Research Article

Application of Fatty Acid Esters on *Meloidogyne incognita* Infected Jew's Mallow Plants

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Abstract | Jew's mallow (*Corchorus olitorius*) is a vegetable of importance in Nigeria which is often times infested with root-knot nematodes (RKNs), thus reducing yield and expected income. Principally, synthetic nematicides are employed in the management of RKNs on agricultural fields. The synthetics are confronted with a web of regulations on account of their unhealty negative effect on humans and the environment. Plant protection is primarily saddled with replacing the synthetics. A promising technique is the application of bio-pesticides. Organic fatty acid esters (FAE) are reassuring materials with nematicidal activities. Medicinal plants are rich source of acid esters, hence *Alstonia boonei* (Apocynaceae) leaves were extracted cold in ethyl acetate. This yielded crude extract that was subjected to column chromatography (silica gel 100-120 mesh grade), which afforded fractions that were analysed with GCMS and FTIR for constituent identification. The result shows octanoic acid; hexanoic acid methyl ester; ethyl octanoate; 9, 12-octadecadienoic acid methyl ester; dodecanoic acid; octadecanoic acid methyl ester; decanoic acid; octadecanoic acid ethyl ester and tetradecanoic acid as the major components while the infra red spectral diagnostic signals agree with the expected vibrational frequencies corresponding to C-H and carbonyl C=O functional groups of fatty acid and esters. Jew's mallow plants infected with *Meloidogyne incognita* on the field were treated with the fatty acid esters (FAE) and compared to deionised water and carbofuran as control in two season trials. There was increase in biomass and vegetative growth with notable reduction in *M. incognita* reproduction in plants treated with FAE at 0.75 mg/ml in the first and repeat experiments. Juvenile population per gram root and soil were reduced significantly at 0.75 and 0.50 mg/ml of FAE in comparison with control. Late flowering was recorded in the untreated control experiment, while plants treated with FAE flowered notably earlier. Application of FAE is recommended for the sustainable management of *M. incognita* in Jew's mallow plants.

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Introduction

Plant parasitic nematodes (PPNs) are common pests in agricultural areas (Fabiyi *et al*., 2020a; Bello *et al*., 2022; Abiodun *et al*., 2022). Root-knot nematodes (RKNs) are of high relevance among PPNs. They are distributed worldwide and are obligate parasites of the roots of many plant species (Caveness, 1967; Fabiyi, 2021a, b, 2022a), yield loss of about 78 billion dollars annually around the globe is accredited to them (Caveness, 1967; Barker, 1998; Caillaud *et al*., 2008; Sun *et al*., 2006; Verdejo-Lucas, 1999).

Vegetable production is a key source of revenue for women in Nigerian rural communities (AVRDC, 1991). It provides great income to low income earners and small scale farmers, while compensating for the scarcity of animal proteins in the diet. Jew's mallow (*Corchorus olitorius*) is a vegetable of importance in Nigeria which is often times infested with RKNs, thus reducing yield and expected income of the farmers. Principally, chemical methods are employed in the management of RKNs. This is flawed with shortcomings and imperfections. Synthetic nematicides are known to be a major pollutant of the ecosystem (Fabiyi and Olatunji, 2021a).

Efforts have been made to study the nematicidal potential of some plant extracts on the survival and reproduction of plant parasitic nematodes (Fabiyi *et al*., 2020b; Fabiyi, 2022b). Citrus fruit canning waste, thiarubrinc a root extract from *Rudbeckia hirta* and common agro wastes such as cocoa-pod husk, cassava, orange, pineapple and potato, peels have been reported to be an effective control against nematodes with subsequent significant improvements in crop yield (Egunjobi and Olaitan, 1986; Babatola, 1989; Viala *et al*., 1998; Fabiyi, 2022c). Bio-pesticides are considered as a good alternative to the synthetic nematicides (Atolani *et al*., 2014a, b). Soil amendments, plant products and manures have also been found effective and successful in the management of RKNs (Sivakumar and Gunasekara, 2011; Atolani and Fabiyi, 2020; Fabiyi, 2020; Fabiyi and Olatunji, 2021b; Fabiyi, 2021c).

Alstonia boonei belongs to the family Apocynaceae. The leaves have been indicated in the treatment of malaria, snake bites, painful micturition and rheumatic conditions (Kayode and Omotoyinbo, 2008; Ojewole, 1984, 2000). The bark and leaves contain several indole alkaloids, including echitamine, echitamidine, akuammidine, picraline, quebrachidine, and its esters, vincamajine, alstonine, and akuammiline. The triterpenes, 13-amyrine and lupeol were reported as accruing in the bark, and ursolic acid in the leaves (Faparusi and Bassir, 1982). Fatty acid methyl and ethyl esters isolated from *Arthrocnemum indicum, Salicornia brachiata, Suaeda maritima, Suaeda monoica* and *Sesuvium portulacastrum* have been reported to have activity against pathogenic fungal and bacterial strains (Chandrasekaran *et al*., 2008, 2011). This research aims to examine the effectiveness of fatty acid esters (FAE) isolated from *A. boonei* leaves in ameliorating root knot diseases of Jew's mallow (*C. olitorius*) plants caused by *Meloidogyne incognita*.

Materials and Methods

Sample preparation

The leaves of *A. boonei* were collected from Fiditi town in Oyo State, Nigeria and authenticated at the University of Ilorin herbarium. The leaves were air dried at ambient temperature (27°C) for four weeks and were milled into powder with the laboratory mill (Christy and Norris Ltd type 8). From the resulting powder, 2 kg was weighed into a 20 liter aspirator for cold extraction with ethyl acetate. The extraction lasted 5 days, it was then decanted, filtered and concentrated with a rotary evaporator under vacuum.

Eight hundred grams (800 g) of the plant crude extract was subjected to open column chromatography on silica gel (I00-120 mesh grade) using a glass column of 10 cm diameter and 50 cm long (Simon, 2006). Column packing was dry. Briefly, after clamping the glass column in a vertical position with its stop cock closed, a small plug of cotton wool was introduced into the bottom of the glass column by means of a long glass rod. This was followed by some industrial sea sand to form a layer of 20 cm on the cotton wool. Then silica gel was added to about 40 cm length of the glass column, while tapping the glass for the silica gel to settle, and any entrapped air was allowed to escape (Consden *et al*., 1994). The plant extract was mixed with silica gel and introduced into the column gently in order not

to disturb the bed, while another 3 cm layer of silica gel was placed on top of it, and finally petroleum ether was added. The outlet valve was opened to allow the solvent to flow under gravity at an appropriate steady rate of 1.5 ml per minute. The first eluting solvent was petroleum ether, this was followed by pet ether dichloromethane ratio 1:1 and finally dichloromethane alone. The eluted fractions were collected at 600 ml per fraction. The various fractions were concentrated using rotary evaporator under vacuum.

Spectroscopic measurements

The FTIR was recorded on Shimadzu 8400_5 Fourier Transform Infra-Red spectrophotometer, while gas chromatography and mass spectroscopy analysis (GC/MS) of the fractions were run on GC/MSQP2010 Plus Shimadzu GCMS equipped with a quadrupole mass spectra detector and an auto-sampler with the following settings; injector, 200 °C; interfaced temperature, 250 °C, solvent cut time, 2.50min; relative detector mode, ACQ mode; scan, start time and end time; 3 minutes and 56 minutes; event time, 0.50 seconds; scan speed, 1428 units. The characteristic mass fragmentation patterns of the fractions were compared with the patterns recorded in NIST.

Field experiment

Vegetable beds of 1.5m^2 with a height of 15 cm was prepared after ploughing an area of land measuring 25 m by 25 m. The experimental design was 2x4x3 factorial experiment organized in a randomised complete block design (RCBD). The experiment was conducted twice between the month of April and August in year 2018 and 2019 at the University of Ilorin Teaching an Research farm. Jew's mallow (*C. olitorius*) seeds were sown at 50 cm in the row and 75 cm between the rows (Fabiyi and Olatunji, 2021a). *C. olitorius* plantlets were thinned five days after emergence. At ten days after emergence, each plant on the bed was inoculated with about 1000 eggs and J2 of *M. incognita* extracted from the infected roots of egg plant (*Solanum melongena* L.) using the sodium hypoclorite method (Riekert, 1995). The egg and juvenile suspension was introduced into the trench created at the root base of each Jew's mallow (*C. olitorius*) plantlet. This was then covered with soil after inoculation. Chromatographic fractions were dissolved in 200 ml of deionised water at 150, 100 and 50 mg to give 0.75, 0.50 and 0.25 mg/ml concentration. Seven days after inoculation, the plants were treated with chromatographic fractions in banded form in the first and repeat experiments. Carbofuran 3G was applied at 1.0, 1.5, and 2.0 kg a.i/ha. The scale of Bridge and Page (1980) was adopted for root gall rating, where 0: root knots absent, 1: very small invisible knots, 2: small but very visible with main roots clean, 3: knots largely visible with main roots clean, 4: large root knots abound with main roots clean, 5: 50% of roots affected, with knots on main root, 6: main root knotted, 7: a handful of main root knotted, 8: all parts of main root knotted, few clean roots visible, 9: severe root knots on root system, 10: severe root knots all over, plant may be dead.

Data collection and statistical analysis

Data were collected from the field on the following parameters: Plant height, number of leaves, and number of branches on weekly basis. Days to 50% flowering was noted before harvest, while shoot weight, nematode population in 250 g soil sample, nematode population in 10 g root sample and root gall rating were assessed in the laboratory after harvest. All data were subjected to analysis of variance. Treatment means were separated using the Duncan's new multiple range test at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

The results of the GCMS analysis are presented in Table 1 and Figure 1. Fifteen compounds were identified and nine were more than 5%. Hexanoic acid methyl ester (15.48%), has the highest percentage among the constituents identified, other compounds present in the fraction include ethyl octanoate (11.44%), dodecanoic acid (11.25%), octanoic acid (9.22%), decanoic acid (11.23%), octadecanoic acid methyl ester (10.30 %), octadecanoic acid ethyl ester (9.19%) and tetradecanoic acid (7.11%). Compounds identified that are lower than 5% include pentadecanoic acid methyl ester (2.01%), 10-octadecenoic acid (1.08%), 9-octadecenoic acid ethyl ester (1.06%), methyl tetradecanoate (2.05%), methyl tetracosanoate (1.01%) and hexadecanoic acid ethyl ester (2.10%). The infra-red analysis of the fatty acid esters revealed several bands like 2924cm^{-1}, 2852 cm^{-1}, 1734cm^{-1}, 1507cm^{-1}, 1464cm^{-1}, 1457cm^{-1}, 1174cm^{-1}, 1095cm^{-1}, 1025cm^{-1}, and 720cm^{-1}

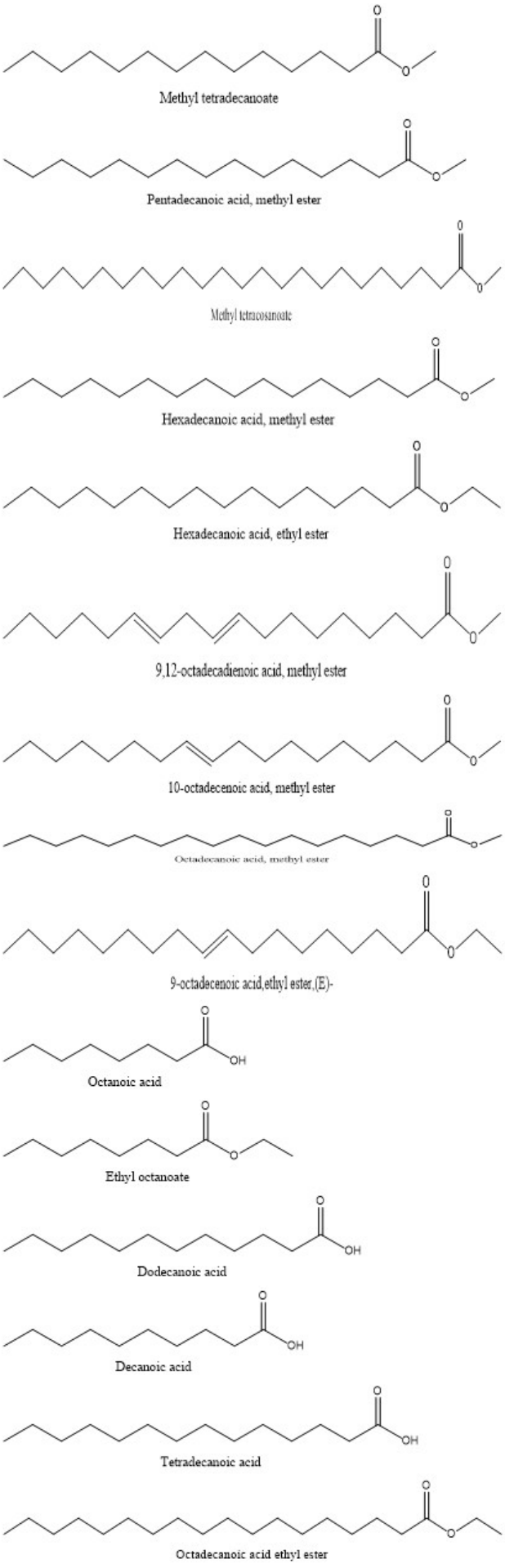


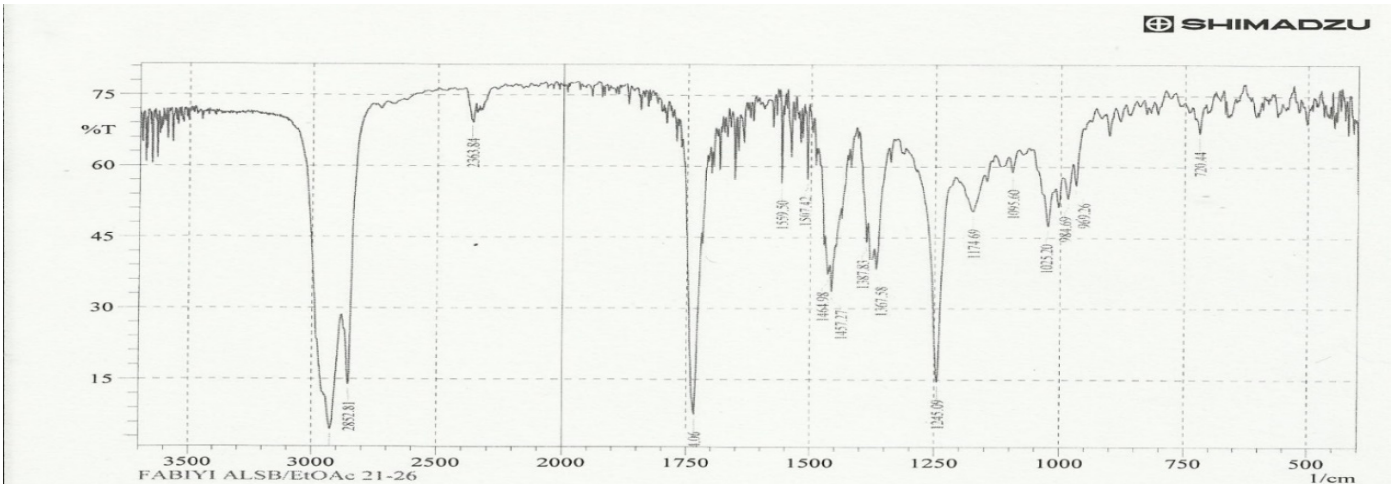
Figure 1: *Constituents of GCMS*

Table 1: *Constituents of GCMS analysis.*

Peak number	Retention time	%	Name of compound
1	26.78	9.22	Octanoic acid
2	29.55	15.48	Hexanoic acid methyl ester
3	30.65	11.44	Ethyl octanoate
4	31.31	5.47	9, 12-octadecadienoic acid methyl ester
5	31.40	11.25	Dodecanoic acid
6	32.05	10.30	Octadecanoic acid, methyl ester
7	32.32	11.23	Decanoic acid
8	33.50	7.11	Tetradecanoic acid
9		9.19	Octadecanoic acid ethyl ester
10	34.01	2.01	Pentadecanoic acid methyl ester
11	34.34	1.08	10-octadecenoic acid
12	35.16	1.06	9-octadecenoic acid ethyl ester
13	35.39	2.05	Methyl tetradecanoate
14	35.46	1.01	Methyl tetracosanoate
15	35.54	2.10	Hexadecanoic acid ethyl ester

which agrees with the expected vibrational frequencies corresponding to C-H and carbonyl (C=O) functional groups of fatty acid and esters (Figure 2).

Tables 2, 3 and 4 show the effect of fatty acid esters and carbofuran on the height, number of leaves and branches of Jew's mallow (*C. olitorius*) plants under nematode infection on the field. The fatty acid esters at 0.75 mg/ml caused a significant ($p<0.05$) increase in height of the plants and higher number of leaves and branches was recorded. The untreated control plants presented low mean number of leaves, branches and height. The variation in dosage of application of the treatments was also notable on all the vegetative parameters measured. The highest concentration (0.75mg/ml) produced significantly taller plants and more leaves and branches. Plants treated with the 0.75 mg/ml concentration also flowered significantly earlier (Table 5), while flowering was delayed in lower treatment concentrations. Shoot weights were also significantly ($p<0.05$) heavier in plants treated with the highest concentrations of fatty acid esters (Table 5). The 0.75 mg/ml dosage of application was the most effective in reducing nematodes in 250 g soil and 10 g root sample at harvest and consequently galling was reduced in the roots of plants administered with the highest concentration in comparison with the untreated control which recorded the highest root gall index (Table 6).



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	720.44	67.093	4.326	727.19	710.79	2.549	0.171
2	969.26	56.086	6.389	974.08	954.8	3.988	0.317
3	984.69	53.218	6.197	996.27	975.05	5.242	0.432
4	1025.2	47.408	7.139	1033.88	1015.56	5.339	0.519
5	1095.6	58.909	3.798	1103.32	1084.99	3.917	0.222
6	1174.69	50.55	7.088	1199.76	1152.51	12.634	1.313
7	1245.09	14.565	43.954	1285.6	1210.37	28.392	10.908
8	1367.58	38.356	6.333	1370.47	1343.46	7.622	0.363
9	1387.83	44.061	7.152	1402.3	1384.94	4.664	0.33
10	1457.27	33.326	6.787	1460.16	1450.52	4.048	0.335
11	1464.98	37.178	4.499	1470.77	1461.13	3.877	0.231
12	1507.42	57.343	15.09	1511.28	1503.56	1.385	0.305
13	1559.5	56.576	17.689	1563.36	1556.61	1.124	0.26
14	1734.06	7.716	43.946	1755.28	1720.56	21.356	11.666
15	2363.84	69.542	0.463	2391.81	2362.88	3.89	-0.05
16	2852.81	13.967	18.96	2867.28	2777.59	31.037	4.483
17	2924.18	4.553	12.735	2946.36	2879.82	62.368	13.473

Figure 2: *FTIR spectral.*

Table 2: *Comparative effect of fatty acid esters and carbofuran on plant height (cm) of Jew's Mallow (Corchorus olitorius) plants under Meloidogyne incognita infection.*

Treatments	Level Mg/ml	2nd WAT	2nd WAT	4th WAT	4th WAT	6th WAT	6th WAT
Fatty acid esters		1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
	0.0	6.21^{c}	7.33^{c}	9.19^{d}	10.26^{d}	12.22^{d}	11.00^{d}
	0.25	9.09^{b}	10.14^{ab}	12.30^{c}	13.00^{c}	17.36^{c}	16.27^{c}
	0.50	10.16^{b}	11.00^{a}	15.21^{b}	16.02^{b}	21.15^{b}	20.00^{b}
	0.75	12.51^{a}	12.10^{a}	19.34^{a}	20.29^{a}	27.23^{a}	26.19^{a}
Carbofuran (kg a.i/ha)	0.0	6.18^{d}	5.48^{c}	8.01^{d}	9.92^{d}	11.04^{d}	10.29^{d}
	1.0	10.06^{c}	11.01^{b}	14.07^{c}	13.53^{c}	19.00^{c}	18.11^{c}
	1.5	12.19^{b}	12.22^{b}	17.39^{b}	16.02^{b}	23.41^{b}	22.01^{b}
	2.0	16.00^{a}	16.77^{a}	20.09^{a}	19.66^{a}	31.05^{a}	30.45^{a}
S.E.M		1.63	0.73	2.06	2.14	3.28	4.33

Means in a segment of a given column followed by the same letter are not significantly different using the new Duncan's multiple range test.

Table 3: *Comparative effect of fatty acid esters and carbofuran on number of leaves of Jew's mallow (Corchorus olitorius) plants under Meloidogyne incognita infection.*

Treatments	Level Mg/ml	2nd WAT	2nd WAT	4th WAT	4th WAT	6th WAT	6th WAT
Fatty acid esters		1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
	0	10.10^{d}	11.04^{d}	17.08^{d}	19.11^{d}	23.06^{d}	21.11^{d}
	25	25.26^{c}	29.19^{c}	57.76^{c}	61.29^{c}	70.00^{c}	67.16^{c}
	50	46.35^{b}	51.27^{b}	78.06^{b}	83.10^{b}	92.23^{b}	89.51^{b}
	75	58.04^{a}	62.16^{a}	91.25^{a}	97.16^{a}	107.08^{a}	105.19^{a}
Carbofuran (kg a.i/ha)	0.0	11.02^{d}	12.37^{d}	15.11^{d}	18.00^{d}	24.29^{d}	20.33^{d}
	1.0	31.45^{c}	33.06^{c}	66.13^{c}	73.29^{c}	85.54^{c}	82.21^{c}
	1.5	49.36^{b}	53.25^{b}	81.19^{b}	87.00^{b}	103.32^{b}	98.40^{b}
	2.0	64.17^{a}	67.00^{a}	99.45^{a}	106.54^{a}	137.28^{a}	131.00^{a}
S.E.M		1.72	1.59	3.71	3.26	4.23	5.11

Means in a segment of a given column followed by the same letter are not significantly different using the new Duncan's multiple range test.

Table 4: *Comparative effect of fatty acid esters and carbofuran on number of branches of Jew's mallow (Corchorus olitorius) plants under Meloidogyne incognita infection.*

Treatments	Level Mg/ml	2nd WAT	2nd WAT	4th WAT	4th WAT	6th WAT	6th WAT
Fatty acid esters		1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
	0	0.00[c]	0.00[b]	0.00[c]	0.00[c]	2.42[d]	2.07[d]
	25	0.00[c]	0.00[b]	3.08[b]	2.79[b]	5.03[c]	4.78[c]
	50	2.07[b]	3.19[a]	4.42[b]	3.86[b]	7.15[b]	6.96[b]
	75	4.11[a]	4.54[a]	7.17[a]	6.37[a]	10.32[a]	11.77[a]
Carbofuran (kg a.i/ha)	0.0	0.00[c]	0.00[b]	0.00[d]	0.00[d]	2.25[d]	2.54[d]
	1.0	0.00[c]	0.00[b]	4.14[c]	3.77[c]	6.09[c]	5.18[c]
	1.5	3.31[b]	4.16[a]	6.22[b]	5.87[b]	9.39[b]	8.00[b]
	2.0	5.22[a]	5.09[a]	8.31[a]	7.92[a]	11.18[a]	10.05[a]
S.E.M		0.01	0.04	0.62	0.11	0.17	0.08

Means in a segment of a given column followed by the same letter are not significantly different using the new Duncan's multiple range test.

Table 5: *Comparative effect of fatty acid esters and carbofuran on yield attributes of Jew's mallow (Corchorus olitorius) plants under Meloidogyne incognita infection.*

Treatments	Level Mg/ml	Days to 50% flowering	Days to 50% flowering	Fresh shoot weight (g)	Fresh shoot weight (g)
Fatty acid esters		1st Trial	2nd Trial	1st Trial	2nd Trial
	0.0	54.21[d]	51.33[d]	88.04[d]	81.64[d]
	0.25	36.04[c]	38.09[c]	128.02[c]	119.65[c]
	0.50	28.17[b]	26.02[b]	135.00[b]	131.03[b]
	0.75	20.00[a]	19.79[a]	169.18[a]	165.12[a]
Carbofuran (kg a.i/ha)	0.0	52.06[d]	56.36[c]	77.00[d]	83.25[d]
	1.0	29.05[c]	28.21[b]	130.03[c]	127.76[c]
	1.5	25.07[b]	26.16[b]	158.00[b]	151.29[b]
	2.0	21.15[a]	20.09[a]	175.11[a]	170.31[a]
S.E.M		1.11	2.08	3.27	3.09

Means in a segment of a given column followed by the same letter are not significantly different using the new Duncan's multiple range test.

Table 6: *Comparative effect of fatty acid esters and carbofuran on nematode populations of Jew's mallow (Corchorus olitorius) plants under Meloidogyne incognita infection.*

Treatments	Level Mg/ml	Nematode population in 250 g soil	Nematode population in 250 g soil sample	Nematode population in 10 g root sample	Nematode population in 10 g root sample	Root gall rating	Root gall rating
Fatty acid esters		1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
	0.0	2512.09[d]	2218.11[d]	1743.04[d]	1532.19[d]	10.00[d]	10.00[d]
	0.25	163.65[c]	152.79[c]	66.36[c]	57.04[c]	4.16[c]	4.03[c]
	0.50	103.59[b]	92.18[b]	31.27[b]	23.15[b]	2.04[b]	2.19[b]
	0.75	34.28[a]	28.06[a]	14.11[a]	11.20[a]	1.17[a]	1.03[a]
Carbofuran (kg a.i/ha)	0.0	2617.43[d]	2508.29[d]	1105.03[d]	1028.72[d]	10.00[c]	10.00[c]
	1.0	25.34[c]	18.78[c]	19.76[c]	12.88[c]	1.48[b]	1.65[b]
	1.5	4.69[b]	3.57[b]	5.17[b]	3.83[b]	0.32[a]	0.41[a]
	2.0	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
S.E.M		2.29	2.05	1.07	2.02	0.11	0.08

Means in a segment of a given column followed by the same letter are not significantly different using the new Duncan's multiple range test.

It is worthy to note that the fatty acid esters from *Alstonia boonei* exhibited some level of nematicidal activity and are close to that of the synthetic nematicide. The fact that the increase in concentration potentiated the toxicity of the fatty acid esters on *M incognita* underscores the sensitivity of nematodes to the esters and this is a good index for dosage specification. The observed nemato-toxic effects of the fatty acid esters can be attributed to the presence of the identified organic compounds as revealed by the GC/MS and infra-red spectroscopic results of the fraction. Some of these organic compounds are either polar compounds, compounds of intermediate polarity or non polar compounds judging from their respective retention time from the GC/MS result. This however underlies partly the basis for the comparatively higher toxicity of the fatty acid esters to *M. incognita* on the field. The C-H stretching is associated with long chain hydrocarbons, alicyclics and aromatics. Hydrocarbons are used as soil fumigants against soil insects and nematodes before planting (Symser, 1990). Hydrocarbon oils have played an important role in crop protection as insecticides and ovicides. Fatty acid esters are employed as surfactants, with activities against insect larvae, and nematodes (Abrogat *et al.*, 2009). A variety of fatty acid esters have been used to manage nematodes *in vitro* and *in vivo*. Some fatty acid esters and fatty acid derivatives in the group of short carbon chains including C_8 to about C_{14} which could be in the epoxide, cyclopropane, methylated or hydroxylated forms have also been confirmed to be toxic to some nematodes (Feitelson and Dullum, 2000).

The results from this research is corroborated by the findings of Zang *et al.* (2012). They affirmed that fatty acids are toxic to *M. incognita*. Their study established that butyric, caprylic, capric, lauric, myristic, palmitic, and oleic acids inhibited egg hatch rate of *M. incognita* by 15.8%, while 50% juvenile mortality was recorded for capric and caprylic acids after 24 hours of exposure at 2000 µmol/L concentration. The fatty acids equally reduced *M. incognita* reproduction significantly on *Cucumus sativus* with an increased biomass growth (Zang *et al.*, 2012). Analogously, the results in this research was sustantiated by Gonçalves da Silva *et al.* (2021). They demonstrated that 80% egg hatch inhibition was achived with ethyl octanoate at 1000 µg mL^{-1} concentration, while octanoic acid, ethyl octanoate, and isovaleric acid provided 80% nematostatic action on *M. incognita* J2. Significant reduction in *M. incognita* reproduction was noted in further greenhouse experiments where ethyl octanoate was found to be comparable with the commercial fumigant dazomet. Organic acid like palmitoleic acid is reported to be a promising nematicidal substance (Morgunov *et al.*, 2016). Ricineloidic, ricinoleic and 12, 13-epoxy-trans-9-octadecenoic acids were also certified to be nematicidal by William *et al.* (2005). In their report, fatty acids were evaluated on root-knot nematodes infecting tomato plants at 100 ppm in pot experiments. A significant reduction in root gall damage on the tomato plants was realized. Munamaka (1983) reiterated that myristic, palmitic, and oleic acids from benzene extract of *Iris japonica* exhibited nematicidal action. Strong nematicidal activity was equally established with the application of 2-undecylenic acid at 10 µg/ml and 80 % mortality was attained (Chitwood, 2002). Similarly, butyric acid, a short chain fatty acid was discovered to be active on *M. incognita and Pratylenchus penetrans* at 880 µg/ml (Sayre *et al.*, 1965; Chitwood, 2002). The activity of fatty acids was further corroborated by Vrain (1980) he reported twelve fatty acids of C_3 to C_{18} with their derivatives, which include seven methyl esters and four primary alcohols in *in vitro* and greenhouse trials. Decanoic acid was toxic to all second stage juveniles of *Meloidogyne hapla* with a high percentage mortality in 24 hours at a concentration of 50 ppm for methyl esters and primary alcohols. Toxicity was noted to increased with increase in carbon chain from C_3 to C_{11}.

Concretely, fatty acid esters could be employed to mananage nematodes at lower concentrations. Kim *et al.* (1996) reported methyl ester of pelargonic acid to be active on root-knot nematodes at 0.005% concentration with 100% mortality after 30 minutes of application, *M. javanica* galling on tomato roots was prevented. In green house experiments, 1.6µl/liter of methyl pelagonate significantly reduced *Heteodera glycine* and *M. incognita* populations on soyabean (Davis *et al.*, 1997), while *Globodera tabacum* the tobacco cyst nematode population was brought down with some fatty acid esters at 1000 µg/ml (Tarjan and Cheo, 1956).

Some micro-organisms like fungi have presented fatty acid esters with nematicidal activity. 2-decenedioic acid from *Pleurotus ostreatus* was

confirmed by Kwok *et al.* (1992) as a nematode paralyzing substance, while remarkably higher nematicidal activity was attributed to monoenoic fatty acids with 8-12 carbons (Chitwood, 2002). Furthermore, linoleic acid isolated from *Arthrobotrys conoides and A. oligospora* was found toxic to *M. incogita* at 50 μg/ml (Anke *et al.*, 1995; Anke and Sterner, 1997). Similarly, Stadler *et al.* (1994) isolated linoleic acid, oleic acid, and palmitic acid from *Hericium coralloides* cultures and they were discovered to be effective towards *C. elegans*.

Additionally, Pineda-Alegria *et al.* (2020) confirmed the effectiveness of fatty acid esters in their research on *Haemonchus contortus* a gastro intestinal nematode of ruminant animals. They found pentadecanoic acid, palmitic acid, stearic acid and linoleic acid to significantly inhibit egg hatch and larval motility of *H. contortus* at 1.25-20 mg/ml. The fatty acid esters employed in this research remarkably reduced the reproduction of *M. incognita* on Jew's mallow plants, thereby improving the vegetative growth which was significantly hindered by *M. incognita* reproduction on the untreated control plants.

Conclusion and Recommendation

The application of plant metabolites in plant protection would reduce the use of synthetic nematicides and this would also alleviate concerns about environmental toxicity. FAEs are cheap and non-toxic. The application of fatty acid esters could serve as an alternative nematode control option in Nigeria. It will help reduce the losses incurred by the vegetable farmers. FAEs could be derived from several plant secondary metabolites. Although practical applications may be hindered by the lack of industrial production.

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Novelty Statement

Fatty acid esters are possible option in Meloidogyne incognita management.

Author's Contribution

O.A.Fabiyi: Conceptualisation, Bench work, Data Collection, Data analysis, Manuscript Draft.
M.T. Baker: Data interpretation Supply of Materials.
G.A. Olatunji: Manuscript Proof Reading, Review and Editing.

Conflict of interest
The authors have declared no conflict of interest.

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