



CONTROL of *Meloidogyne incognita* and *Pratylenchus zae* USING *Embelia schimperi* EXTRACTS †

[CONTROL de *Meloidogyne incognita* y *Pratylenchus zae* USANDO EXTRACTOS de *Embelia schimperi*]

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SUMMARY

Background. Some secondary metabolites found in plants have been used to control pests and pathogens. The plant *Embelia schimperi* contains complex compounds that can be used to biosynthesize agrochemicals for the control of plant-parasitic nematodes. **Objective.** This work analysed the phytochemical profile of the *E. schimperi* plant and assessed the biological potential of its crude extracts. **Methodology.** The phytochemicals were extracted in three solvents: ethanol, dichloromethane, and hexane, utilising maceration and ultrasonication procedures. **Results.** These solvents performed well in extracting flavonoids, phenolics, terpenoids, tannins, and saponins, according to the findings. **Implication.** The root-knot nematode *Meloidogyne incognita* can be inhibited from hatching, and the lesion nematode *Pratylenchus zae* can be killed as a result of these chemicals' bioassay activities. **Conclusion.** Plant-parasitic nematode may be controlled with crude extracts from this plant, which can be processed into a botanical insecticide.

Keywords: *Embelia schimperi*; plant-parasitic nematodes; botanicals.

RESUMEN

Antecedentes. Algunos metabolitos secundarios encontrados en las plantas se han utilizado para combatir plagas y patógenos. La planta *Embelia schimperi* contiene compuestos complejos que pueden usarse para biosintetizar agroquímicos para el control de nematodos fitoparásitos. **Objetivo.** Este trabajo analizó el perfil fitoquímico de la planta de *E. schimperi* y evaluó el potencial biológico de sus extractos crudos. **Metodología.** Los fitoquímicos se extrajeron con tres disolventes: etanol, diclorometano y hexano, utilizando procedimientos de maceración y ultrasonidos. **Resultados.** Estos solventes funcionaron bien en la extracción de flavonoides, fenólicos, terpenoides, taninos y saponinas, según los hallazgos. **Implicación.** Se puede inhibir la eclosión del nematodo agallador *Meloidogyne incognita*, y el nematodo lesionador *Pratylenchus zae* puede morir como resultado de las acciones de bioensayo con estos productos químicos. **Conclusión.** El nematodo parásito de las plantas se puede controlar con extractos crudos de esta planta, que se pueden procesar en un insecticida botánico.

Palabras clave: *Embelia schimperi*; nematodos parásitos de plantas; insecticidas herbales.

INTRODUCTION

Plant-parasitic nematodes have become ubiquitous in agricultural fields and controlling them is expensive. Farmers are unaware of the nematode problems; therefore, they use inadequate management practises that, in addition to increasing production expenses result in severe yield losses (Abd-Elgawad and Askary, 2015). Furthermore, most agricultural systems in Kenya have a significant diversity of plant-parasitic nematodes, according to research (Coyne *et al.*, 2018, Mwangi *et al.*, 2014). For example, *Meloidogyne incognita* and *Pratylenchus zae* are common in Kenya and are

anticipated to cause yield losses of up to 5%, equivalent to US\$ 157 billion (Singh and Kumar, 2015, Sardari *et al.*, 2015). There is a lack of an effective management plan that is appropriate for Kenyan agro-ecological systems.

Synthetic nematicides have previously been used to control plant-parasitic nematodes. Chemical nematicides, on the other hand, have been withdrawn or restricted due to public knowledge of the hazards they present to the environment and human health. Because of their ozone-depleting qualities, methyl bromide and aldicarb nematicides have been prohibited under the Montreal Protocol (Nyczepir and Thomas,

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2009). To address the concerns related to the extensive usage of conventional nematicides, eco-friendly and less hazardous nematode control solutions should be found.

Plants are a great source of novel ecologically friendly compounds that could be used to control nematodes. Many phytochemicals with a variety of structures have been extracted from a variety of higher plants, and their nematode-killing abilities have been tested against a variety of nematode species (Khan *et al.*, 2019, Faria *et al.*, 2016, Ntalli and Caboni, 2012, Chitwood, 2002). The use of innovative and safe plant products with minimal toxicity, particularly the utilisation of phytochemicals naturally generated by plants, has been advocated as a possible alternative to the negative effects of synthetic nematicides (Seo *et al.*, 2014).

The Maasai people of Kenya and Tanzania use extracts from the *Embelia schimperi* (L.) plant, which belongs to the Myrsinaceae family, to eradicate adult *Taenia saginata*, also known as the beef tapeworm (Murthy and Joseph, 2011). The plant contains embelin (2, 5- dihydroxy-3-undecyl-1, 4-benzoquinone), a quinone derivative with antihelmintic and antibacterial properties (Bøgh *et al.*, 1996). The ethno-anthelmintic and antibacterial characteristics of the Myrsinaceae family of plants are well-known. In Kenya, five species of Myrsinaceae have been utilised in ethnopharmacology to control illnesses and pests by diverse ethnic groups. The use of plant extracts from these plant species is commonly passed down the generations. Indigenous knowledge must be combined with modern technology, particularly in the realms of extract extraction, standardisation, and biological analysis.

Furthermore, there is no information on the potential of *E. schimperi* extracts in management of plant-parasitic nematodes. In the current work, the phytochemicals contained in *E. schimperi* extracts were profiled in order to identify the phytochemicals present and evaluate the crude extracts' in-vitro nematicidal effectiveness against plant parasitic nematodes.

MATERIAL AND METHODS

Sample collection, drying and grinding

Embelia schimperi samples used in this study were collected from the western slopes of Mau ecosystem in Kericho County, Kenya (Location 00°20.133' S and 035°22.434' E; Elevation 2,400 m). The samples were cleaned of any necrotic parts, rinsed using tap water, stocked in sacks and transported to the Chemistry and Biochemistry Laboratory of Moi University for extraction of phytochemicals. The stem barks

were used in the extraction of phytochemicals. The samples were dried under laboratory conditions (18±2°C) for three weeks, cut into small pieces and ground using a nutribullet blender into fine powder which was later sieved using a 105 µm sieve. This powder was stored in khaki brown paper bags at room temperature until further use.

Extraction of phytochemicals

Three organic solvents were used for extraction: hexane, dichloromethane (DCM), and ethanol. Hexane was chosen due to its low polarity, dichloromethane for its medium polarity, and ethanol for its high polarity. The two most common extraction procedures were maceration and ultrasonication. In a conical flask, 100 mL of each solvent were added to 20 g of dry powder in each extraction procedure (Ginovyian *et al.*, 2017). Flasks were wrapped with aluminium foil and kept at room temperature for 72 hours with frequent shaking in the maceration process. The extracts were filtered through Whatman filter papers (no 1) and the filtrate rota-evaporated under reduced pressure at a maximum temperature of 25°C to remove the solvents. Afterwards, the dry compounds were reconstituted using the same solvents and stored at room temperature until further use.

For ultrasonication method, the ground powder of the stem barks of *E. schimperi* were further ground into fine powder using a Disc Mill Model – FFC 23 and homogenized. The homogenized samples were freeze dried and added into conical flasks. A mixture of the ethanol, dichloromethane and n- hexane solvents were added into the conical flasks. The flasks were connected to the condenser and immersed in the ultrasonic water bath with automatic temperature controller. Oxygen free nitrogen gas flowed through the condenser to minimize oxidation, isomeration and degradation of crude extract during processing. The sonication was done for 10, 20, 30 and 40 min at room temperature. After extraction, the flasks were removed and cooled to room temperature and the mixture filtered. One millilitre of ultrapure water was added to the filtrate and centrifuged to provide distinct separation of the sample phases.

Phytochemical screening and quantification

This test was performed to determine the different classes of compounds present in the extracts. The targeted classes of compounds were phenols, steroids, cardiac glycosides, tannins, saponins, alkaloids, terpenoids and flavonoids. The methodology applied for determination of the different compounds is summarized in Table 1. These phytochemicals were confirmed by colour changes.

Table 1. Methods applied in analysis the different classes of compounds present in *Embelia schimperi* extracts.

Class of compounds	Methodology	Indicator	Reference
Saponins	A volume of 5 ml of each extract (ethanol, DCM and hexane) was added to 5ml of distilled water and shaken vigorously for 15 minutes. The extract was allowed to stand for another 10 minutes before analysing the results.	Formation of a 1-cm foam indicates the presence of saponins.	Thilagavathi <i>et al.</i> , 2015
Glycosides	3-4 drops of ferric acid, acetic acid and sulphuric acids were successively added to 1 ml of each extract (hexane, DCM and ethanol) while gently shaking.	A colour change from blue to green indicates the presence of glycosides.	Rao <i>et al.</i> , 2016
Tannins	5 ml of each extract (hexane, DCM and ethanol) was added to 2 ml of 5% FeCl ₃ solution and gently shaken until a change of colour was detected.	A change of colour from green to black indicates the presence of tannins.	Rao <i>et al.</i> , 2016
Flavonoids	1 to 5 drops of concentrated hydrochloric acid (HCl) were added into 1 ml of each extract (hexane, DCM and ethanol) while gently shaking.	Formation of red colour indicates the presence of flavonoids.	Rao <i>et al.</i> , 2016
Steroids	A volume of 10 ml of chloroform was added to 2 ml of each extract (hexane, DCM and ethanol) and gently shake. Later 1 ml of acetic hydrant and 2ml of sulphuric acids were added successively.	A colour change from blue to green indicates the presence of steroids	Thilagavathi <i>et al.</i> , 2015
Alkaloid	The presence of alkaloids was determined by stirring 1ml of active solvent extract (hexane, DCM and ethanol) with 1ml of 1% HCl on a steam bath and adding 2–3 drops of Wagner's reagent.	The appearance of orange to red precipitate indicates the presence of alkaloids.	Thilagavathi <i>et al.</i> , 2015
Terpenoids	A layer was formed by carefully adding concentrated H ₂ SO ₄ (3ml) to 0.2g of extract (hexane, DCM and ethanol) in 2ml of chloroform.	A reddish-brown coloration of the interface indicates the presence of terpenoids.	Das <i>et al.</i> , 2014
Phenolics	The presence of phenolics was determined using the Phthalein Dye Test. Phenol was heated with phthalic anhydride in the presence of concentrated sulfuric acid, it condenses and forms phenolphthalein.	The presence of phenolphthalein indicates the presence of phenolics	Waterhouse, 2002

Quantification of phytochemicals

i. Total Phenolic Content using Folin-ciocalteu method

An aliquot of 0.5 ml of the extract (hexane, DCM and ethanol) was mixed with 2.5 ml of 10% folin reagent and 2.5 ml of 15% Sodium carbonate, mixture incubated at 25 °C for 20 minutes in the dark and the absorbance recorded using a Beckham coulter DU 720 UV/VIS spectrophotometer at a fixed wavelength of 725 nm.

A 1000µg/ml stock solution of gallic acid was prepared from which serial dilutions of 20 µg/ml, 40 µg/ml, 75 µg/ml, 100 µg/ml, and 125 µg/ml, were prepared. The results were expressed as mg gallic acid equivalent (GAE) per gram of extract based on the standard curve of gallic acid (Blainski and De Mello 2013).

ii. Total flavonoid content (TFC)

An aliquot of 1.0ml of the extract (hexane, DCM and ethanol) of different concentrations (10 µg/ml, 20 µg/ml, 40 µg/ml, 80 µg/ml and 100 µg/ml) was taken in a test tube, 3 ml of methanol added, 200 µl of 10 % aluminum chloride and potassium acetate were added into the test tube. Distilled water was added into the test tube and then samples incubated at 25 °C for 30 minutes to complete the reaction. The absorbance of solution was measured at 420 nm. The flavonoid content of the extract was expressed as a mg of quercetin equivalent/gm of dried extract (Da Silva and Soares 2015).

iii. Total tannins content

Total tannins content was determined using Folin Ciocalteu method. To achieve this 0.1 ml of hexane, DCM and ethanol extract was added with 7.5 ml of distilled water, 0.5 ml of Folin Phenol reagent, 1 ml of 35% sodium carbonate solution and diluted to 10 ml with distilled water. The mixture was shaken evenly and stored at room temperature for 30 mins. Absorbance was measured at 725 nm. The results of tannins content are expressed in terms of gallic acid mg/g of extract (Solihah *et al.*, 2012).

Culturing and extraction of plant-parasitic nematodes

The root-knot nematode *M. incognita* was cultured on the susceptible tomato plants (cv. money maker) while cultures of the lesion nematode *P. zoeae* were maintained on carrot discs (Coyne *et al.*, 2014). For extraction of *M. incognita*, roots of tomato plants were washed clean using tap water and cut into small pieces.

The roots were transferred into a kitchen blender containing 30 ml of 5% sodium hypochlorite solution and blended for 3 to 4 minutes at maximum speed. The obtained solution with the nematode eggs was sieved through 250 µm and 25 µm sieves before transfer into falcon tubes. *Pratylenchus zoeae* juveniles were gently washed from carrot discs using tap water as described by Coyne *et al.*, (2014). A dissecting microscope was used to estimate the density of *P. zoeae* juveniles and *M. incognita* eggs.

In-vitro nematocidal activity tests

Stock solutions were prepared from 1 g of the extracts dissolved in 10 ml of 10% (10 ppm) dimethyl sulphoxide (DMSO). The stock solutions were then diluted to obtain concentrations of 2.5 ppm, 5.0 ppm, 7.5 ppm and 10 ppm (Pavaraj *et al.*, 2012). The nematocidal effect of crude extracts on *P. zoeae* juveniles and *M. incognita* eggs was tested in the laboratory. DMSO was used as a control. The solutions were then transferred into sterile 96-well plates. Each well contained 100 µl of DMSO or the extract solution and 20 eggs. The treatments were replicated three times at room temperature. Hatched juveniles from the eggs were counted after 24, 48, 72 and 96 hrs. The toxicity of crude extract was determined by calculating the mean percentage of hatched eggs.

The effects of the crude extract on *M. incognita* and *P. zoeae* juveniles were determined distinctly after 24, 48, 72 and 96 hrs. With the use of 50µl of 1 N NaOH, dead or alive *P. zoeae* juveniles were recorded. Live nematodes changed shape from straight to curl or hook shaped within 30 seconds. Nematodes that changed their body form in response to NaOH within 3 minutes were regarded alive, while those that did not respond within 3 minutes and remained stationary were assumed to be dead (Chen and Dickson, 2000).

Data analysis

Data on the number of hatched juveniles from the eggs or the dead/live nematodes was analysed using SPSS software (version 21). The mean difference between treatments was calculated using two-way factorial ANOVA based on completely randomized design (to evaluate the interaction between concentrations, plant crude extracts and time), followed by Tukey post hoc tests and differences were considered significant when $p < 0.05$.

RESULTS AND DISCUSSION

The study's specific objectives were to extract components of the *Embelia schimperi* plant, as well as to assess their biological activity. The

findings show that this plant species includes a diverse range of chemicals. Importantly, both extraction techniques found presence of tannins, alkaloids, flavonoids, saponins, and phenolic compounds; however, the amounts recovered varied depending on the extraction method. Terpenoids, cardiac glycosides, and steroids could not be extracted using either solvents or extraction procedures. When the maceration extraction procedure was used, the alkaloids were not detected in the hexane or DCM solvents (Table 2).

Secondary metabolites are an important defence mechanism in plants against pathogenic organisms and pests (Tembo *et al.*, 2018). Mekonnen *et al.*, (2018) found considerable amounts of phenolic in *Euclea schimperi* leaf extracts, a close species of *Embelia schimperi*. In addition, ethanol and dichloromethane showed the best extraction capacity, particularly for low and high molecular weight phenolic, flavonoids, tannins, alkaloids and saponins chemicals. According to several studies, an aqueous combination of acetone, methanol and ethanol has a higher extraction capability for these chemicals. Methanol extract displayed highest level of phenolic content and it shares high polarity with ethanol.

E. schimperi crude extracts significantly inhibited the hatching of *M. incognita* juveniles from the eggs at all dosages. After 24 hours, the control, dimethyl sulfoxide, had the greatest hatching percentage (45 percent). Compared to dichloromethane and hexane extracts, ethanol extract was the most efficient in limiting egg hatchability ($P = 0.0001$). Table 3 shows that the highest concentration of extracts (10 ppm) had the lowest hatchability of 6.67 percent, 8.83 percent, and 15 percent in ethanol, dichloromethane, and hexane, respectively,

whereas the lowest concentration (2.5 ppm) had the highest hatchability of 13.33 percent, 21.67 percent, and 18.33 percent in ethanol, dichloromethane, and hexane, respectively, 24 hours after treatment.

Phytochemicals such as phenolics and flavonoids have previously been shown to have nematicidal activities (Chin *et al.*, 2018, Batish *et al.*, 2008, Chitwood, 2002). Flavonoids exhibit interactions mostly in nematode resistant plant genotypes, where they accumulate in large quantities, resulting in pathogen defence mechanisms (Chin *et al.*, 2018). Flavonoids, for example, exhibit chemotactic, repellent, and attractant characteristics in nematodes (Chin *et al.*, 2018, Warnock *et al.*, 2016;). Crude extracts hindered *M. incognita* egg hatching and *P. zae* juvenile mobility, according to our findings. Furthermore, as indicated by Choudhary, (2012) and Muthee, (2013), the outcomes of this study corroborate the proposal that plant species in the Myrsinaceae family have anthelmintic properties (Zebeaman and Gebeyehu, 2018). Helminthes are closely related to plant-parasitic nematodes.

The hatchability of nematode eggs was significantly different ($P = 0.0001$) 48 hours after treatment between the three extracts: ethanol, dichloromethane, and hexane. Ethanol extracts were more efficient than dichloromethane and hexane extracts in reducing egg hatchability. The lowest concentration (2.5 ppm) had the best hatchability in all extracts, whereas the maximum concentration (10 ppm) had the lowest egg hatchability (Table 3). In the control experiment, *M. incognita* eggs hatched at a rate of 60% in all extracts, but only 11.67%, 13.33%, and 15% of *M. incognita* eggs hatched in ethanol, dichloromethane, and hexane, respectively at 10 ppm extract concentration.

Table 2. Phytochemical's profile of stem barks extract of *E. schimperi*. Extraction methods applied in this study include maceration and Ultrasonication. The solvent used in this study include hexane, dichloromethane and ethanol.

Extraction method	Maceration			Ultrasonication		
	Hexane	DCM	Ethanol	Hexane	DCM	Ethanol
Secondary metabolites						
Tannins	+	++	++	+	+	++
Alkaloids	-	-	+	+	+	+
Flavonoids	+	++	++	++	++	++
Terpenoids	-	-	-	-	-	-
Cardiac glycosides	-	-	-	-	-	-
Saponins	+	+	+	+	+	+
Phenolic	+	++	++	++	++	++
Steroids	-	-	-	-	-	-

Key: + = the presence, ++ = Intense - = the absence

Table 3. *M. incognita* hatchability in ethanol, dichloromethane, and hexane extract treatments after 24h, 48h, 72h and 96h.

Plant crude extracts	24-h		48-h		72-h		96-h	
	Mean±SE	%	Mean±SE	%	Mean±SE	%	Mean±SE	%
Dimethyl sulphoxide (Control)	9.00±1.00a	45.00	12.00±1.00a	60.00	16.33±1.20a	81.67	19.67±0.33a	100.00
Ethanol (ppm)								
2.5	3.67±1.45b	13.33	4.33±0.33b	25.00	9.00±1.15b	45.00	15.00±2.52ab	61.67
5.0	3.67±0.33b	13.33	4.00±0.58b	25.00	7.33±0.67bc	36.67	14.33±1.20ab	50.00
7.5	4.00±1.00b	10.00	3.33±0.33b	15.00	5.33±0.67bc	26.67	8.33±1.20b	33.33
10	3.00±0.58b	6.67	3.00±0.58b	11.67	3.67±0.33c	18.33	8.33±1.86b	23.33
Dichloromethane (ppm)								
2.5	4.33±0.33b	21.67	12.00±1.00a	30.00	16.33±1.20a	51.67	19.67±0.33a	63.33
5.0	3.33±0.33bc	16.67	5.67±0.33b	18.33	10.33±2.03ab	43.33	12.67±3.48ab	53.33
7.5	2.33±0.33bc	11.67	3.67±0.33b	21.67	8.67±1.45b	33.33	10.67±0.67b	46.67
10	1.67±0.33c	8.33	4.33±0.88b	13.33	6.67±1.76b	33.33	9.33±1.33b	38.33
Hexane (ppm)								
2.5	2.67±0.33b	18.33	5.33±0.33b	20.00	13.33±2.19ab	66.67	12.33±2.40b	75.00
5.0	2.67±0.33b	18.33	5.33±0.33b	20.00	13.67±1.20ab	68.33	10.00±1.53ab	71.67
7.5	2.00±0.58b	20.00	3.00±0.58bc	16.67	8.00±1.53b	40.0	6.67±0.88ab	41.67
10	1.33±0.33b	15.00	2.33±0.33c	15.00	7.67±1.67b	38.33	4.67±0.33b	41.67

Table 4. *Pratylenchus. zae* mortality in ethanol, dichloromethane and hexane extract treatments after 24h, 48h and 72h.

Plant crude extracts	24-h		48-h		72-h	
	Mean±SE	%	Mean±SE	%	Mean±SE	%
Dimethyl sulphoxide (Control)	0	0	0	0	0	0
Ethanol (ppm)						
2.5	1.00±0.58ab	10.00	6.67±0.67b	68.33	8.33±0.67b	88.33
5.0	1.67±0.24ab	21.67	8.33±0.33bc	83.33	8.67±1.45b	95.00
7.5	2.67±0.67ab	30.00	8.33±0.33bc	86.67	10.67±1.67b	100
10	3.33±0.33b	30.00	9.33±0.33c	85.00	11.00±0.58b	100
Dichloromethane (ppm)						
2.5	2.33±0.33ab	10.00	11.00±0.58b	55.00	13.33±0.88b	66.67
5.0	3.33±0.88bc	16.667	12.33±0.33bc	61.67	13.67±0.88b	68.33
7.5	3.33±0.33bc	16.667	13.67±0.67cd	68.33	15.00±1.15bc	75.00
10	4.67±0.33c	23.333	15.33±0.33d	75.00	18.00±1.00c	90.00
Hexane (ppm)						
2.5	2.33±0.33ab	5.00	13.67±1.86b	33.33	17.67±0.33b	41.67
5.0	4.33±0.33bc	5.00	16.67±1.33b	40.00	19.00±0.58bc	43.33
7.5	6.00±0.58c	13.333	17.33±0.67b	41.67	19.67±0.33c	53.33
10	6.00±0.58c	15.00	17.00±0.58b	46.67	19.67±0.33c	55.00

The hatchability of *Meloidogyne incognita* eggs increased considerably in all treatments after 72 hours (Table 3). Dimethyl sulfoxide treatment boosted hatchability to 81.67 percent, whereas 2.5 ppm, 5 ppm, 7.5 ppm, and 10 ppm treatments enhanced hatchability to 45-66.67 percent, 36.67-68.33 percent, 26.67-40 percent, and 18.33-38.33 percent, respectively. The 10 ppm concentration provided the best results in terms of lowering egg hatchability (Table 3). In the control experiment, the maximum egg hatchability (100%) was attained after 96 hours. The lowest hatchability was found in the 10 ppm treatment, followed by 2.5 ppm, 5 ppm, and 7.5 ppm in all extracts. In comparison to dichloromethane and hexane extracts, ethanol extracts had the least hatchability at all concentrations.

In comparison to dichloromethane and hexane, ethanol extracts demonstrated the strongest nematicidal effects after 24 hours in the root-lesion nematode *P. zaeae* ($P = 0.0001$). Ethanol extract produced 30% mortality at a concentration of 10 ppm, whereas dichloromethane and hexane caused 23.33 percent and 15%, respectively. Across all concentrations examined, this trend was constant. The control, dimethyl sulphoxide, had no confirmed fatality after 24 hours (Table 4).

Pratylenchus zaeae mortality increased with longer exposure to *E. schimperi* extracts. When compared to dichloromethane and hexane extracts at 10 ppm concentration, ethanol extract at 10 ppm exhibited the greatest mortality (85%) after 48 hours (75 percent & 46.67 percent, respectively). The 5 ppm, 7.5 ppm, and 10 ppm treatments in the ethanol extract sample had no statistically significant change ($P = 0.67$). Table 4 shows that dichloromethane had the second greatest mortality, whereas hexane had the lowest. Ethanol extracts killed 100 percent of *P. zaeae* juveniles after 72 hours at 10 ppm and 7.5 ppm doses. The lowest death rates were 41.67 percent, 43.33 percent, 53.33 percent, and 55 percent for 2.5 ppm, 5 ppm, 7.5 ppm, and 10 ppm of hexane extract, respectively. In ethanol, dichloromethane and hexane extracts, nematode motility changed significantly ($P = 0.0001$).

Chitwood (2002) showed that phytochemicals from diverse plant extracts had an inhibitory effect on *Meloidogyne* spp. egg hatching fecundity. Wuyts *et al.* (2006) studied the nematicidal effects of phenylpropanoids (simple phenolics and flavonoids), as well as selected monoterpenoids and alkaloids, on migratory and stationary endoparasite nematodes including *Radopholus similis*, *P. penetrans*, and *M. incognita*. Simple phenolic compounds operate as repellents and motility inhibitors against *R. similis* and *M. incognita*, whilst phloretin compounds have been demonstrated to

hinder the hatching of *P. penetrans* eggs. Another research (Wuyts *et al.*, 2006) found that Flavonols had high repellent action against *R. similis* and *M. incognita*.

Flavonol compounds exhibit motility inhibitory properties for *M. incognita* in their degradable condition. Flavonoids and phenolic (Sithole *et al.*, 2021, Maistrello *et al.*, 2010, Hewlett *et al.*, 1997, Bird, 1959) revealed larval mortality and slowed egg hatching of *M. incognita*, whereas tannins had repellent, attractant and no impact against certain phytonematodes, according to Wuyts *et al.* (2006). Saponins from *Medicago* species have been shown to inhibit the root-knot nematode *M. incognita*'s infection and reproduction. Saponins are a class of compounds made up of triterpene or steroids aglycone (D'Addabbo *et al.*, 2020). In animals, saponins have been shown to be effective against the gastrointestinal nematodes from donkey and goats (Maestrini *et al.*, 2019; 2020).

CONCLUSION

Ethanol proved to be an efficient solvent for extracting phytochemicals from *Embelia schimperi* plants, according to the findings of this study. Additionally, crude extracts from *Embelia schimperi* inhibited root-knot nematodes, *M. incognita*, eggs hatchability and caused mortality to root-lesion nematode juveniles, *P. zaeae*. For the control of plant-parasitic nematodes, these extracts might be synthesised into botanical insecticides.

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Compliance of ethical standards. Does not apply

Data availability. The data is available with Ms Beth Waweru and Dr Njira Njira upon request.

Author contribution statement (CRediT). **Beth Wangui Waweru, Wabusya Moses Wetiba and Lusweti Dorcas** - Methodology, data curation and writing. **Margaret Koske** - Phytochemical screening. **Njira Njira Pili, Rose Ramkat and**

Ambrose Kiprop - Conceptualization, editing, supervision and funding acquisition.

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