticks (Acari: Ixodidae) in three regions of Brazil. Journal of Economic Entomology. 2012;105(6):1979-81.
102. Gahan AB. The serphoid and chalcidoid parasites of the hessian fly. US Department of Agriculture. 1933.
103. Takasu K, Nakamura S. Life history of the tick parasitoid Ixodiphagus hookeri (Hymenoptera: Encyrtidae) in Kenya. Biological Control. 2008;46(2):114-21.
104. Howard LO. Another chalcidoid parasite of a tick. The Canadian Entomologist 1908;40(7):239-41.
105. Gaye M, Amanzougaghene N, Laidoudi Y, Niang EH, Sekeyová Z, Laroche M, Bérenger JM, Raoult D, Kazimírová M, Fenollar F, Mediannikov O. Hymenopteran parasitoids of hard ticks in western Africa and the Russian Far East. Microorganisms. 2020;8(12):1992.
106. Smith CN, Cole MM. Studies of parasites of the American dog tick. Journal of Economic Entomology. 1943;36(4).
107. Geevarghese G. A new species of chalcid (Hymenoptera: Encyrtidae), parasitizing Haemaphysalis bispinosa from Karnataka, India. Oriental Insects 1977;11(1):49-52.
108. Biological control of tick populations: review and reflections. *Cadernos de Saúde Pública* 1994;*10*:47-52.
109. Samish M, Ginsberg H, Glazer I. Anti-tick biological control agents: assessment and future perspectives. Biology, Disease and Control. 2008;*447*.
110. Santos TR, da Paixão FR, Catão AM, Muniz ER, Ribeiro-Silva CS, Taveira SF, Luz C, Mascarin GM, Fernandes ÉK, Marreto RN. Inorganic pellets containing microsclerotia of Metarhizium anisopliae: A new technological platform for the biological control of the cattle tick Rhipicephalus microplus. Applied Microbiology and Biotechnology. 2021;105(12):5001-12.
111. Angelini SG, Stachurski F, Lancelot R, Boissier J, Allienne JF, Marco S, Maestrini O and Uilenberg G. Ticks (Acari: Ixodidae) infesting cattle and some other domestic and wild hosts on the French Mediterranean island of Corsica. Parasites and Vectors. 2016;9:582-592.

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