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How to get rid of ticks – a mini-review on tick control strategies in parks, gardens, and other human-related environments

Dagmara Wężyk[1,B-D,F], Anna Bajer[1,A,E-F], Dorota Dwużnik-Szarek[1,B]

[1] *Department of Eco-Epidemiology of Parasitic Diseases, University of Warsaw, Poland*
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Abstract

Introduction and Objective. In recent years, the geographical range of many tick species has expanded significantly, increasing the threat of emerging tick-borne diseases. Th aim of this review is to assess the current state of tick control in the environment, highlighting the limitations of existing methods and the need to develop new approaches.

Review methods. The literature was systematically reviewed using such databases as Google Scholar, PubMed, and ResearchGate. Key word searches focused on tick control and prevention of tick-borne diseases in environments. Evaluation criteria included efficacy and feasibility of various tick control measures.

Brief description of the state of knowledge. Biological control of ticks in the environment relies on entomopathogenic fungi, particularlythe Metarhizium species, delivered as granules. Synthetic acaricides, including pyrethroids and organophosphates, are widely used, with liquid formulations proving more effective than granules. Innovative approaches, such as the TickBot robot and devices targeting reservoir hosts such as deer, show promise. Future directions include the development of vaccines targeting tick antigens, and translational biotechnological strategies for tick population control.

Summary. The prevention of tick-borne diseases involves various control methods, such as the use of acaricides, fungi, pheromones and innovative approaches, such as bait tubes and boxes. Each method has its own set of pros and cons, emphasizing the need for an integrated and strategic approach. While innovative methods, including vaccines and molecular approaches, show promise, further research and testing in natural environments are necessary to confirm their effectiveness. Achieving long-lasting and comprehensive tick control remains a challenging task in promoting public health.

Key words

environment, acaricides, tick control, bait tubes, bait box, deer feeders

INTRODUCTION AND OBJECTIVE

Ticks are found on almost all continents – Asia, Africa, North and South America, Europe [1] – where they act simultaneously as efficient vectors of many pathogens causing Lyme disease: babesiosis, anaplasmosis, rickettsiosis, ehrlichiosis, tick-borne encephalitis and Powassan virus [2]. Ticks are characterized by a wide range of hosts [3], posing a threat not only to humans, but also to domestic and farm animals [4, 5]. It is estimated that there are 899 species of ticks parasitize vertebrates, encompassing the tick families: Argasidae (185 species), Ixodidae (713 species) and Nuttalliellidae (1 species) [6].

Current tick control relies mainly on the use of repellents and acaricides and is largely targeted at livestock [7]. However, these methods have side-effects as many tick species become resistant to chemicals, and chemicals contribute to contamination of the environment, milk and livestock meat [8]. For humans, the prevention of tick bites and tick-borne diseases depends largely on individual decisions to use protective measures, such as repellents, protective clothing, and avoiding tick-inhabited habitats [9]. However, the development of new acaricides and repellents is a long and expensive process which reinforces the need for new and innovative tick control methods that could also be applied directly in the environment [10]. Tick control agents that can be applied in the environment (in forests, meadows, pastures, lawns, gardens, city parks, etc.), or directly to tick hosts, can be divided into chemical and biological measures [11]. This aim of this review is to assess the current state of tick control in the environment, highlighting the limitations of existing methods and the need to develop new approaches.

Address for correspondence: Dagmara Wężyk, Department of Eco-Epidemiology of Parasitic Diseases, Medical University, Warsaw, Poland
E-mail: d.wezyk@uw.edu.pl

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REVIEW METHODS

Data was systematically retrieved from electronic databases, including Google Scholar, PubMed, and ResearchGate, utilizing pre-defined key words, including 'tick control', 'environmental factors', and 'acaricides'. In the process of literature selection, a discerning criterion was applied to exclusively include studies where control methods were tested within natural environmental settings. Articles exclusively evaluating control methods under laboratory conditions were excluded. Additionally, comprehensive review articles elucidating control methodologies, for example, the mechanisms of action of acaricides, were incorporated into the substantive content of the manuscript. Due to the small number of articles matching the authors' criteria, they were not limited to the year of publication, although an attempt was made to select the most recent works.

STATE OF KNOWLEDGE

Tick control in the environment – Entomopathogenic fungi. Biological control of ticks in the environment is largely based on the use of various types of lethal microorganisms, e.g. fungi [12]. Fungi are considered to be the main pathogens of ticks due to their common occurrence in soil, broad host spectrum, and ability to penetrate the cuticle [13]. Studies in Europe have shown that up to 50% of *Dermacentor* and *Ixodes* ticks can be infected with fungi [13]. However, these methods have their limitations, such as the presence of microbial competitors and unfavourable environmental conditions for the growth of fungi [14]. Among the fungi used to control arthropods, the genus Metarhizium [15] constitutes the most common active component of mycoinsecticides and mycoacaricides marketed worldwide [16]. Fungi of the genus Metarhizium can not only infect and kill the target pest, but can also colonize surrounding plants for their benefit [17]. Fungi are delivered to the environment mostly as granules, and attract particular attention as cost-effective biocontrol agents, and are especially useful in agriculture [18]. In the case of ticks, this method of control affects not only tick eggs that are laid in the soil, but also females and newly-hatched larvae still present in the soil during this period [19]. Therefore, the application and impact of fungal pellets to/on eggs and larvae in pastures would be more effective in controlling tick populations than the anti-tick treatment of cattle, and would also minimize the initial infestation level on the host cattle [20]. The effectiveness of the fungal pellets, which resulted in a decrease in the number of eggs laid by fungi-infected female ticks, is well documented in the literature (Tab. 1) [21–23].

Acaricides. In addition to biological tick control, environmental acaricides (biological, organic or synthetic) are often used. Synthetic chemical control is the most effective strategy for tick control in the environment when used correctly [24]. A number of substances from different classes of pesticides, e.g. pyrethroids, organophosphates and carbamates, have been tested and the use of synthetic acaricides has been shown to reduce tick densities by at least 70% over a period of one month [24]. Both liquid (spray) and granular preparations are commercially available [25]. Schulze and Jordan (2019) showed that the use of a widely available liquid acaricide (bifethrin) effectively combats nymphs of *I. scapularis* and *Amblyomma americanum* for most of their period of activity [26]. Other studies have also demonstrated the effectiveness of control agents of common tick species [27]. Three acaricides in both liquid and granular form (Advanced Complete Insect Killer, Spectracide Triazicide Insect Killer and Ortho Bug-B-Gon) were used in the study and applied to a forested area. All three preparations in liquid form ensured control of *I. scapularis* and *A. americanum* nymphs at the level of 98% (Tab. 1). These studies have also reported that liquid preparations are more effective than granules containing the same chemical

Table 1. Tick control agents which can be applied in the environment

Type of control	Tick species	Tick stages	Percentage of ticks killed (%)	Author of the article
Fungi				
Metarhizium anisopliae sensu lato (s.l.),isolate Ma 959 with 20% concentrations of mineral oil	*Rhipicephalus microplus*	adult ticks	87.54	[22]
		larvae	99.06	
		eggs	100	
Beauveria bassiana, isolate Bb 986 with 20% concentrations of mineral oil	*Rhipicephalus microplus*	adult ticks	21.67	
		larvae	52.50	
		eggs	92.64	
Metarhizium anisopliae isolated from soils of cattle farms	*Rhipicephalus microplus*	adult females	≥90	[23]
conidia and blastospores of *Metarhizium robertsii*	*Rhipicephalus microplus*	adult females	98 (blastospores) 71 (conidia)	[21]
conidia and blastospores of *M. anisopliae* sensu lato (s.l.)	*Rhipicephalus microplus*	adult females	93 (blastospores) 63 (conidia)	
conidia and blastospores of *Beauveria bassiana* sensu lato (s.l.)	*Rhipicephalus microplus*	adult females	79 (blastospores) 59 (conidia)	
Acaricides				
Advanced Complete Insect Killer	*Ixodes scapularis*	nymphs	95.8	[27]
	Amblyomma americanum	nymphs	94.8	
Spectracide Triazicide Insect Killer	*Ixodes scapularis*	nymphs	98.5	
	Amblyomma americanum	nymphs	98.5	
Ortho Bug-B-Gon	*Ixodes scapularis*	nymphs	100	
	Amblyomma americanum	nymphs	98.9	
Pheromones				
stop pheromone and acaricide (permethrin)	ticks *Ixodes* spp.	nymphs	nd*	[35]
		adult ticks	nd*	

*nd (no data) - no specific data on what percentage of ticks were killed.

agent [27]. Acaricides in the form of granules are also widely used. Their effectiveness has been confirmed by Schulze and colleagues, who showed that granular deltamethrin (0.15 kg/ha) resulted in a 95% reduction of *I. scapularis* nymphs [28]. The results were similar to those obtained with granular carbaryl, chlorpyrifos [29] and liquid cyfluthrin [30].

The use of aerosol and granular acaricides has both advantages and disadvantages. First, acaricide sprays affect all types of ground-dwelling arthropods, while application of granules to the soil surface has a lower adverse effect on non-target species [31]. On the other hand, the effect of granules can be longer (they need more time to take action) and less effective than spraying for tick control [29, 31]. In addition, the application of tick acaricides may have a pronounced effect on epigeic invertebrates [32].

Pheromones. With the development of the acaricide market and the emergence of new chemical compounds, the resistance of many tick species to each subsequent generation of acaricides had been developed [33]. To prevent this, already known acaricides were combined with pheromones, compounds emitted by tick individuals to influence the behaviour of other ticks of the same species [34].

An agent containing an arrestment pheromone and an acaricide (permethrin) in the form of oil drops which, when applied to vegetation, kills ticks accumulating on the droplets [34]. This formula makes it possible to control ticks with a single application since the active compounds are released gradually over a long period of time [34]. This allows the use of acaricides in a highly selective and effective manner, thus limiting the impact of acaricides on the environment [34]. A field trial using this technology demonstrated a significant reduction in the activity of *I. scapularis* nymphs in areas treated with the Last Call™ pheromone-based agent compared to control fields [34]. According to the authors, the preparation may also be useful in the control of other tick species, such as: *Ixodes ricinus, Ixodes pacificus, Ixodes persulcatus* or *Ixodes holocyclus*. In addition, the authors declared that the preparation could be in liquid form as well as granules or capsules, and can be used together with other acaricides or biological control agents [35].

TickBot. Gaff et al. constructed a semi-autonomous, four-wheeled robot ('TickBot') pulling a miticide-treated fabric (permethrin) [The 'TickBot' Takes the Bite out of Bugs (youtube.com)] and tested it for its ability to kill ticks in a natural environment in Portsmouth, Virginia [36]. To attract ticks to the treated area, carbon monoxide gas (CO_2) was distributed through a tube equipped with evenly spaced pores and flow control valves, allowing even distribution of the gas. Prior to the treatment, a control sweep without CO_2 and permethrin was performed to determine the initial tick count at the study site. TickBot has been shown to be very effective in reducing overall tick density to near zero when equipped with carbon dioxide and permethrin cloth. After passing through the treated area for 60 minutes, the number of adult *A. americanum* ticks was practically reduced to zero and this effect persisted for another 24 hours [36]. However, further studies with this equipment are needed to test its effectiveness against other important tick species, such as *I. scapularis* and the American dog tick, *Dermacentor variabilis* [36].

Landscape management. Landscaping is a part of integrated ticks management and serves a variety of purposes, from improving aesthetics to promoting environmental health. By altering the landscape, it is possible to create an environment less hospitable to the main hosts of ticks, thus reducing their numbers in certain areas. Well-maintained lawns harbour fewer ticks, with the exception of wooded areas, stone walls or dense vegetation. Interestingly, the presence of exotic invasive plants that are resistant to deer biting is associated with higher tick populations [37].

Implementing tick management strategies in landscaping includes such techniques as removing leaf litter and installing wood chip barriers, both of which have been shown to reduce the presence of ticks on lawns. Adjusting the landscape to increase exposure to sunlight and decrease moisture levels can make an area less inviting to ticks. When managing habitats, it is essential to concentrate efforts on the spaces regularly utilized by the household rather than tackling the entire property. To diminish the presence of ticks near homes, it is recommended to trim trees, maintain a well-mown lawn, eliminate leaf litter buildup around the house and lawn perimeters, and clear grass, weeds, and underbrush along the edges of lawns, stonewalls, and driveways. Additionally, pruning plants to create a gap between the ground and the plant base can be beneficial [37]. Typically, individual shade trees in open lawns are unlikely to contribute to tick populations unless they are surrounded by dense ground cover.

The use of hard landscaping, mulches and landscaping techniques can be effective in reducing tick habitat and creating barriers in the yard to isolate areas from tick sites. Hardcapes, such as patios, terraces and paths, are inanimate elements that can contribute to this. Mulches, usually organic materials such as bark or gravel, not only suppress weeds and retain moisture in the soil, but also impede the movement of ticks. Around homes, a barrier of wood chips, at least three feet wide, can help reduce the number of ticks on a lawn, although results may vary depending on factors such as the density of the woodland, level of shade and the initial tick population [37].

However, it is important to remember that although landscaping practices can create zones with a lower risk of ticks, on their own they may not eliminate them completely. It is often necessary to combine these measures with other tick control measures [37]. Landscaping for tick control can be costly and may not be suitable for all residents. Furthermore, the responsibility for landscape modifications lies with individual property owners [37].

STATE OF KNOWLEDGE

Tick control on reservoir hosts – deer tick control applicators. Wild ungulates, including deer, are important and often final hosts for various tick species. In the presence of deer, ticks can multiply to such enormous numbers that they become a major problem in parks and other recreational areas [38]. The spread of borreliosis (Lyme disease) in the USA is also believed to be associated with the increase in deer populations in recent years, and the concomitant increase in the number of *I. scapularis* ticks [39]. Tick densities were controlled mainly by reducing or eliminating the deer populations [40]. Soneshine et al. constructed a self-treatment device for deer

[41] which consisted of a barrel divided into a food container (above) and a stand-alone acaricide tank (below). The device also included a vertical, centrally-located ceramic column that extends from the tank to the food container. The acaricide is taken up into the column from a closed tank by absorption. Animals attracted to the food in the device ingest the acaricide while feeding when they come into direct physical contact with the top of the column [41]. The device developed by the team proved to be effective. Following this treatment, deer hunted in the treated site were infected with significantly less *I. scapularis* than deer from the control site.

A similar device for the tick control of deer was developed by Pound et al. and named the 'four-poster' [42] – a passive deer treatment bait station that locally apply acaricide to the head, ears, and neck of the deer when they touch the acaricide-impregnated rollers while feeding on corn kernels (https://www.youtube.com/watch?v=rVbByLywpQw) [43]. The use of 2% amitraz on deer during the tick season for three consecutive years provided 92–94% tick reductionion animals (Tab. 2) [42, 43]. The 'four-poster' was also tested against *I. scapularis* ticks using 10% permethrin instead of amitraz at the National Aeronautics and Space Administration's Goddard Space Center during 1995 – 1998, resulting in 100% control of deer and 86 and 91% reduction in *I. scapularis* nymphs in the second and third year of the study [44].

Host-directed tick control has been gaining popularity in recent years, resulting in the emergence of new control concepts. Recently, an oral treatment of deer with fipronil was examined for tick control efficiency [45]. Deer were initially fed with fipronil-containing forage for two or five days (two experimental groups), and the ticks were then attached to such deer using specially constructed capsules. The efficiency was 96.2% for *I. scapularis* and 94% for *A. americanum* ticks following the five-day treatment (Tab. 2) [45]. The effectiveness in a group of deer fed for two days was slightly lower – 71.7% and 86.2%, for *I. scapularis* and *A. americanum* ticks, respectively [45]. Unfortunately, this type of deer feed has only just being invented and it will take years before it will be commercially available..

Deer fencing and resistant plantings. Erecting fences is the best way to keep deer away from a property, and therefore ticks as well. Studies have shown that the use of high-strength slanted electric fencing in areas of 15–18 acres can significantly reduce *I. scapularis* tick nymphs by 84% and larvae by 100% within a radius of about 70 metres inside the fenced area. To effectively contain deer, the fenced area must be large enough to extend beyond the range of smaller animal hosts. These fences do not stop small animals or ticks from moving in. Fencing smaller areas can still help, but it may also be necessary to manage ticks inside the fence and apply insecticides around its perimeter [37].

When choosing a deer fence, factors such as the number of deer in the area, the size of the area you want to protect and the terrain should be taken into consideration. The most common types of fencing are plastic or wire mesh structures. Electric fencing is another option. However, it is important to remember that local communities often have regulations on the type and height of fencing allowed, so you should consult your local authority before installing them [37].

Using less palatable plants in the landscape may discourage deer from munching on ornamental plants, potentially reducing damage and making the yard less attractive to deer. However, there is no guarantee that the use of deer-resistant plants will affect the tick population. It is important to remember that how much plants are eaten depends on factors such as deer population, food availability and deer preferences, which can vary from region to region. When choosing plants, consider the terrain – whether it is sunny and moist, dry and sunny, dry and shady, or moist and shady. It is advisable to use native shrubs and trees and avoid invasive plants as they can compete with native species. Some non-native invasive plants, such as Japanese barberry and multiflora rose, are resistant to biting by deer but can harm native ecosystems. Lists of banned and invasive species, along with alternatives, can usually be found from state agencies, universities or environmental groups [37].

BaitBox. Another method for controlling ticks on their hosts is the 'BaitBox', originally developed by Leo Kartman in 1958 and mainly targeted at rodents [46]. As the name implies, Baitboxes are baited boxes where rodents dust themselves with pesticide-infused powder as they enter or exit the boxes. Small mammals are attracted to a box by bait, such as food or fibre, and are treated with an acaricide while harvesting it [46]. This method was used to control rodent fleas in the San Francisco Bay area in the USA, and in later years it was also used as a tick control method.

Table 2. Tick control agents targeted on the host

Objective	Objective	Objective	Objective	Objective
4-poster: Rolls impregnated with acaricide	*Amblyomma americanum*	adult ticks	92*	[42]
		nymphs	92.6*	
		larvae	100*	
Fipronil deer feed	*Ixodes scapularis*	adult ticks	96.2^	[45]
	Amblyomma americanum	adult ticks	94^	
BaitBox with pesticide-infused powder	*Ixodes scapularis*	nymphs	97.3	[48]
Bait tube with stop pheromone and acaricide (pennethrin)	*Dermacentor occidentalis*	adult ticks	100	[50]
		nymphs	97.1	
		larvae	99.26	
	Ixodes pacificus	adult ticks	100	
		nymphs	100	
		larvae	100	

*Effectiveness after the third application; ^ Effectiveness after 5 days

Two versions of similar lure boxes were used to control ticks in a more recent study in the USA [47]. The 'Baitboxes' were placed on several properties where the rodents attracted to the food bait in the box had to come into contact with a wick treated with fipronil to reach the bait (Fig. 1). The authors reported a decrease in the number of tick nymphs by more than 50% on properties where bait boxes were used, compared to properties where no bait was used. The use of baitboxes also resulted in a reduction of the proportion of tick nymphs infected with *Borrelia burgdorferi* and *Anaplasma phagocytophilum* pathogens by 67% and 64%, respectively [47].

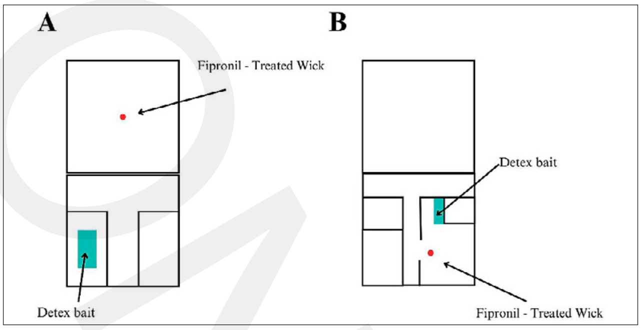

Figure 1 A). Diagram of 'Protecta Jr.' modified bait consisting of a cotton cord impregnated with fipronil, attached to the lid of the box. **B)** The second version of the Baitbox used in the experiment.
Source: based on photography by Dolan et al. [47]

Another study testing SELECT TCS bait boxes resulted in a significant decrease in the abundance and occurrence of *I. scapularis* ticks, and a significant decrease in the number of host-seeking nymphs (Tab. 2) [48].

The use of bait boxes has proven to be extremely effective in tick control [47] and have the potential to reduce the infection rate of humans [49], as well as reducing the infection rate of host-seeking ticks [47]. However, this method has several disadvantages, such as costs related to the purchase of traps and acaricide, and relatively short period of action, as fipronil is active in rodents for only 42 days [47]. It has also been shown that the effectiveness of the method can also be influenced by the density of bait boxes and the possibility of immigration of untreated hosts from neighbouring areas [24].

Bait tube. Bait tubes were a version of baited trap designed for small mammals/rodents. A 'bait tube' used in a study by Lane et al. was a tube approximately 10 cm in diameter by 50 cm long, lined inside at both ends with a piece of liner and containing a bait block inside (Fig. 2). The rodent, trying to get to the bait, rubbed against the lining, which was covered with acaricide at both ends of the tube [50].

In an early study in 1998, such tubes were used to control ectoparasites in dusky-footed woodrat (*Neotoma fuscipes*) [50]. The ends of the linings were soaked with 1.25% permethrin, 0.12% pyrethrin, 10.00% piperonyl butoxide and 88.63% inert ingredients, and then, after several days, the trapping of rodents was performed. These bait tubes were extremely effective, with only 22 ticks collected from rodents in experimental slots in comparison to 2,427 ticks collected from rodents in the control areas (effectiveness of tubes is presented in Table 2). The number of fleas collected in the experimental slots (21 fleas) was also significantly lower compared to the control area (342 fleas) [50]. The effectiveness of this control measure for ticks was maintained for up to two months, and for fleas up to eight months.

This method seems very promising as a tool for controlling the ectoparasite vectors of pathogens dangerous to humans in rural and home environments. Additionally, this host-targeted ectoparasite method saves time and uses a pyrethroid pesticide that is stable, effective at low doses, and has low mammalian toxicity [51]. However, to a large extent, the success of the device depends on the local wildlife – the more abundant it is, the more frequent applications and increased tube densities are needed in the environment [52]. In addition, acaricide-containing cotton is orally transmitted by small mammals, and despite the low dose of the acaricide, there are concerns about unintentional swallowing by wild animals. Additionally, the general public has expressed concerns about the ingestion of cotton by young children or pets after application [52].

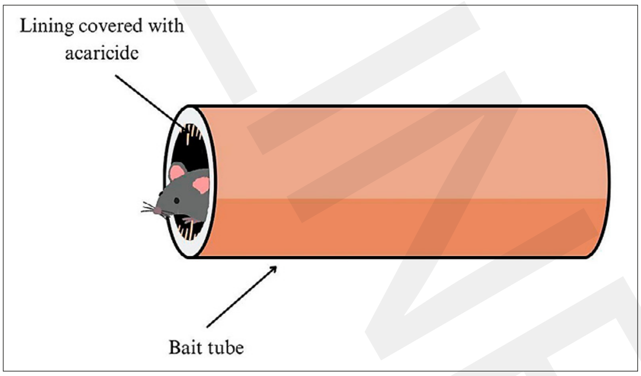

Figure 2. Diagram of a bait tube.
Source: based on photography by Lane et al. [50]

Promising plans for the future. Considering the discovery of novel tick-borne pathogens and their different nature, coupled with the limited success in creating vaccines targeting individual pathogens, there is a strong need for a comprehensive strategy in developing vaccines against ticks. A potential method to counteract one or more diseases transmitted by ticks involves innovating early detection methods and thwarting the arthropod ability to successfully feed on blood.

In a study carried out by Sajid et al. [53], an effort was made to induce acquired resistance to ticks or enhance host immunity against *I. scapularis*. This was achieved by utilizing 19 salivary proteins with various functions in tick feeding, interactions with pathogens or host responses, representing the part of tick sialome [53]. To enhance the immune response, a nucleoside-modified mRNA-LNP platform was proposed, enabling a more sustained delivery of the antigen [54]. Consequently, this approach potentially bore a closer resemblance to a natural tick bite.

The outcome of the Sajid et al. [53] study was the development of 19ISP immunization, capable of triggering acquired immunity against *I. scapularis* and averting tick-borne *B. burgdorferi* infections in guinea pigs. Historically, vaccines for human infectious diseases have predominantly targeted pathogens or microorganisms directly. Furthermore, existing commercial tick vaccines in animals have primarily focused on reducing the tick burden without conclusively preventing the transmission of infectious diseases [55, 56]. The introduction of 19ISP may revolutionize this paradigm by showcasing the potential of a human tick vaccine to prevent infectious diseases. This suggests that a vaccine inducing quicker tick recognition might suffice to prevent infection. Further investigations in diverse animal models and human subjects will ascertain whether immunization with 19ISP can elicit robust immunity against ticks, and definitively determine the level of protection against the Lyme disease causative agent. These findings underscore the prospect that a multivalent mRNA vaccine targeting *I. scapularis* antigens holds the promise to prevent a prevalent tick-borne infectious disease [53].

Another promising future direction is leveraging translational biotechnology to transform biomolecules and molecular mechanisms into innovative interventions and precision medicine. Strategies targeting the tick-host-pathogen interactions have the potential to generate novel interventions crucial for addressing global challenges posed by ticks and tick-borne diseases (TBD). This versatile approach applies to biomolecules from ticks and pathogens, as well as biological processes affecting humans, wild, and domestic animal hosts, impacting on both health and the economy [57]. Ongoing research involves modelling tick infestations, assessing pathogen risks, and evaluating vaccines. Formulations incorporating DNA, RNA, and virus-like particles, maximize immune response against ticks and associated pathogens. Tick protein modifications and glycoproteins play protective roles while targeting tick microbiota and tick cement proteins, offers strategies to control ticks and mitigate pathogen transmission. Understanding tick epigenetics, glycoprotein synthesis, and tick elementome is essential for developing effective control interventions. Tick paratransgenesis, using CRISPR-Cas9 to modify midgut bacteria, reduces tick fitness and pathogen transmission. Genetic manipulation of *Metarhizium* spp. fungi and tick midgut bacteria, along with non-tick transmissible live vaccines, are also promising strategies for control of the tick population [57–63].

SUMMARY

Controlling ticks in the environment can prevent both the spread of these vectors to new areas and the spread of the tick-borne disease agents. Many tick control methods have been developed so far, but most of them use chemicals such as acaricides and repellents. Their side-effects result in attempts to create new, effective methods of tick control worldwide. The methods presented in the current mini-review focused mainly on the direct control of ticks in the environment and attempts to control ticks on natural/reservoir/amplification hosts, and each method comes with its own set of advantages and disadvantages (Tab. 3). Tick control pellets contain acaricides and are often applied to specific areas where ticks are prevalent, such as lawns, gardens, or the edges of wooded areas. When ticks come into contact with the treated surface, they are exposed to the acaricide and eliminated. Liquid formulations of acaricides can be sprayed or applied to vegetation, outdoor surfaces,

Table 3. Advantages and disadvantages of methods used in tick control

Method	Advantages	Disadvantages
Fungi	Environmentally-friendly and biodegradable	May have slower action compared to chemical acaricides
	Effective in reducing tick populations over time	Effectiveness influenced by environmental conditions
	Can target multiple tick life stages	Limited availability and commercial formulations
	Minimal risk to non-target species and ecosystems	Requires further research for optimal application
Acaricides	Broad application on vegetation and outdoor surfaces	Potential toxicity to non-target species
	Quick and effective tick elimination on contact	Frequent re-application may be necessary
	Suitable for large-scale tick control efforts	Environmental persistence
Pheromones	Highly targeted approach, affecting tick behaviour	Limited effectiveness for reducing tick populations
	Environmentally friendly, minimal impact on ecosystems	Higher cost compared to some other methods
	May disrupt tick mating and reproduction	Additional research needed for optimization
Landscape management	Reduction of tick habitat	Incomplete elimination of ticks
	Customization for specific needs	Individual responsibility
	Enhancement of aesthetics	Costliness
Deer Feeders	Targets a significant host for adult ticks	Potential disturbance to natural deer behavior
	Broad application of acaricides to tick hosts	Potential risks to other wildlife feeding at stations
	May reduce tick populations by targeting adult stages	Cost and logistical challenges in implementation
Deer fencing	Most effective method for keeping deer away from property	Fences can create barriers for wildlife movement
	Minimal environmental impact	Regulatory restrictions
Deer-Resistant Plantings	Choosing native shrubs and trees promotes biodiversity	Effectiveness dependent on a number of factors
	Require less work than other options	Lack of tick control
Bait Boxes	Targets mammal hosts for tick control	Potential risks to non-target animals
	Kills ticks when they feed on treated hosts	Maintenance and refilling required
	Helps reduce tick numbers in the environment	Limited impact on adult tick populations
Bait Tubes	Effective in targeting small mammal hosts	May require frequent replenishment of bait
	Low risk to non-target species	Limited effectiveness against adult ticks

or on treated clothing. The liquid acaricides work similarly to pellets, killing ticks upon contact. Bait tubes are devices designed to target small mammals, such as mice and voles, which are known as reservoir hosts for some tick-borne diseases. The exposure to acaricides helps eliminate juvenile ticks that feed on these hosts, thereby disrupting the tick life cycle. Similar to bait tubes, bait boxes are used to target the hosts. It is also important to control ticks in forests where there are many hosts, for example, deer are important hosts for adult ticks, and controlling their population can have an impact on tick numbers/densities. Some areas implement deer feeding stations where acaricides are mixed with the feed. When deer consume the treated feed, they become carriers of acaricides, which can kill ticks during the feeding process.

These various control methods should be integrated and strategically implemented to maximize their effectiveness. Public education and community involvement play crucial roles in successful tick control efforts. Moreover, it is essential to consider the environmental impact of these control measures and use them judiciously to minimize harm to non-target species, and maintain ecological balance. Regular monitoring and research are vital for evaluating the effectiveness of these control strategies and identifying emerging challenges in tick management. By employing a comprehensive and adaptable approach, controlling ticks in the environment becomes more achievable, leading to a reduction in tick-borne diseases and improved public health outcomes. However, each of these methods has its advantages and disadvantages (Tab. 3), and does not ensure 100% long-lasting effectiveness, which is confirmed by the fact that effective control of ticks in the environment and pathogens carried by them remains a difficult and progressing challenge.

The described innovative methods for combating ticks and tick-borne diseases represent prospective approaches for the future control of these parasites. Research on the 19ISP vaccine strains and the use of the mRNA-LNP platform have shown promising results, indicating the potential for developing tick antigen-based antiviral vaccines. However, many of the new-generation molecular methods, such as tick genome manipulation or paratransgenic approaches, have not yet been adequately tested in the natural environment. Therefore, further studies are necessary to confirm their effectiveness and practical application. The introduction of these innovative strategies can significantly influence tick population control and mitigate associated public health risks.

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