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Review Article

Nanoparticles as effective acaricides against ticks—A review

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ABSTRACT

Ticks serve as vectors of a wide range of infectious agents deleterious to humans and animals. Tick bite prevention is based to a large extent on the use of chemical repellents and acaricides. However, development of resistance in targeted ticks, environmental pollution, and contamination of livestock meat and milk are major concerns. Recently, metal, metal oxide and carbon nanoparticles, particularly those obtained through green fabrication routes, were found to be highly effective against a wide array of arthropod pests and vectors. We summarize current knowledge on the toxicity of nanoparticles against tick vectors of medical and veterinary importance. We also discuss the toxicity of products from botanical- and bacterial-based as well as classic chemical nanosynthesis routes, showing differences in bioactivity against ticks based on the products used for the fabrication of nanoparticles. Further research is needed, to validate the efficacy of nanoparticle-based acaricides in the field and clarify mechanisms of action of nanoparticles against ticks. From a technical point of view, the literature analyzed here showed little standardization of size and weight of tested ticks, a lack of uniform methods to assess toxicity and concerns related to data analysis. Finally, an important challenge for future research is the need for ecotoxicology studies to evaluate potential negative effects on non-target organisms and site contamination arising from nanoparticle-based treatments in close proximity of livestock and farmers.

1. Introduction

Ticks serve as vectors of a wide range of infectious diseases deleterious to humans and animals, including anaplasmosis, babesiosis, borreliosis, and ehrlichiosis (Brake et al., 2010; Löscher and Burchard, 2010; Dantas-Torres et al., 2012; Deplazes et al., 2013; Pfäffle et al., 2013; Guglielmone et al., 2014). They transmit more infectious agents than any other group of blood-feeding arthropods worldwide, affecting humans, livestock, wildlife, and pets (George, 2000; Sonenshine et al., 2002; Bissinger and Roe, 2010). Humans are incidental hosts for several tick species (Estrada-Penã and Jongejan, 1999; Guglielmone et al., 2006). Human-biting tick species differ from region to region and are associated with wildlife and domestic animals that serve as reservoir hosts of several zoonotic agents (Estrada-Penã and Jongejan, 1999; Casher et al., 2002; Eisen et al., 2004; Dantas-Torres, 2007; Piesman and Eisen, 2008).

Tick bite prevention is based to a large extent on the use of chemical repellents and acaricides (Ghosh et al., 2006; Piesman and Eisen, 2008; Dantas-Torres et al., 2012). However, chemical acaricides currently marketed have shown several drawbacks, due to the development of resistance in ticks, environmental pollution, contamination of meat and milk from livestock and high costs (Sonenshine et al., 2002). Therefore, searching for alternative methods of tick vector control is crucial (Benelli, 2016a). The development of new acaricidal and repellent products can be helpful to mitigate development of acaricide resistance (Semmler et al., 2011; Abdel-Ghaffar et al., 2015; Khater et al., 2016;

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Table 1
Toxicity of metal and metal oxide nanoparticles fabricated using green-mediated fabrication and classic chemical routes against tick vectors.

Tick species	Instar	Nanoparticle	Synthesis route	L_{50}	Oviposition inhibition I_{50}	References
Rhipicephalus microplus	Larva	Ag and AgCl presence	Green nanosynthesis, extract of *Mimosa pudica*	8.98 mg/l	–	Marimuthu et al. (2011)
Hyalomma anatolicum	Larva	AgCl (low Ag presence)	Green nanosynthesis, extract of *Ocimum canum*	0.78 mg/l	–	Jayaseelan and Rahuman (2012)
Hyalomma isaaci	Larva	AgCl (low Ag presence)	Green nanosynthesis, extract of *Ocimum canum*	1.51 mg/l	–	Jayaseelan and Rahuman (2012)
Haemaphysalis bispinosa	Larva	Ag (low AgCl presence)	Green nanosynthesis, extract of *Musa paradisiaca*	1.87 mg/l	–	Jayaseelan et al. (2012)
Haemaphysalis bispinosa	Adult	Ag	Green nanosynthesis, extract of *Euphorbia prostrata*	2.30 mg/l	–	Zahir and Rahuman (2012)
Rhipicephalus microplus	Larva	Ag	Green nanosynthesis, extract of *Manilkara zapota*	16.72 mg/l	–	Rajakumar and Rahuman (2012)
Rhipicephalus microplus	Larva	Ag (low AgCl presence)	Green nanosynthesis, extract of *Cissus quadrangularis*	50.00 mg/l	–	Santhoshkumar et al. (2012)
Haemaphysalis bispinosa	Larva	AgCl	Nanosynthesis using the marine actinobacterium *Streptomyces* sp. LK3	16.45 mg/l		Karthik et al. (2014)
Rhipicephalus microplus	Larva	AgCl	Nanosynthesis using the marine actinobacterium *Streptomyces* sp. LK3	16.10 mg/l		Karthik et al. (2014)
Rhipicephalus microplus	Larva	Ag	Neem coating of Ag nanoparticles	35.40 ppm	–	Avinash et al. (2017)
Rhipicephalus microplus	Adult	Ag	Neem coating of Ag nanoparticles	261.08 ppm	8.02 ppm	
Rhipicephalus microplus	Larva	Ag	Delthametrin-neem coating of Ag nanoparticles	3.87 ppm	–	
Rhipicephalus microplus	Adult	Ag	Delthametrin-neem coating of Ag nanoparticles	21.95 ppm	0.034 ppm	
Rhipicephalus microplus	Larva	Ag	2, 3 Dehydrosalannol coating of Ag nanoparticles	14.42 ppm	–	
Rhipicephalus microplus	Adult	Ag	2, 3 Dehydrosalannol coating of Ag nanoparticles	298.07 ppm	37.09 ppm	
Rhipicephalus microplus	Larva	Ag	Quercetin dihydrate coating of Ag nanoparticles	22.6 ppm	–	
Rhipicephalus microplus	Adult	Ag	Quercetin dihydrate coating of Ag nanoparticles	454.13 ppm	76.55 ppm	
Rhipicephalus microplus	Larva	Cu	Polyol process from copper acetate as precursor and capping Tween 80	14.14 mg/l	–	Ramyadevi et al. (2011)
Rhipicephalus microplus	Larva	Ni	Polyol process from Ni-hydrazine as precursor and capping Tween 80	10.17 mg/l	–	Rajakumar et al. (2013)
Hyalomma anatolicum	Larva	Ni	Polyol process from Ni-hydrazine as precursor and capping Tween 80	10.81 mg/l	–	
Haemaphysalis bispinosa	Adult	TiO_2	Green nanosynthesis, extract of *Calotropis gigantea*	35.22 mg/l	–	Marimuthu et al. (2013)
Rhipicephalus microplus	Larva	TiO_2	Green nanosynthesis, extract of *Calotropis gigantea*	24.63 mg/l	–	
Hyalomma anatolicum	Larva	TiO_2	Green nanosynthesis, extract of *Solanum trilobatum*	25.85 mg/l	–	Rajakumar et al. (2014)
Rhipicephalus microplus	Larva	TiO_2	Green nanosynthesis, extract of *Mangifera indica*	28.56 mg/l	–	Rajakumar et al. (2015)
Hyalomma anatolicum	Larva	TiO_2	Green nanosynthesis, extract of *Mangifera indica*	33.17 mg/l	–	
Haemaphysalis bispinosa	Larva	TiO_2	Green nanosynthesis, extract of *Mangifera indica*	23.81 mg/l	–	
Rhipicephalus microplus	Adult	ZnO	Green nanosynthesis, extract of *Lobelia leschenaultiana*	1.7 mg/ml	–	Banumathi et al. (2016)
Rhipicephalus microplus	Larva	ZnO	Wet chemical route	13.41 mg/l	–	Kirthi et al. (2011)
Rhipicephalus microplus	Larva	ZnO	Green nanosynthesis, extract of *Momordica charantia*	6.87 mg/l	–	Gandhi et al. (2017)