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EFFICACY OF AQUEOUS AND POWDERED LEAF EXTRACTS OF *Chromolaena odorata* (ASTERALES: ASTERACEAE) AND *Ficus mucuso* (ROSALES: MORACEAE) BOTANICALS ON ROOT-KNOT NEMATODE INFECTING WATERMELON IN KWARA STATE, NIGERIA

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ABSTRACT. Watermelon production in Kwara State, Nigeria, is affected by root-knot nematode (RKN), as all varieties of the crop are susceptible. The aim of this study was to identify readily available and environmentally safe nematicides for the management of RKN. The field was located at the Teaching and Research Farm of the University of Ilorin and set out in a randomised complete block design, with four replications. Aqueous and powdered extracts of *Chromolaena odorata* (L) King and Robinson and *Ficus mucuso* Welw. ex Ficalho were applied alone and in combination. There were seven total treatments: *C. odorata* aqueous, *F. mucuso* aqueous, *C. odorata* powder, *F. mucuso* powder, *C. odorata* and *F. mucuso* aqueous, *C. odorata* and *F. mucuso* powder, and the control. Data were collected on growth, yield and nematode populations. All data collected were subjected to analysis of variance, and treatments were compared using Duncan's multiple range test at a 5% level of significance. The essential oil of each botanical was determined using gas

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chromatography-mass spectrometry. The vine length (185.61) and yield (2401.05) of plants treated with botanicals were significantly higher than those of the control at P<0.005. The nematode population was also significantly lower in plants treated with botanicals than in the control (318.30 and 230.00, first and second year, respectively) at P<0.005. Among the treatments, the combination of *C. odorata* and *F. mucuso* powders was the most effective, with higher growth and yield performance. The experiment showed that aqueous and powdered extracts of *C. odorata* and *F. mucuso* were effective in managing RKN in the field.

Keywords: Botanicals; *C. odorata*; extracts; *F. mucuso*; watermelon.

INTRODUCTION

Citrullus lanatus (Thunb.) Matsum. and Nakai (watermelon) belongs to the Cucurbitaceae family. It is unique for its fleshy and tasty fruit with a high water content. Watermelon is also used for nutritional, medicinal, economic and cultural purposes (Sabo *et al.*, 2013). It is cultivated worldwide, both in the sub-tropic and tropics. In Sub-Saharan Africa, it is a source of income.

The largest producers of watermelon in the world are China, Iran and Turkiye (Atlasbig, 2022). Watermelon production in developing nations is affected by factors such as insufficient farm inputs, soil infertility, poor transportation, inadequate storage facilities and the prevalence of pests and other disease-causing organisms (Adojutelegan *et al.*, 2015).

Of these factors, plant disease is one of the biggest constraints. Diseases are usually caused by insect pests and/or pathogens, such as bacteria, fungi, viruses and nematodes. Globally, diseases account for about 20-40% of the annual loss incrop yield, with an economic loss of around $220 billion (FAO, 2019). In watermelon, root-knot nematodes are among the most problematic pathogens, causing yield loss (Thies *et al.*, 2016).

Root-knot nematodes (*Meloidogyne* spp.) are the most economically important plant parasitic nematodes (Shakeel *et al.*, 2020). They are also the most damaging plant nematode, having the broadest host range and infecting over 1200 plant species, including watermelon (Bello *et al.*, 2020). All cultivated varieties of watermelon are susceptible to root-knot nematode (Thies *et al.*, 2016). Most plants in the cucurbit family are also very susceptible to nematodes (Noling, 2019). Root-knot nematode threats are compounded by numerous species adapted to different climatic conditions. Over 100 nematode species have been reported throughout the world, with 22 found in Africa (Onkendi *et al.*, 2014). Of these, 4 nematode species (*Meloidogyne incognita*, *Meloidogyne javanica*, *Meloidogyne enterolobii* and *Meloidogyne arenaria*) have been associated with watermelon in Africa (Bello *et al.*, 2020). On cultivated land, the root-knot nematode can cause a yield loss of 25-50% (Feyisa, 2021).

To combat the scourge of root-knot nematode, different management practices have been adopted. Some of them include synthetic pesticides, biological control and solarisation (Aioub *et al.*, 2022; Ali *et al.*, 2022; Bhat *et al.*, 2023; Feyisa, 2021; Forghani and Hajihassani, 2020). While they may be effective in controlling nematodes,

they also have limitations that arise from a low rate of acquisition, overuse and regulation bottlenecks.

For instance, the use of synthetic pesticides has been associated with abuse in Sub-Saharan Africa, which leaves pesticidal residue on crop produce, causes soil contamination and pollutes underground water (Fuhrimann *et al.*, 2022).

Similarly, the adoption of biological controls is generally low in the region. This is because of high-cost purchases and inadequate awareness of the new technology among local farmers. *Chromolaena odorata* (L) King (*Figure 1*) and Robinsonand *Ficus mucuso* Welw. ex Ficalho (*Figure 2*) were selected for this study because of their availability and easy accessibility to farmers in the state. Some earlier reports have also indicated that they contain phytochemicals, such as tannins, alkaloids, saponins, tannins, terpenoids and phenols, that could have nematocidal properties (Usunomena and Efosa, 2016). This may serve as a practical alternative to the use of synthetic pesticides.

Therefore, the purpose of this study wasto examine the effects of botanicals as a practical alternative in the management of root-knot nematode. Specifically, this study aimed to determine the efficacy of *C. odorata* and *F. mucuso* botanicals on the growth and yield attributes of watermelon infected by root-knot nematode in Kwara state, Nigeria. Botanicals are environmentally friendly, accessible and readily available for use by farmers (El-Ashry *et al.*, 2023; Eldeeb *et al.*, 2022; Olabiyi, 2004).

MATERIALS AND METHODS

Description of the experimental site

The experiment was carried out at the Teaching and Research Farm of the University of Ilorin, Ilorin, during the 2018 and 2019 cropping seasons, starting in September. The site was located at 8”29N, 43”5E of the equator. It is characterised by two rainfall patterns, which are highest between July and September, with a short dry spell in August.



Figure 1 – *Chromolaena odorata* plant
Source: Wikipedia



Figure 2 – *Ficus mucuso* leaf
Credit: Photo by N.J. Cordeiro, Post-Production by J. Quicho. Licenced under CC BY 2.0

The soil type of the area issandy-loam, and rainfall ranges annually from 1000 to 1200 mm (Ajala *et al.*, 2021). The average length of daylight is 12 hours, which does not vary substantially throughout the year. The topography of

the study area is plain, and the land is typically used for rain-fed agriculture.

The site was cultivated with vegetables and maize in previous years. Some cucurbits that have recently been cultivated in the field include cucumber and fluted pumpkin. Other crops cultivated around the field include vegetables, sugarcane, tuber, cucumber and spices. The soil has a history of root-knot nematodes, such as *M. incognita* and *M. javanica* (Sossou *et al.*, 2021).

Collection of planting materials and botanicals

The watermelon variety used for this experiment was kaolak. This variety was selected because it is the most widely cultivated watermelon variety in the state. The botanicals *C. odorata* and *F. mucuso* were collected on the premises of the University of Ilorin, Ilorin. The identification of both plants was done at the Department of Plant Biology, University of Ilorin.

Field preparation and experimental layout

Weeds and debris were cleared manually from the field. A land area measuring 15 m × 40 m was ploughed and arrowed into ridges. A pre-emergence herbicide, Paraquat, was sprayed into the soil to prevent weeds atthe site. The experiment was set out in a randomised complete block design (RCBD) and each treatment was applied in four replicate plots. The land was divided into 20 plots with each plot measuring 6.3 m × 5.2 m. A 1-m alley was left between plots and a 2-m alley between blocks. Before planting, composite samples were collected from each plot at a depth of 15 cm to determine the initial nematode population and the physiochemical properties of the soil.

Sowing of watermelon seeds

Four seeds of the kaolak variety were sown at a depth of 2.5 cm, with a space of 90 cm × 75 cm between plants (Enujeke, 2013). The seeds were watered after sowing. Germinated seedlings were reduced to two per stand to prevent overcrowding.

Preparation of aqueous and powdered leaf extracts of botanicals

Preparation of the aqueous extract

Leaf samples of *C. odorata* and *F. mucuso* were collected separately and airdried at room temperature (27°C) for 14 days. The leaves were then pulverised using a pestle and mortar. Precisely 500 g of the pulverised leaf powder was soaked in 5000 mL of warm distilled water for 24 hours (Olajide *et al.*, 2018). The resulting suspension was filtered through a muslin cloth, and the sieved extract was diluted to a 95% concentration. The aqueous extract from each of the botanicals was kept inside a sealed plastic bottle until it was ready for use. The remaining samples were used for gas chromatography-mass spectrometry (GC-MS) analysis. GC-MS analysis was performe during the standard procedure described by Vimalavady and Kadavul (2013).

Preparation of the leaf powder

The leaves of both botanicals were separately air-dried for 14 days and finely pulverised to powder using a pestle and mortar. About 10 kg of the powder was prepared from each botanical and applied at a concentration of 100 g per watermelon plant (Moosavi, 2012).

Treatment application

The prepared treatments are described in *Table 1*. The treatments were applied twice, 1 week after planting and 1 month after germination.

Round holes were made around the base of each plant, and 200 ml of aqueous crude extract was applied to the holes. For the powder extract, 100g was incorporated into the holes and covered with soil. The dosage used for the treatments was based on the historyof RKN in the field (Sossou *et al.*, 2021). Untreated plots were used as a control.

Determination of the nematode population

The numberof nematodes per 100 g of soil was determined using the modified extraction tray method by Whitehead and Hemming (1965). The root-knot nematodes present in the soil were identified under a compound microscope using the CABI Crop Protection Compendium (CABI, 2007) and interactive diagnostic keys (Coyne *et al.*, 2007).

Cultural practices

Manual weeding was performed with hoes every 14 days. Seedlings were thinned to 2 per stand by hand. Water was supplied to the roots of the plants using watering cans during dry spells throughout the experiment.

Data collection and analysis

Data were collected on vine length, fruit weight and shoot weight. The length of the highest vine was taken as the vine length, and the average weights of the fruit and shoots of the plants were taken as the fruit and shoot weights, respectively. The vine length was determined using a measuring tape and a measuring scale was used to determine the weights of the fruit and shoots. Data on vine length werecollected between 2 and 11 weeks after planting (WAP), while the shoot and fruit weights were determined at 11 WAP.

Other data collected include the initial nematode population, population after 1 month, final nematode population, reproduction index, gall index and egg mass/root. The reproduction index was determined using the formula, R=Pf/Pi, where Pf represents the final nematode population and Pi represents the initial nematode population.

The gall index was rated using the Bridge and Page (1980) method, as described below:

0 – No knots on roots;

1 – Few small knots, difficult to find;

2 – Small knots only, but clearly visible, main roots clean;

3 – Some larger knots visible, main root clean;

4 – Large, knots predominant but main root clean;

5 – 50% of roots affected knotting on some main roots;

6 – Knotting on main roots;

7 – Majority of main roots knotted;

8 – All main roots, including tap roots, knotted. Few clean roots visible;

9 – All roots severely knotted;

10 – All roots severely knotted; no root system. Plant usually dead.

All numerical data were analysed by an analysis of variance (ANOVA) using SPSS software, and significant means were separated using Duncan's Multiple Range Test (DMRT) at alpha = 0.05.

Table 1 – The botanical treatments applied in the management of root-knot nematode and their full description

S/N	Treatments	Treatment description
1.	Chromo aq.	*Chromolaenaodorata* Aqueous
2.	Ficus aq.	*Ficusmucuso* Aqueous
3.	Chromo pw.	*Chromolaenaodorata* Powder
4.	Ficus pw.	*Ficusmucuso* Powder
5.	Chromo+ Ficus aq.	*Chromolaenaodorata* and *Ficusmucuso* Aqueous
6.	Chromo+Ficus pw	*Chromolaenaodorata* and *Ficusmucuso* Powder
7.	Control	Untreated

S/N= serial number

RESULTS

Table 2 shows the effect of treatments on the vine length of watermelon. The results revealed an increase in vine length among all treatments, from 2 to 11 WAP. At 2 WAP, the plants treated with *C. odorata* and *F. mucuso* powder had a vine length of 9.08 cm and performed significantly better than the other treatments. From 3 WAP until the end of the experiment, all plants treated with botanicals performed significantly better than the controls. Among the botanicals, Chromo and Ficus pw-treated plants had a significantly longer vine length than the other treatments (4-11 WAP). A similar trend was observed in 2019.

The effects of the treatments on yield (fruit and shoot weight) are shown in *Table 3*. The weight of the watermelon fruit treated with botanicals was significantly higher than that of the control at $P < 0.05$. The performance among the botanical treatments revealed that *C. odorata* and *F. mucuso* pw. had the highest fruit weight, which was significantly higher than treatment with *C. odorata* aq., *F. mucuso* aq., *C. odorata* pw., *F. mucuso* pw., and *C. odorata* and *F. mucuso* aq. However, in 2019, the shoot weight of the treated plants was not significantly different from that of the control.

Table 4 shows the effects of treatments on the root-knot nematode population initially, one month after planting, and at harvest, the gall index, the reproduction index and egg mass/root during the 2018 and 2019 planting seasons. In 2018, the root-knot nematode population in plants treated with botanicals was significantly lower than in the control. This reduction in the nematode population was observed among all botanical treatments. The reproduction index, gall index and egg mass/root was also higher in the control plantsthan botanicals. Similarly, the root-knot nemato depopulation, reproduction index, gall index and egg mass/root were higher in the control during the 2019 planting season. *Table 5* shows the essential oils identified from *C. odorata* and *F. mucuso* using GC-MS. Nine essential oils were identified in *C. odorata*, while eight were discovered on *F. mucuso*. Four of the compounds, namely Bicyclo[3.1.1] heptane, 2,6,6-trimethyl-(1.alpha., 2.beta., 5.alpha.), n-Hexadecanoic acid, Phytol and Isophytol, were found in both *C. odorata* and *F. mucuso*. However, the remaining essential oils were discovered separately in each botanical.

Table 2 – Effect of treatments on watermelon vine length

Treatments	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP
Year 1 (2018)										
Chromo aq.	6.71^{de}	26.13^{d}	37.10^{c}	61.15^{c}	99.75^{c}	113.93^{c}	126.05^{c}	133.21^{c}	144.15^{c}	147.23^{c}
Ficus aq.	6.13^{e}	19.54^{f}	25.33^{e}	37.17^{e}	59.79^{e}	86.55^{e}	99.77^{e}	112.95^{ef}	121.25^{ef}	122.61^{e}
Chromo pw.	7.64^{c}	29.81^{c}	37.89^{c}	45.95^{d}	71.03^{d}	91.56^{d}	106.31^{d}	121.45^{d}	131.15^{d}	134.13^{d}
Ficus pw.	6.99^{d}	21.49^{e}	29.35^{d}	35.13^{f}	60.83^{e}	81.05e^{f}	95.62^{ef}	112.07^{ef}	122.67^{ef}	123.99^{e}
Chromo+Ficus aq.	8.38^{b}	48.97^{a}	59.97^{b}	94.46^{b}	110.55^{b}	136.69^{b}	151.97^{b}	157.96^{b}	165.55^{b}	167.61^{b}
Chromo+Ficus pw.	9.08^{a}	42.01^{b}	64.25^{a}	113.24^{a}	133.00^{a}	147.85^{a}	160.59^{a}	170.78^{a}	182.57^{a}	185.61^{a}
Control	7.07^{cd}	16.03^{g}	23.55^{f}	29.77^{g}	38.55^{f}	53.96^{g}	70.13^{g}	83.56^{g}	91.10^{g}	93.21^{f}
SEM	0.207	0.295	0.476	0.415	0.379	0.343	0.312	0.263	0.379	0.57
Year 2 (2019)										
Chromo aq.	6.66	13.64	22.48	37.94	90.76^{ab}	105.33^{ab}	119.71^{bc}	132.11^{bc}	137.57^{bc}	139.05^{bc}
Ficus aq.	6.06	13.66	22.06	41.39	91.99^{ab}	97.53^{b}	109.93^{d}	105.79^{d}	108.41^{d}	109.25^{d}
Chromo pw.	6.35	11.56	18.41	33.93	97.29^{a}	108.02^{ab}	117.42^{bc}	124.06^{c}	127.73^{c}	127.91^{bc}
Ficus pw.	6.97	13.85	22.06	41.29	95.75^{a}	118.84^{a}	131.03^{ab}	142.39^{ab}	145.68^{b}	146.29^{b}
Chromo+Ficus aq.	6.96	14.52	25.69	39.03	75.79^{bc}	93.81^{b}	110.76^{cd}	127.73^{bc}	133.83^{bc}	135.27^{bc}
Chromo+Ficus pw.	7.04	13.69	21.63	40.36	95.91^{a}	119.53^{a}	144.43^{a}	153.64^{a}	170.38^{a}	176.93^{a}
Control	5.74	13.87	21.93	31.54	60.91^{c}	74.38^{c}	83.92^{e}	90.59^{d}	96.66^{d}	98.23^{d}
S.E.M	0.468	1.091	1.923	3.77	6.096	5.077	5.204	5.809	5.219	5.041

Means within a column followed by the same letter(s) are not significantly different (P=0.05); S.E.M= Standard Error of Mean. Means were separated using DMRT. WAP= Weeks after planting. Chromo aq.=*Chromolaenaodorata* aqueous, Ficus aq.= *Ficusmucuso* aqueous, Chromo pw. =*C.odorata* powder, Ficus pw.=*F.mucuso* powder, Chromo+ Ficus aq. =*C.odorata* and *F.mucuso* aqueous, Chromo+Ficus pw.= *C.odorata* and *F.mucuso* powder, 7 = Control

DISCUSSION

The use of botanicals in the management of plant pathogens has been widely viewed as one of the most practical alternatives to the abuse of synthetic pesticides, especially in developing nations. Botanicals are cheaper, readily available and can be easily adopted by local farmers (Ngegba *et al.*, 2022). This study demonstrated the pesticidal potential of *C. odorata* and *F. mucuso* in the management of root-knot nematodes infecting watermelon. All applied botanicals (alone and in combination) showed toxicity to the nematode, leading to a reduction in the reproduction rate, gall index and population density. This reduction in the nematode population could be attributed to the presence of pesticidal compounds in *C. odorata* and *F. mucuso* extracts. Some of the essential oils found in extracts have been reported to have anti-microbial properties that inhibit the function of pathogens in plants (Murgananthan and Pabbithi, 2012). For instance, findings by Vimalavady and Kadavul (2013) showed that compounds such asn-Hexadecanoic acid, which is associated with both *C. odorata* and *F. mucuso*, have antimicrobial and antioxidant activities against many pathogens.

A similar investigation by Kamatchi *et al.* (2019) revealed that an aqueous extract of *C. odorata* led to the suppression of egg hatching and an increase in juvenile mortality of nematodes. Murgananthan and Pabbithi (2012) made a similar observation of the bioactive compounds of *F. mucuso* against some pathogens.

Among the botanical treatments, the combination of *C. odorata* and *F. mucuso* powder was the most effective in suppressing the nematode population and enhancing the growth and yield attributes of watermelon (*Table 2* and *Table 3*). This suggests that there was a higher concentration of essential oils in extract combinations than in single extracts, thereby increasing their nematocidal properties. The presence of n-Hexadecanoic acid and Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-(1.alpha., 2.beta., 5.alpha.) in both *C. odorata* and *F. mucuso* could have increased the concentration of the compounds and also increased their toxicity to the root-knot nematode.

The type of extract may also determine its effectiveness on nematodesin the field. Unlike aqueous extracts, which can be taken up within hours or a few days, powder takes a longer time to decompose, making it more effective over a longer period.

The powders may also act as composts to provide a form of organic supplement, thereby adding nutrients to the plants. The nutrients released can be taken up by plants and used as part of the photosynthates. *Chromolaena odorata* are known to provide useful hormones to standing crops, enhance soil organic carbon and steadily release nutrients during crop growth, thereby contributing to better growth and yield (Kumari *et al.*, 2013).

These factors can enhance plant growth under field conditions. All botanical-treated plants had higher growth and yield than the control.

Table 3 – Effect of treatments on watermelon yield

Treatment	Year 1 (2018)		Year 2 (2019)	
	Fruit weight (g)	Shoot weight (g)	Fruit weight (g)	Shoot weight (g)
Chromo aq.	423.90^{e}	25.95^{f}	841.94^{cd}	19.09^{ab}
Ficus aq.	1332.71^{c}	39.55^{b}	923.28^{bc}	26.01^{a}
Chromo pw.	755.38^{d}	31.17^{d}	838.56^{cd}	20.57^{ab}
Ficus pw.	419.08^{e}	27.44^{e}	142.79^{e}	15.45^{ab}
Chromo+Ficus aq	1717.12^{b}	38.05^{c}	1272.11^{b}	26.57^{a}
Cromo+Ficus pw.	2401.05^{a}	53.5^{a}	1843.91^{a}	28.74^{a}
Control	120.34^{f}	20.59^{g}	140.42^{e}	19.88^{ab}
S.E.M	4.121	0.167	3.471	3.149

Means within a column with the sameletter(s) are not significantly different (P=0.05); S.E.M= Standard Error of Mean. Means were separated using DMRT. Chromo Aq. = *Chromolaena odorata* aqueous, Ficus aq. = *Ficus mucuso* aqueous, Chromo pw. = *C. odorata* powder, Ficus pw. = *F. mucuso* powder, Chromo+ Ficus aq. =*C. odorata* and *F. mucuso* aqueous, Chromo+Ficus pw. = *C. odorata* and *F. mucuso* powder, 7 = Control

Table 4 – Effect of treatments on the population of nematodes initially, 1 month after planting and at harvest., reproductive index, gall index and the egg mass in the root

Treatment	Year 1 (2018)						Year 2 (2019)					
	Nematode population						Nematode population					
	Initial	1 Month	Harvest	Reproductive index	Gall index	Egg mass/ root	Initial	1 Month	Harvest	Reproductive index	Gall index	Egg mass/ root
Chromo aq.	300	99.00^{f}	34.00^{b}	0.11	0	3.31^{a}	186	60.00^{e}	24.33^{b}	0.13	0	2.31^{a}
Ficus aq.	300	88.00^{e}	34.00^{b}	0.11	0	3.42^{a}	186	45.00^{d}	30.00^{c}	0.16	0	2.54^{a}
Chromo pw.	300	66.00^{c}	33.30^{b}	0.11	1	3.11^{a}	186	40.00^{c}	20.00^{a}	0.11	0	3.28^{a}
Ficus pw.	300	76.00^{d}	29.00^{ab}	0.1	0	2.11^{a}	186	34.67^{b}	25.00^{b}	0.13	0	2.12^{a}
Chromo+Ficus.	300	54.00^{b}	26.00^{a}	0.09	0	2.29^{a}	186	35.00^{b}	20.00^{a}	0.11	0	2.89^{a}
Chromo+Ficus pw.	300	39.00^{a}	24.00^{a}	0.08	0	1.68^{a}	186	30.00^{a}	20.00^{a}	0.11	0	1.98^{a}
Control	300	444.00^{g}	318.30^{e}	1.06	4	14.7^{b}	186	290.00^{f}	230.00^{d}	1.24	3	12.46^{b}
S.E.M	0.98	0.655	0.651			2.321	0.46	0.372	0.483			2.143

Means within a column with the similar letter(s) are not significantly different (P=0.05); S.E.M = Standard Errror of Mean. Mean separated using DMRT. Chromo Aq. = *Chromolaena odorata* aqueous, Ficus aq. = *Ficus mucuso* aqueous, Chromo pw. =*C. odorata* powder, Ficus pw. = *F. mucuso* powder, Chromo+ Ficus aq. = *C. odorata* and *F. mucuso* aqueous, Chromo+Ficus pw. = *C. odorata* and *F. mucuso* powder, 7 = Control

Table 5 – List of essential oils found in *Chromolaena odorata* and *Ficus mucuso* using gas chromatography-mass spectrometry (GC-MS)

Botanical	S/n	Essential oil	Molecular formula	Quality	Peak area (%)
Chromolaena odorata	1	1,9-Nonanediol, dimethanesulfonate	$C_{11}H_{24}O_6S_2$	64	16.92
	2	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-(1.alpha.,2.beta.,5.alpha.)	$C_{10}H_{18}$	58	16.92
	3	9-Octadecyne	$C_{18}H_{34}$	64	6.13
	4	1-Methoxy-3-(2-hydroxyethyl)nonane	$C_{12}H_{26}O_2$	46	6.13
	5	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	99	38.59
	6	Tetradecanoic acid	$C_{14}H_{28}O_2$	83	38.59
	7	Phytol	$C_{20}H_{40}O$	91	12.19
	8	Isophytol	$C_{20}H_{40}O$	53	12.19
	9	(Z)6,(Z)9-Pentadecadien-1-ol	$C_{15}H_{28}O$	90	23.01
Ficus mucuso	1	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-(1.alpha.,2.beta.,5.alpha.)	$C_{10}H_{18}$	70	5.73
	2	Z-12-Tetradecen-1-ol	$C_{16}H_{30}O_2$	49	5.73
	3	Camphor	$C_{10}H_{16}O$	38	2
	4	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	99	34.12
	5	Tridecanoic acid	$C_{13}H_{26}O_2$	83	34.12
	6	Phytol	$C_{20}H_{40}O$	86	12.75
	7	Isophytol	$C_{20}H_{40}O$	80	12.75
	8	Oleic Acid	$C_{18}H_{34}O_2$	92	45.4

% = percentage

This is understandable because a reduction in the pathogen population is expected to lead to better crop growth and yield (Shakeel *et al.*, 2022a,b).

This finding agrees with the study of Izuogu *et al*. (2016) on the effectiveness of botanicals in suppressing the population of root-knot nematodes infecting cucurbits. Similar to their report, this investigation revealed that botanicals could be a cheaper alternative to synthetic pesticides in the management of RKN, especially in fields with a history of this nematode.

CONCLUSIONS

This study has established the importance of botanicals in the management of root-knot nematodes. Both *C. odorata* and *F. mucuso* were identified as major biopesticides that could effectively reduce the nematode population, leading to improved crop growth and yield. Therefore, we recommend the use of botanicals. We also suggest that more studies should be done to identify and optimise the essential oils present in botanicals to formulate them into effective pesticides.

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