ANIMAL HUSBANDRY & VETERINARY SCIENCE | RESEARCH ARTICLE

Larvicidal effectiveness of aqueous extracts of Solanum incanum L. (Solanaceae) against Boophilus decoloratus (Acari: Ixodidae) cattle tick larvae

Desta Berhe Sbhatu\textsuperscript{1}, Haftom Baraki Abraha\textsuperscript{1,4}, Gebreselema Gebreyohannes\textsuperscript{1} and Gebremariam Miruts Demewoz\textsuperscript{2}

Abstract: Livestock tick infestation and tick-borne diseases cause significant loss in the livestock sector. This problem is especially severe for livestock owners in developing countries who have limited or no access to modern veterinary information and services. Therefore, the use of medicinal plant-based formulations is better alternatives for tick control. Solanum incanum L. is one of the medicinal plants used against livestock tick infestation in Ethiopia. However, limited efforts were made to investigate the larvicidal effects of extracts of the plant against the larvae of the most common tick species. This study reports the larvicidal effects of crude aqueous extracts of the aboveground parts of S. incanum L. against Boophilus decoloratus. Fruit, leaf, and stem extracts were effective in killing B. decoloratus larvae at 5%, 10%, 20%, and 40% (w/v) concentration after 24 and 48 hrs of treatment. Fruit crude aqueous extract at 40% (w/v) concentration resulted in the highest mortality rate after 24 (92.0 ± 6.3) and 48 hours (97.6 ± 2.1) (p ≤ 0.05). The larvicidal effects of crude leaf extract (at 20 and 40% (w/v)) were also high. The fact that leaf crude

ABOUT THE AUTHOR

HB Abraha, DB Sbhatu, and G Gebreyohannes are faculty members of Mekelle University, Tigrai, Ethiopia. GM Demewoz is a trained veterinarian (DVM) and a livestock development expert in the Tigrai Bureau of Agriculture and Natural Resources. HB Abraha is now PhD fellow at the Chonbuk National University, South Korea. He studied plant biotechnology and is now studying for his PhD in Food Science and Technology (Bioinformatics). DB Sbhatu is an associate professor engaged in teaching, research, and service in biosciences, biotechnology and STEM education. He researches on the propagation of ecologically and economically important plants and characteristics of their secondary metabolites in formulating useful products. G Gebreyohannes is an assistant professor and researches on active ingredients of plants and mushrooms against pathogenic bacteria. GM Demewoz is a trained veterinarian working on the control of animal parasites. The researchers came together to conduct this study by synergizing their expertise towards solving a locally relevant problem.

PUBLIC INTEREST STATEMENT

The use of fruit extracts of Solanum incanum in tick control is commonly reported. However, there is no evidence that suggests that this ethnoveterinary knowledge and practice is widely known by many local farmers and pastoralists. And yet, since the lifestyles of the new generations of farmers and pastoralists are changing due to socioeconomic and cultural developments, this ethnoveterinary knowledge can be lost before it is scientifically verified and documented. Moreover, where only fruit extracts are used in tick control, livestock owners will be obliged to find other alternatives or incur the damage during non-fruiting seasons. By virtue of its finding that showed that leaves are good sources of extracts for formulating effective portions for tick control, this study assists livestock owners and local extension agents in managing tick infestation of their animals. The finding can be disseminated and documented as part of ethnoveterinary knowledge in the study area and beyond.

© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.
extracts have resulted in high larvicidal effects opens ample opportunities for livestock owners to use the leaves in preparing formulations for tick control throughout the year. Studies aiming at elucidating the biocidal properties, phytochemical constituents, medicinal and pharmaceutical potential, industrial applications, and effective conservation strategies can help in establishing a comprehensive profile and mechanisms of sustainable use of the plant.

**Subjects:** Entomology; Agriculture; Entomolog

**Keywords:** Aqueous extracts; Boophilus decoloratus; larvicidal activities; Solanum incanum L

1. **Introduction**

Livestock are important sources of livelihoods and revenues worldwide. They are highly valued in Ethiopia and the greater East African region for their products such as meat, milk, hide, skin and dung as well as for their services as draught animals (Asresie & Zemedu, 2015; Herani et al., 2008; Wesonga et al., 2010). However, livestock production is constrained by myriads of problems. This is especially true for small-scale, traditional livestock owners. Ticks infestation is one of the critical constraints affecting livestock production and productivity. Ticks are blood-sucking ectoparasites of mammals, birds and reptiles. They cause direct loss of animal biomass through blood sucking and injury, and by transmitting several protozoal, bacterial and viral diseases such as babesiosis, theileriosis, ehrlichiosis, and anaplasmosis (Bazarusanga et al., 2007; Nana, 2010; Teglas et al., 2005; Wesonga et al., 2010).

Livestock tick infestation is often controlled by chemotherapy with the help of synthetic acaricides (Li et al., 2007). However, synthetic acaricides have many critical limitations. They have slow natural degradation rates, produce non-degradable residues with adverse effects to the environment, cause the development of resistant strains of ticks, poison operators if sufficient care is not done, and are unaffordable for small-scale holders (Miller et al., 2005; Oliveira-Perez et al., 2011; Undeger & Basaran, 2005). These limitations justify for efforts that aim at identifying alternative mechanisms of tick control.

The use of safer and cheaper potions of plant extracts is common by small-scale livestock keepers of developing countries to prevent continuous and seasonal outbreaks of tick infestation and tick-borne diseases (Robert et al., 2010). Ethiopian livestock keepers and farmers are not exceptions. They are not economically endowed and technically knowledgeable to seek veterinary information and services. Therefore, many of them depend on plant extracts to treat their livestock to control tick infestation. Several studies showed that acaricidal botanicals are more effective, cheaper, and easier to use for small-holder farmers and pastoralists than conventional synthetic acaricides (Mwale et al., 2005; Wanzala et al., 2005).

Fruit extract of **Solanum incanum** L. (Solanaceae) is one of the botanicals used in preparing potions to control livestock ticks by farmers and pastoralists in Ethiopia (Regassa, 2000). *S. incanum* is a non-cultivated, multi-purpose plant with several traditional applications in many Ethiopian communities. The species is native to and widely distributed in the Horn of Africa. It has thorny leaves, yellow fruits, and blue flowers with yellow pistils (Abebe et al., 2014). The plant propagates by seeds, and the seeds germinate slowly. It grows around rural houses, overgrazed grasslands, wastelands, road sides, and farmlands (Teijo, 2004).

Five hard (ixodid) tick taxa; namely, the genera of *Amblyomma*, *Haemaphysalis*, *Hyalomma*, and *Rhipicephalus* and subgenus Boophilus are most common in Ethiopia (Lefebvre et al., 2010). Similarly, of the 47 tick species reported in the country, *Amblyomma variegatum* (A. variegatum), *A. gemma*, *A. cohaerens*, and *Boophilus decoloratus* are the most important livestock parasites (Kumsa et al., 2016, 2015; Mekonnen et al., 2001). Several survey studies conducted in many parts of Ethiopia showed that *A. variegatum* and *B. decoloratus* are the most widely distributed parasites of livestock (Degefa et al., 2018;
Eshetu, 1988; Hadgu et al., 2018; Kebede, 2004; Kiros et al., 2014; Mekonnen et al., 2007; Mesele, 1989; Morel, 1980; Pegrarn et al., 1981; Werede & Afera, 2014). Thus, the aim of this study was to assess the efficacy of crude aqueous fruit, leaf and stem extracts of S. incanum (Solanaceae) in killing the larvae of B. decoloratus ticks (Acar: Ixodidae) (also called Rhicephalus decoloratus, Rhipicephalus (B.) decoloratus, and Rhipicephalus decoloratus).

The study was carried out based on the following five rationales. (a) The use of S. incanum fruit extract in tick control is commonly reported. However, there is no evidence that suggests that this ethnoveterinary knowledge and practice are widely known by Ethiopian farmers and pastoralists. (b) The lifestyles of the new generations of Ethiopian farmers and pastoralists are changing due to socioeconomic and cultural developments. This leads to the loss of ethnoveterinary knowledge before it is scientifically verified and documented (Mathias, 2004). (c) Where only fruit extracts are used in tick control, livestock owners will be obliged to find other alternatives or incur the damage during non-fruited seasons. There is no empirical evidence or traditional knowledge about the use of leaf and stem extracts for tick control. (d) There is no empirical research that established the biocidal efficacy of S. incanum plant extracts against the B. decoloratus tick larvae. (e) The experimental evidence generated by the present study can serve as a foundation for developing standardized tick control procedures, investigating the medicinal and pharmaceutical potential of the plant, and putting strategies for its conservation and sustainable use.

2. Materials and methods

2.1. Study lab and field location
Laboratory research was conducted in the Veterinary Parasitological Lab of the College of Veterinary Science at Kellamino Campus, Mekelle University. S. incanum specimens were collected from Gola’a-Genahti area, northeast of Adigrat city (lat./long.: 14.307/39.473; alt.: 2,447) and Romanat area, northwest of Mekelle city (lat./long.: 13.586/39.428; alt.: 1,921), Tigray, Ethiopia. Preliminary field test was carried out in Kellamino area (lat./long.: 13.447/39.463; alt.: 2,121) at the southern outskirts of Mekelle city, Tigray, Ethiopia. Likewise, the Boophilus decoloratus ticks for the laboratory research were collected from Kellamino area. The species was identified by the fourth author.

2.2. Collections and preparations of plant crude extracts
Fruiting S. incanum plants (Tigrinya: engula) were located in non-cultivated lands at Gola’a-Genahti and Romanat areas with the assistance of local farmers. The plants were conspicuous with purple flowers and green unripe and yellow ripe fruits (Abebe et al., 2014). The plant was verified using fresh specimens by a botanist. Ripe yellow fruits, healthy mature leaves, and mature stems were collected in January 2014. Collection of biological materials by natives (Ethiopians) for research is granted by Article 15, Clause 1 of the Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation of Ethiopia (No. 482/2006).

The fruit, leaf and stem specimens were sorted and cleaned off dust and dirt by washing with tap water. The leaves included meristematic shoot tips with unopened leaves. The stems were prepared by removing the leaves and green, soft shoot tips. The fruits were sliced for easy drying. Then, all the plant materials were placed on laboratory bench top and air-dried at room temperature. The dried plant materials were pulverized separately into powders with mechanical grinders and stored in airtight containers. For each plant part, four 400 mL homogenates were prepared by mixing the powders with distilled water at 5, 10, 20, and 40% (w/v) concentrations. Then, homogenates were kept for 48 hrs at room temperature (ca. 25°C) and filtered using muslin cloth to collect crude aqueous extract.

2.3. Collection of ticks and preparation of tick larvae
The study on the effects of S. incanum crude aqueous extracts in controlling B. decoloratus tick larvae started with on-field preliminary test. Tick-infested cattle were treated with S. incanum extract in their field to acquire preliminary information for conducting the in vitro anti-larvae study. Tick-infested body parts of the cattle were wetted (drenched) with the extract at four days interval.
The effects of the extracts were quick and the population of the ticks began to drop starting the second day of application. After the effectiveness of the extract was confirmed through the preliminary test, detailed anti-larvae tests were designed with *B. decoloratus* tick larvae.

In Ethiopia, *B. decoloratus* belongs to one of the five common tick taxa called subgenus *Boophilus*. (Walker et al., 2003). *B. decoloratus* ticks were collected from cattle in Kellamino area. Fully engorged female *B. decoloratus* ticks were collected into well-aerated paper box by hand picking from around the scrotum of oxen and udder of cows. The ticks were taken to the laboratory, washed with distilled water, and dried and kept in the paper box. A 1,000 mL Erlenmeyer flask, bedded with wet soil was prepared. The relative humidity (RH) of the flask was adjusted to 85%. Five fully engorged *B. decoloratus* ticks were put into the flask. The flask was tightly closed with fine wire mesh and placed in incubator at 28°C to encourage it to produce hundreds of eggs and larvae. The flask was inspected daily to find any eggs and larvae. Whereas eggs were observed after 15 days of incubation, larvae were observed after 21 to 28 days.

### 2.4. Experimental design

The effects of *S. incanum* crude aqueous extracts were tested on 14 to 21-days old *B. decoloratus* tick larvae. Four experimental, one positive control and one negative control treatments were prepared. The experimental treatments were prepared using 5, 10, 20, and 40% (w/v) extracts. Whereas the positive control was prepared using Amitraz (12.50% EC) diluted to 0.2% by adding tap water, the negative control was prepared using distilled water. Each treatment was replicated five times and each replicate had 80 mL content (i.e. extract, Amitraz, or distilled water) in 200 mL beaker.

For each treatment, five triangular pyramidal paper packets (with 4 cm × 4 cm × 4 cm bases) were prepared from 80 g A4 white papers. The papers were finely perforated with needle to allow aeration. Likewise, five Petri dishes were prepared. The paper packets and Petri dishes were labeled. Whatman No. 1 filter papers were finely shredded and placed onto each of the Petri dishes. Ten (10) mL aliquots were taken from the 80 mL contents in the 200 mL beakers and poured onto the labeled Petri dishes holding the shredded filter papers. The shredded filter papers were kept for 3 to 5 min to absorb the aliquots. Then, they were transferred onto labeled dry Petri dishes and air-dried.

Twenty five (25) tick larvae were collected from the Erlenmeyer flask and put onto the labeled Petri dishes holding the shredded and treated filter papers. The shredded filter papers and tick larvae were put into the pyramidal paper packets. Then, the paper packets were sealed by folding and stapling at the edges of their bases and incubated at 28°C and 85% RH at completely randomized fashion. Live and dead larvae were counted after 24 and 48 hrs incubation. Larvae capable of crawling or moving were considered live while those that do not crawl or move were considered as dead. Naturally, live *B. decoloratus* larvae are very active and would move in search of food. Acquired data were analyzed using inferential statistical methods and mean comparisons were made at *a priori* fixed p-value of ≤0.05.

### 3. Results and discussions

As indicated in Section 2.3, on-field preliminary test demonstrated that direct application *S. incanum* plant extract on infested parts of cattle caused a quick drop in tick concentration (population). Our laboratory study also showed that fruit, leaf, and stem aqueous extracts of the plant have strong larvicidal effect against *B. decoloratus* tick larvae. Data analysis using analysis of variance (ANOVA) showed that the different concentrations of aqueous plant extracts resulted in statistically significantly different mean mortality rates against the *B. decoloratus* tick larvae (p ≤ 0.05) (Table 1). Fruit aqueous extracts at 20 and 40% (w/v) resulted in high mean larvicidal activities both after 24 and 48 hrs of treatment (i.e., exposure). Fruit aqueous extract at 40% (w/v) concentration has caused statistically significantly highest mortality after 24 (92.0 ± 6.3) and 48 (97.6 ± 2.1) hrs (p ≤ 0.05; Table 1). Similarly, fruit crude extract at 20% (w/v) concentration caused statistically higher mortality after 24 (88.8 ± 5.9) and 48 (95.2 ± 3.3) hrs compared to 10% and 5% (w/v) concentrations. Leaf aqueous extracts also caused high larval mortality at 20 and 40% (w/v)
Table 1. Mean mortality rate of B. decoloratus tick larvae exposed to different concentrations of S. incanum crude aqueous extracts after 24 and 48 hours of exposure

| Treatments | Aqueous Fruit Extract | Aqueous Leaf Extract | Aqueous Stem Extract |
|------------|------------------------|----------------------|----------------------|
|            | 48 Hours | 24 Hours | 48 Hours | 24 Hours | 48 Hours | 24 Hours |
| 5% (w/v)   | 63.2 (3.3)a     | 46.4 (5.4)b     | 48.0 (6.3)a     | 40.0 (8.0)a     | 20.8 (4.4)e     | 7.2 (3.3)b     |
| 10% (w/v)  | 89.6 (6.1)c     | 80.8 (6.6)c     | 52.0 (10.2)d    | 44.8 (7.2)e     | 28.8 (5.1)cd   | 14.4 (3.5)cd   |
| 20% (w/v)  | 95.2 (3.3)c     | 88.8 (5.9)c     | 77.6 (6.1)c     | 70.4 (7.3)c     | 33.6 (7.3)cde  | 18.4 (8.3)cde  |
| 40% (w/v)  | 97.6 (2.1)cde   | 92.0 (6.3)cde   | 88.0 (7.5)cde   | 79.2 (6.6)cde   | 41.6 (10.0)cde | 26.4 (8.8)cde |
| Amitraz    | 100.0 (0.0)e    | 98.2 (2.5)cde   | 100.0 (0.0)e    | 99.2 (1.8)e     | 100.0 (0.0)e   | 99.2 (1.8)e   |
| Water      | 0.0 (0.0)e     | 0.8 (1.8)cde    | 0.0 (0.0)e     | 0.0 (0.0)e     | 0.0 (0.0)e    | 0.0 (0.0)e   |
| Mean       | 74.3         | 67.8         | 60.9         | 55.6         | 37.5         | 27.6         |
| CV (%)     | 3.6          | 6.7          | 10.1        | 10.8        | 16.8        | 20.3        |
| LSD        | 3.6          | 6.0          | 3.6         | 7.9         | 8.3         | 7.4         |

Means with different letter(s) in the same column are statistically significantly different at p ≤ 0.05; CV = Coefficient of Variance; LSD = Least Significant Different.

after 24 and 48 hrs of treatment. However, the effects of the stem aqueous extracts were lower. The larvicidal effect of 40% (w/v) fruit extract was statistically comparable to that of the synthetic acaricide Amitraz.

Increasing the concentrations of aqueous fruit extracts from 10% to 40% (w/v) and aqueous leaf extracts from 20% to 40% (w/v) both after 24 and 48 hrs of treatment brought about limited increase in the larval mortality rates (Table 2). Even though the larvicidal effects of aqueous leaf extracts are comparably lower than that of the fruit extracts, they have yielded high larval mortality both after 24 and 48 hrs of treatment ranging from 70.4 (± 7.3) to 88.0 (± 7.5) (Table 1). Likewise, aqueous stem extracts caused some degree of larval mortality.

Stem specimens that can be collected during the fruiting season was considerably hardened due to some degree of secondary growth. We believe that unhardened soft stems of the plant can yield enough extract with high larvicidal activities. These observations show that fruit and leaf extracts are effective for tick control at as low as 10% and 20% (w/v), respectively, after 24 to 48 hrs of treatment. These, in turn, lead us to state that the choice between fruits and leaves for preparing larvicidal formulations depends on the abundance or availability (of the plants parts) rather than on the type of the plant parts.

It is apparent that the larvicidal effects of the extracts of the plant parts depend, among other things, on concentration and the exposure time—where increasing the concentration and exposure time increases larval morality (Khudratulla & Joganath, 1998). Likewise, our on-field preliminary test on adult ticks demonstrated that exposure time increases acaricidal activity like the many studies reported by other workers (Khodadad & Mehdi, 2007; Wang et al., 2007; Zaman et al., 2012). However, our study showed that, at higher concentrations, increasing the exposure time from 24 to 48 hrs brings about small increase in the larval mortality rates.

Several studies explored into the acaricidal and larvicidal efficacy of extracts of many plant species and reported useful results. Crude leaf extract of Schinus molle (L) was found be effective against field population of B. decoloratus and Rhipicephalus pulchellus ticks (Feyera & Abdisa, 2016). Ethanol and methanol extracts of leaves of Synadenium glaucescens (Euphorbiaceae) also showed good larvicidal and acaricidal efficacy against B. decoloratus and B. microplus (Nyigo et al., 2016). Leaf extracts of Ricinus communis were effective against synthetic acaricide resistant strains of Rhipicephalus (B.) microplus (Ghosh et al., 2013). Extracts of many Solanum species were also reported to have high biocidal effects against B. microplus larvae (Rosado-Aguilar et al., 2010). Moreover, Aloe yavellana latex was report to be
Table 2. Differences in mean mortality rates of *B. decoloratus* tick larvae exposed to different concentrations of *S. incanum* aqueous extracts after 24 and 48 hrs of exposure

| Treatments | Aqueous Fruit Extract | Aqueous Leaf Extract | Aqueous Stem Extract |
|------------|-----------------------|----------------------|----------------------|
|            | 48 Hrs  | 24 Hrs  | Variation | 48 Hrs  | 24 Hrs  | Variation | 48 Hrs  | 24 Hrs  | Variation |
| 5% w/v     | 63.2    | 46.4    | 16.8      | 48.0    | 40.0    | 8.0       | 20.8    | 7.2     | 13.6      |
| 10% w/v    | 89.6    | 80.8    | 8.8       | 52.0    | 44.8    | 7.2       | 28.8    | 14.4    | 14.4      |
| 20% w/v    | 95.2    | 88.8    | 6.4       | 77.6    | 70.4    | 7.2       | 33.6    | 18.4    | 15.2      |
| 40% w/v    | 97.6    | 92.0    | 5.6       | 88.0    | 79.2    | 8.8       | 41.6    | 26.4    | 15.2      |
| Amitraz    | 100.0   | 98.2    | 1.8       | 100.0   | 99.2    | 0.8       | 100.0   | 99.2    | 0.8       |
very effective against *Amblyomma variegatum* tick larvae (Hailesilassie et al., 2018). Choudhury (2009) reported that 20 to 100% neem seed oil results in 100% mortality of *B. decoloratus* larvae in 24 to 27 hrs.

It is apparent that exposure to the biocidal constituents of plant extracts kills tick larvae and adults in many ways. In the present study, the larvae were kept in finely perforated pyramidal paper packets holding extract treated, finely shredded, and air-dried tissue paper. The perforation allows the free movement of air into the packets while restricting the escape of the larvae. As air (oxygen) movement was not hindered, the larvae were most likely killed by certain volatile biocidal constituents of the extract that enter into their vital systems by diffusion or inhalation, resulting in the obstruction of the vital activities of the systems.

*S. incanum* is an important source extracts with excellent biocidal effects against *B. decoloratus* larvae and adults. Fruit extract of *S. incanum* was effective against engorged female *B. decoloratus* (Regassa, 2000). Similarly, aqueous fruit extracts of the plant were found to be effective in killing the larvae of other tick species (Madzimure et al., 2013). The present study further demonstrated that all the aboveground parts of the plant are important sources larvicidal constituents against *B. decoloratus*. The fruit of the plant is the principal source of extracts for preparing acaricidal and larvicidal formulations (Madzimure et al., 2013; Nyahangare et al., 2015). However, since the use of fruits is seasonal (Nyahangare et al., 2015), the use of leaves and meristematic shoots not only solve the problem of seasonality of fruiting but also offers the opportunity to harvest abundant plant material for preparing sufficient volume of acaricidal formulations. In fact, several ethnobotanical studies carried out in Ethiopia and elsewhere reported about the common use of leaves in the preparation of remedies of human and animal ailments and anti-parasite formulations (Adefa & Getaneh, 2013; Alemayehu et al., 2015; Amenu, 2007; Nyahangare et al., 2015; Osman et al., 2020; Vineger & Yewhalaw, 2007).

4. Concluding remarks

Fruit, leaf and stem extracts of *S. incanum* were found to be good sources of alkaloids, saponins, flavonoids, glycosides, terpenoids, and steroids (Sbhato & Abraha, 2020). Aqueous and ethanol extracts of all the aboveground parts demonstrated biocidal effects against bacteria, tick, nematode and other species (Al-Marby, 2017; Almoulah et al., 2017; Haftom & Gebrehiwot, 2019; Madzimure et al., 2013; Sbhato & Abraha, 2020). This study showed that aqueous extracts of the aboveground parts of the plant are effective in killing *B. decoloratus* larvae. This finding will help small- and large-scale cattle owners as well as extension agents in developing better protocols of formulating acaricidal and larvicidal potions using the plant parts. The findings also open additional opportunities for livestock owners to use all aboveground parts of the plant. Moreover, the evidence generated by this study can serve as a foundation for developing standardized tick control protocols. Studies aiming at describing the biocidal properties, investigating the phytochemical constituents, elucidating the medicinal and pharmaceutical potential, exploring into its industrial applications, and placing effective strategies for conservation of the plant can help in establishing its comprehensive profile and strategies of its sustainable use.

Funding

Mekelle University, Ethiopia, has funded this research. The authors are very grateful for the funding; Mekelle University (NA).

**Author details**

Desta Berhe Sbhato¹

ORCID ID: [http://orcid.org/0000-0003-3602-1578](http://orcid.org/0000-0003-3602-1578)

Haftom Baraki Abraha¹

E-mail: haftom.baraki@mu.edu.et

Gebreselama Gebreyohannes¹

Gebremariam Miruts Demewoz²

¹ Department of Biological and Chemical Engineering, Mekelle Institute of Technology, Mekelle University, PO Box 1632, Mekelle, Ethiopia.

² Humera Branch, Tigray Bureau of Agriculture, Humera, Tigray, Ethiopia.

Availability of Data and Materials

The data used to support this study can be obtained from the corresponding author upon request.

Disclosure Statement

The authors declare no conflict of interest.

Citation information

Cite this article as: Larvicidal effectiveness of aqueous extracts of *Solanum incanum* L. (Solanaceae) against *Boophilus decoloratus* (Acari: Ixodidae) cattle tick larvae, Desta Berhe Sbhato, Haftom Baraki Abraha, Gebreselema
References

Albe, H., Gbreyohannes, G. & Gebremariam, M. (2019). In vitro antimicrobial activities of crude extracts of two traditionally used Ethiopian medicinal plants against some bacterial and fungal test pathogens. The International Journal of Biotechnology, 8(2), 104–114. https://doi.org/10.18488/journal.57.2019.82.104.114

Hodgu, M., Taddese, H., Girma, A., Abraha, H., & Hagos, H. (2018). Prevalence of ixodid ticks infesting Raya cattle breeds in Semi-arid areas of Raya Azebo district, northern Ethiopia. Ethiopian Veterinary Journal, 22(2), 53–64. https://doi.org/10.4314/evj.v22i2.5

Hollesilassie, T., Bisrat, D., & Asres, K. (2018). Larvicidal effects of the leaf latex of Aloe yovallana Reynolds and its major compounds against Amblyomma variegatum (Ixodidae). Veterinary Parasitology, 263, 23–26. https://doi.org/10.1016/j.vetpar.2018.09.015

Herani, G. M., Wasis, P., Rajar, W. A., & Shaikh, A. R. (2010). Livestock: A reliable source of income generation and rehabilitation of environment at Thrarparkar. MPRA Paper 8700, University Library of Munich, Germany.

Kebede, A. G. (2004). Seasonal dynamics of ticks (Amblyomma caharens and Boophilus decoloratus) and development of management plan for ticks and ticks borne diseases control in cattle in Jimma Zone, Southern Ethiopia [Unpublished Doctoral Dissertation]. Georg August University.

Khodadad, P., & Mehdii, R. (2007). Biological activities of chamomile (Matricaria chamomile) flowers' extract against the survival and egg laying of the cattle fever tick (Acari Ixodidae). Journal of Zhejiang University. Science. B, 8(9), 693–696. https://doi.org/10.1631/jzus.2007.B0693

Khadrathulla, M., & Jagannath, M. (1998). Biocontrol of ixodid ticks by forage legume Stylosanthes scabra (Vogel). Indian Journal of Animal Science, 68(5), 428–430.

Kiros, S., Awol, N., Tsegay, Y., & Hadush, B. (2014). Hard ticks of camel in Southern Zone of Tigray, Northern Ethiopia. Journal of Parasitology and Vector Biology, 6(10), 151–155. https://doi.org/10.5897/JPVB2014.0162

Kumsa, B., Laroche, M., Almeras, L., Medinnikov, O., Rouault, D., & Parola, P. (2015). Spotted fever group Rickettsiae in ixodid ticks in Oromia, Ethiopia. Ticks and Tick-Borne Diseases, 6(1), 8–15. https://doi.org/10.1002/ttbdis.2014.08.001

Lefebvre, P. C., Blancou, J., Chermette, R., & Uilenberg, G. (Eds.). (2011). Infectious and parasitic diseases of livestock (Vol. 1). Editions Tec & Doc.

Li, A., Chen, A., Miller, R., Davey, R., & George, J. (2007). Acaricide resistance and synergism between permethrin and omatriz against susceptible and resistant strains of Boophilus microplus (Acari: Ixodidae). Pest Management Science, 63(9), 882–889. https://doi.org/10.1002/ps.1417

Mathias, E. (2004). Ethnoveterinary medicine: Harnessing its potential. Veterinary Bulletin, 74(8), 27–37.

Mekonnen, S., Hussein, I., & Bedone, B. (2001). The distribution of ixodid ticks (Acari: Ixodidae) in central Ethiopia. Veterinary Research, 32, 135–142.
Ethiopia. Ondersteoogt Journal of Veterinary Research, 68(4), 243–251.
Mekonnen, S., Pegram, R., Gebre, S., Mekonnen, A., Jobre, Y., & Zewde, S. (2007). A synthesis review of Ixodid (Acari: Ixodidae) and argasid (Acari: Argasidae) ticks in Ethiopia and their possible roles in disease transmission. Ethiopian Veterinary Journal, 11(2), 1–22.
Mesele, A. (1989). Bovine Tick Survey in Bahir Dar Awraja. Unpublished DVM Thesis, Faculty of Veterinary Medicine, Addis Ababa University.
Miller, R., Davey, R. B., & George, J. (2005). First report of organophosphate-resistant Boophilus microplus (Acari: Ixodidae) within the United States. Journal of Medical Entomology, 42(5), 912–917. https://doi.org/10.1603/0022-2585(2005)042[0912:FROBM2.0.CO;2
Morel, P. (1980). Study on Ethiopia Ticks (Acarida, Ixodidea). Republic of France, Minister of Foreign Affairs, French Veterinary Mission, Addis Ababa, C.J.E. M.V.T. pp.7–332.
Mwale, M., Bhebhe, E., Chimonyo, M., & Hailamini, T. (2005). Use of herbal plants in poultry health management in the Mushongashne small-scale commercial farming area in Zimbabwe. International Journal of Applied Research in Veterinary Medicine, 3(2), 163–171. https://www.researchgate.net/publication/285501183
Nana, P. (2010). Potential of integrating Calpurnia aurea with entomopathogenic fungus Metarhizium anisopliae for the control of Rhipicephalus appendiculatus and Rhipicephalus pulchellus [Unpublished PhD Dissertation]. Jamo Kenyatta University of Agriculture and Technology.
Nyahangare, E. T., Mvumi, B. M., & Mutibvu, T. (2015). Ethnoveterinary plants and practices used for ectoparasite control in semi-arid smallholder farming areas of Zimbabwe. Journal of Ethnobiology and Ethnomedicine, 11(30), 1–16. https://doi.org/10.1186/s13002-015-0006-6
Nyigo, V. A., Mdegela, R. H., Malebo, H. M., Mabiki, F. P., & Fouche, G. (2016). Evaluation of acaricidal efficacy of Synadenium gracenscens (Euphorbiacea) against Boophilus species. Journal of Medical Plant Research, 10(23), 279–285. doi: 10.5897/JMPR2016.6099
Oliveres-Perez, J., Rojas-Hernandez, S., Valencia-Almezan, M., Gutierrez-Segura, I., & Mireles-Martinez, E. (2011). Prevalence of resistant strains of Rhipicephalus microplus to acaricides in cattle ranch in the tropical region of Tecpan de Galeana, Guerrero, Mexico. Pakistan Veterinary Journal, 31, 366–368.
Osman, A., Sbhatu, D. B., & Giday, M. (2020). Medicinal plants used to manage human and livestock ailments in Koye Kobo District of Amhara Regional State, Ethiopia. Evidence-Based Complementary and Alternative Medicine, 2020, Article ID 1329170. https://doi.org/10.1155/2020/1329170
Pegram, R., Hoogstraal, H., & Wasson, H. (1981). Ticks (Acari: Ixodidae) of Ethiopia: Distribution ecology and host relationship of species infecting livestock. Bulletin of Entomology Research, 71(2), 339–359. https://doi.org/10.1017/S0007485300008173
Regassa, A. (2000). The use of herbal preparations for tick control in western Ethiopia. Journal of the South African Veterinary Association, 71(4), 240–243. https://doi.org/10.4102/jsava.v7i4.722
Robert, O., Akol, A., & Okello, O. (2010). Ethnoveterinary botanicals used for tick control in the Acholi Subregion of Uganda. Journal of Animal Veterinary Advancement, 9(23), 2951–2954. https://doi.org/10.3923/java.2010.2951.2954
Rosado-Aguilar, J. A., Aguilar-Caballero, A. J., Rodriguez-Vivas, R. I., Rogers-Arteaga, R., Garcia-Vazquez, Z., & Mendez-Gonzalez, M. (2010). Screening of the acaricidal efficacy of phytochemical extracts on the cattle tick Rhipicephalus (Boophilus) microplus (Acari: Ixodidae) by larval immersion test. Tropical and Subtropical Agroecosystems, 12(2), 417–422. http://www.revista.ccba.uady.mx/urn:ISSN:1870-0462-tsae.v12i2.358
Sbhatu, D. B., & Abraha, H. B. (2020). Preliminary antimicrobial profile of Solanum incanum L.: A Common medicinal plant. Evidence-Based Complementary and Alternative Medicine, 2020, Article ID 3647065. https://doi.org/10.1155/2020/3647065
Teglas, M., Matern, E., Lein, S., Foley, P., Mahon, S., & Foley, J. (2005). Ticks and tick-born disease in Guatemalan cattle and horses. Veterinary Parasitology, 131(1), 119–127. https://doi.org/10.1016/j.vetpar.2005.04.033
Tejo, Y. (2004). Extraction and planar chromatographic separation techniques in the analysis of natural products. Master’s Thesis, University of Helsinki, Helsinki, Finland.
Undeger, U., & Basaran, N. (2005). Effects of pesticides on human peripheral lymphocytes in vitro: Induction of DNA damage. Archives of Toxicology, 79(3), 169–176. https://doi.org/10.1007/s00204-004-0616-6
Walker, A., Bouattour, A., Cancias, J., Estrada-Pena, A., Horak, I., & Latif, A. (2003). Ticks of domestic animals in Africa: A guide to identification of species. The University of Edinburgh.
Wang, Y., Shi, G., Zhao, L., Liu, S., Yu, T., Clarke, S., & Sun, S. (2007). Acaricidal activity of Juglans regia leaf extracts on Tetranychus viennensis and Tetranychus cinnabarinus (Acari: Tetranychidae). Journal of Economic Entomology, 100(6), 1298–1303. https://doi.org/10.1603/0022-0493(2007)100[1298:AAOJRL]2.0.CO;2
Wanzala, W., Zessin, H., Kyule, M., Baumann, O., Mathias, E., & Hassanali, A. (2005). Ethnoveterinary medicine: A critical review of its evolution, perception, understanding and the way forward. Livestock Research for Rural Development, 17, Article No.: 119.
Werde, H., & Afera, B. (2014). Prevalence of ixodid ticks on bovine of Werieleke Wereda, Tigray. Acta Paradigraphica Globalis, 5(2), 146–150. doi: 10.5829/idosi.2014.5.2.8541
Wesonga, F., Kitanya, P., Gathuma, J., Njenga, M., & Ngumi, P. (2010). An assessment of tick-borne diseases constraints to livestock production in smallholder livestock production system in Machakos District, Kenya. Livestock Research for Rural Development, 22(4), Article No.: 111. http://www.lrd.org/lrrd22/4/woeso22111.html
Yineger, H., & Yewhalaw, D. (2007). Traditional medicinal plant knowledge and use by local healers in Sekouro District, Jimma Zone, Southwestern Ethiopia. Journal of Ethnobiology and Ethnomedicine, 3(1), Article No.: 24. https://doi.org/10.1186/1746-4269-3-24
Zaman, M., Ijebi, Z., Abbas, R., Khan, M., Muhammad, G., Younus, M., & Ahmed, S. (2012). In vitro and in vivo acaricidal activity of herbal extract. Veterinary Parasitology, 186(3–4), 431–436. https://doi.org/10.1016/j.vetpar.2011.01.018
