



NEMATICIDAL PROPRIETIES OF COMMERCIAL SEED OILS OF CERTAIN MEDICINAL PLANTS ON EGG HATCHING AND JUVENILE MORTALITY OF THE ROOT-KNOT NEMATODE, *Meloidogyne incognita* In Vitro

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ABSTRACT: Cold pressed commercial seed oils of castor bean (*Ricinus communis*) colocynth, (*Citrullus colocynthis*) jojoba, (*Simmondsia chinensis*) and moringa (*Moringa oleifera*) at three concentrations (S, S/2 and S/4) showed nematicidal activity against egg-masses, free eggs and second stage juveniles of *Meloidogyne incognita* in vitro experiments. Egg hatching and juvenile mortality were significantly ($P \leq 0.05$) influenced by tested oil, concentration and exposure time. Colocynth and jojoba oils gave a relatively higher effect followed by moringa oil while castor bean oil was the lowest effective one. Percentages inhibition in hatching when 5 fresh and uniform size egg-masses or 100 free eggs were separately exposed to the standard solution of colocynth, jojoba, moringa and castor bean after 7 days post treatment were 89.7 (63.8), 88.8 (54.4), 79.8 (52.5) and 43.4 (41.2)%, respectively. Egg hatching inhibition was inversely proportion to the dilution of the tested oil. On the other hand, as exposure time increased from 1 to 7 days after treatments, ovicidal effect of the tested oils was obviously increased at all the tested concentrations in treatments of egg-masses while the opposite was true in treatments of free eggs. Statistical analysis ($P \leq 0.05$) showed that egg-masses were more sensitive to the tested oils compared to free eggs with all the tested oils at the three concentrations. Similarly, the tested oils were found to be significantly ($P \leq 0.05$) effective against second stage juveniles of *M. incognita*. Among which, jojoba was the most effective oil followed by colocynth and moringa while castor bean was the lowest toxic one. The highest value of juvenile mortality was detected with jojoba at the standard solution, 7 days after exposure (48.6 %) followed by colocynth (43.0%) and moringa (31.0%) while castor bean (17.4%) was the lowest toxic one. Juvenile mortality was dependent on the concentration and exposure time also. Generally, in vitro treatments revealed that the tested oils displayed nematicidal effect against egg-masses, free eggs and juveniles of *M. incognita*. Further studies are needed under greenhouse and field conditions.

Key words: *Meloidogyne incognita*, cold pressed commercial seed oils, castor bean, colocynth, jojoba, moringa, egg hatch, juvenile mortality, in vitro.

INTRODUCTION

Root-knot nematodes, *Meloidogyne* spp. are a member of an economically important group of soilborne pathogens widely distributed and causing an estimated \$100 billion loss/year worldwide (Oka *et al.*, 2002) and approximately 5% of global crop losses (Eisenback and Triantaphyllou, 1991; Hussain *et al.*, 2011). There are about one hundred valid species

belong to genus *Meloidogyne* Goeldi (Trinh *et al.*, 2019). The most dangerous species is *M. incognita* (Kofoid and White) Chitwood which cause great damage in most agricultural crops worldwide (Moens *et al.*, 2009). In Egypt, this species is considered one of the most common and economically important plant-parasitic nematodes cause considerable damage to majority of economic crops especially in localities with sandy soils (Ibrahim, 1985).

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Management of *Meloidogyne* species is difficult because they are sedentary endoparasites and therefore protected in plant tissues, besides they have high reproductive potential and extensive host range

Control methods varied greatly by using cultural practice, resistant cultivars and chemical nematicides, which are generally recommended for the control of root-knot nematodes and targeted by 48% of globally use across crops (Coyne *et al.*, 2009). However, the nematicides have been applied widely to control plant-parasitic nematodes with fast-acting and considerable results but, they are unfriendly methods, costly and produce environmental hazards. For instances, aldicarb residues exceeded the reference doses in orange fruits at Sharkia Governorate, Egypt (Tchounwou *et al.*, 2002). On the other hand, resistant cultivars are not available for many crops and repeated use of these cultivars can select virulent biotypes that break resistance (Whitehead, 1998). These procedures stimulated scientists to find new alternative control strategies that are environmentally safe and economically convenient at the same time. In this respect, plants are a source of many active nematicidal compounds and essential oils (Kong *et al.*, 2007). Moreover, a wide variety of plant species, representing 57 families have been shown to have nematicidal compounds such as alkaloids, isothiocyanates, phenols, glycosides, thiophenics, tannins, saponins and fatty acids (Gommes, 1981; Chitwood, 2002). In the previous century, the first attempt to evaluate the nematicidal effect of pineapple leaves (*Ananas sativus* Schult.) as organic soil amendment against *Meloidogyne* sp. was conducted by Linford *et al.* (1938). Followed studies revealed that essential oils have no negative effect on non-target organisms, humans and animals and are environment friendly. They are classified as safe by the U.S. Food and Drug Administration and have negative effect on embryonic development of eggs or juvenile mortality of *M. incognita*. On the other hand, many authors reported the nematicidal effect of certain seed oils of many plant species included castor bean, *Ricinus communis* (Desheesh and Abdel-Aty, 2008; Abdel-Aty, 2010; Chaudhary and Kaul, 2013; Mostafa *et al.*, 2017), colocynth, *Citrullus colocynthis* (Desheesh and Abdel-Aty,

2008; Abdel-Aty, 2010; Rizvi and Shahina, 2014); jojoba, *Simmondsia chinensis* (Ismail *et al.*, 2009; Gomaa *et al.*, 2016; El-Nagdi *et al.*, 2017; Hafez *et al.*, 2017) and moringa, *Moringa oleifera* (El-Shrief *et al.*, 2014; Gomaa *et al.*, 2016; Bello *et al.*, 2019). Therefore, the main option of the present research was designed to estimate the nematicidal effect of aqueous commercial seed oils of castor bean, colocynth, jojoba, and moringa on egg hatching and juvenile mortality of *M. incognita* under *in vitro* conditions.

MATERIALS AND METHODS

Culturing of the Root-Knot Nematode, *M. incognita*

Pure culture of *M. incognita* was maintained in the greenhouse on the tomato susceptible cultivar Super Strain B for using as a source of egg-masses, free eggs and second stage juveniles. A single egg-mass was used to establish a nematode population. Species identification was based on second stage juvenile measurements and examination of the perineal pattern system of adult females according to Eisenback *et al.* (1981) and Jepson (1987).

Preparation of Egg-Masses, Free Eggs and Second Stage Juveniles Needed for Experiments

Infected tomato roots were cut into pieces of 2-cm long and placed in a 600-ml flask with 200 ml of 0.5% sodium hypochlorite (180 ml water + 20 ml Clorox). The tightly capped flask was shaken for 3 minutes. The shaking partially dissolved the gelatinous matrix thus freeing eggs from egg-masses (Hussey and Barker, 1973). The liquid suspension of eggs was poured through a 200-mesh sieve nested upon a 500-mesh sieve. Eggs collected on the 500-mesh sieve were immediately washed free of residual sodium hypochlorite solution under a slow stream of tap water and incubated in Petri dishes at 25±2°C until hatching. Newly hatched juveniles were collected by using a micropipette. Egg-masses of equal size needed to study the effect of the tested oils on *M. incognita* egg hatching were hand-picked with fine forceps from small galls on the infected tomato roots obtained from previously maintained pure

culture. The collected egg-masses were surface sterilized in 1:500 *V/V* aqueous solution of sodium hypochlorite for 5 min (Haseeb *et al.*, 2005).

Seed Oils Used in the Experiments

The experiments were conducted with four commercially available cold pressed extracted seed oils of castor bean, *Ricinus communis* L. (Family: Euphorbiaceae); colocynth, *Citrullus colocynthis* (L.) Schrad., Family: Cucurbitaceae; jojoba, *Simmondsia chinensis* (Link) Schneid., (Family: Simmondsiaceae) and moringa, *Moringa oleifera* Lam. (Family: Moringaceae). To prepare standard solutions (S), required amounts of these oils (10 ml/liter) were dissolved in a small quantity of water and 2 drops of the surfactant, Tween 80 0.5% *V/V* were added and then volume was made up 1 liter with distilled water only. With these arbitrarily standard solutions, two concentrations of oils (S/2 and S/4) were prepared by diluting with distilled water for different experiments.

Effect of Four Commercial Seed Oils on Egg Hatching and Juvenile Mortality of *M. incognita* In vitro

Effect on egg-masses

Five fresh and uniform size egg-masses were transferred to 10-cm diameter Petri dishes contained 10 ml of each concentration *i.e.*, S (100%), S/2 and S/4. Control treatment (0.0 concentration) was prepared using distilled water. Each treatment was replicated five times. All treatments were left under laboratory temperature 25±4°C. Numbers of hatched juveniles were counted using a research microscope (100X magnification). The cumulative number of hatched juveniles in each Petri dish was counted after 1, 2, 3, 5 and 7 days post treatment. The percentage of hatching inhibition was calculated in comparison with the control treatment, according to the following equation:

Egg hatching inhibition (%)=

$$\frac{\text{Control} - \text{treatment}}{\text{Control}} \times 100$$

Effect on free eggs

Free eggs of *M. incognita* were extracted from infected tomato roots using the method

described by Hussey and Barker (1973) as mentioned before. Extracted eggs were suspended by distilled water and counted by using a counting slide under a research microscope (100X magnification). The number of eggs per 1 ml was adjusted to about 1000 eggs by diluting the suspension. Approximately 100 free eggs in 0.1 ml water were exposed to 10 ml of S (standard oil solution), S/2 and S/4. The Petri dishes of 10 cm were kept at 25 ±4°C for 7 days and number of hatched juveniles in each Petri dish was counted after the aforementioned exposure periods. The cumulative number of hatched juveniles was calculated in comparison with the control treatment and the percentage of egg hatching inhibition was determined by the equation mentioned before.

Egg hatching inhibition (%)=

$$\frac{\text{Control} - \text{treatment}}{\text{Control}} \times 100$$

Effect on juvenile mortality

The suspension concentration of emerged juveniles was adjusted to 1000 juveniles per 1ml. An amount 0.1 ml of the suspension containing about 100 juveniles were added to a final volume of 10 ml of the three concentrations (S, S/2 and S/4) for each oil dilution in 10 cm diameter Petri dishes. Control treatment was done using only distilled water. All treatments were left under room temperature (25±4°C) to assess the effect of these materials on juvenile mortality. Each treatment was replicated five times. Tested materials were observed daily for juvenile mortality but tables only contain data of 1, 2, 3, 5 and 7 days as mentioned before. Juveniles showing inactive straight posture or did not show any movement after prodding were considered dead (Elizabeth *et al.*, 2003). Mortality counts were observed using a research microscope under 100X magnification in 1 ml over the specified periods. The cumulative number of dead juveniles was calculated in comparison with the control treatment of distilled water. The mortality percentages were calculated as the following equation:

$$\text{Mortality (\%)} = \frac{\text{Dead juveniles}}{\text{Total number of juveniles}} \times 100$$

Statistical Analysis

The experiments were carried out in a completely randomized design. Data were subjected to analysis of variance (ANOVA) using MSTAT VERSION 4 (1987). Means were compared by Duncan's multiple range test at $P \leq 0.05$ probability.

RESULTS

Ovicidal Activity of Castor Bean, Colocynth, Jojoba, and Moringa Seed Oils on Egg Hatching of *M. incognita* *in vitro*

Effect on egg-masses

The egg hatching of *M. incognita* was significantly ($P \leq 0.05$) inhibited by the exposure of egg-masses to three concentrations (S, S/2 and S/4) used to judge the ovicidal effect of the tested oils (Table 1). The inhibitory effect varied according to oil type, concentration and exposure time. One day after exposure, the highest ovicidal effect was detected with colocynth followed by jojoba, moringa and castor bean at the standard solutions. Numbers of emerged juveniles were 20.4, 21.6, 40.0 and 57.6 juveniles, respectively compared to 73.8 juvenile hatched in control treatment of distilled water. Percentages inhibition in these treatments were 72.3, 70.7, 45.7 and 21.9%, respectively (Table 1). As the dilution increased to S/2 and S/4, numbers of hatched juveniles were increased to reach 43.8 (49.2), 47.2 (50.8), 54.6 (62.4) and 59.4 (61.2) juveniles, respectively. The parallel inhibition values were 40.6 (33.3)%, 36.0 (31.1)%, 26.0 (15.4)% and 19.5 (17.0) consequently. The same trend was observed after 2 and 3 days post treatment. After 5 and 7 days of treatment, the inhibitory effect of the tested oils was expanded to reach a relatively higher values at S concentration *i.e.*, colocynth (86.7 and 89.7%), jojoba (86.6 and 88.8%), moringa (73.8 and 79.8%), and castor bean (47.2 and 59.7%), respectively (Table 1). With all the tested oils, a relatively lower values of egg hatching inhibition were recorded with concentrations S/2 and S/4, that is mean that as concentration increased, the egg hatching inhibition (%) also increased. On the other hand, as exposure time increased from 1 to 7 days after treatments, ovicidal effect of the tested oils was obviously increased at most of the tested concentrations. The distilled water

treatment (control) gave significantly ($P \leq 0.05$) highest numbers of juveniles that emerged from egg-masses compared to other treatments. Seven days after treatment, mean hatch per egg-mass was 156.9 juveniles in distilled water treatment compared to 16.1, 17.5, 31.6 and 63.2 juveniles per egg-mass in treatments of colocynth, jojoba, moringa and castor bean, respectively at the hundred percent concentration (S). Generally, among the tested oils colocynth and jojoba gave a relatively higher effect with insignificant variations followed significantly by moringa, while castor bean showed significantly lower effect.

Effect on free eggs

Similarly, the tested oils were found to be significantly ($P \leq 0.05$) effective against free eggs of *M. incognita* after exposure to the concentrations S, S/2 and S/4 (Table 2). The egg viability of *M. incognita* was influenced by the time of exposure as well as type and concentration of oils. Among which, colocynth was the most effective one followed by jojoba, moringa while castor was the lowest effective one. One day after exposure, numbers of hatched juveniles and percentage of hatching inhibition in colocynth, jojoba, moringa and castor bean treatments at S concentration were 0.8 (95.1%), 2.0 (87.9%), 2.8 (83.1%) and 4.8 (71.0%) respectively (Table 2). The same arrangement was noticed after 2, 3 and 5 days post treatment. At the seventh day of treatment with S solution, cumulative numbers of hatched juveniles and percent of hatching inhibition in Petri dishes treated with colocynth, jojoba, moringa and castor bean were 33.0 (63.8%), 41.6 (54.4%), 43.4 (52.5%) and 54.6 (40.2%), correspondingly as compared to 91.4 juveniles hatched in distilled water treatment. While in half and quarter dilutions, percentages of egg hatching inhibition after the same period were 56.0 (45.5), 50.1 (45.9), 47.7 (42.6) and 34.1 (20.3)%, respectively. It was found that as the exposure time increased, percentage of hatching inhibition was decreased especially at S solution with all tested oils. For instances, percent of reduction in colocynth treatment at S concentration were 95.1, 82.2, 68.8, 65.8 and 63.8 after 1, 2, 3, 5 and 7 days post treatment. Generally, the nematicidal effect of the tested oils on *M. incognita* eggs was directly proportion to concentrations and exposure time.

Table 1. Effect of certain commercial seed oils on number of juveniles emerged from egg-masses of *M. incognita* at different intervals during 7 days of exposure *in vitro*

Treatment	Concentration	Mean number of juveniles emerged after				
		1	2	3	5	7
Castor bean, <i>Ricinus communis</i>	Standard solution (S)	57.6 ^{bcd}	160.0 ^c	206.6 ^c	265.0 ^d	316.2 ^e
		(21.9)	(44.0)	(43.4)	(47.2)	(59.7)
	S/2	59.4 ^{bc}	259.8 ^b	301.0 ^b	388.0 ^c	471.8 ^c
		(19.5)	(9.1)	(18.1)	(22.8)	(39.8)
	S/4	61.2 ^{bc}	270.8 ^b	299.2 ^b	433.8 ^b	541.2 ^b
		(17.0)	(5.3)	(17.6)	(13.7)	(31.0)
Colocynthus, <i>Citrullus colocynthis</i>	Standard solution (S)	20.4 ⁱ	43.2 ⁱ	52.0 ^h	66.4 ^h	80.8 ⁱ
		(72.3)	(84.8)	(85.7)	(86.7)	(89.7)
	S/2	43.8 ^{gh}	77.8 ^{gh}	92.2 ^{fg}	114.8 ^g	140.2 ^h
		(40.6)	(72.79)	(74.76)	(77.16)	(82.1)
	S/4	49.2 ^{efg}	100.4 ^{ef}	110.2 ^{ef}	157.6 ^f	189.8 ^g
		(33.3)	(64.72)	(69.84)	(68.65)	(75.8)
Jojoba , <i>Simmondsia chinensis</i>	Standard solution (S)	21.6 ⁱ	46.8 ⁱ	53.4 ^h	69.0 ^h	87.8 ⁱ
		(70.7)	(83.6)	(85.3)	(86.6)	(88.8)
	S/2	47.2 ^{fg}	91.4 ^{fg}	103.4 ^{ef}	113.8 ^g	148.4 ^h
		(36.0)	(68.0)	(71.7)	(77.3)	(81.0)
	S/4	50.8 ^{def}	107.4 ^e	121.2 ^e	179.8 ^e	206.2 ^g
		(31.1)	(62.4)	(66.8)	(64.2)	(73.7)
Moringa , <i>Moringa oleifera</i>	Standard solution (S)	40.0 ^h	66.4 ^h	75.6 ^{gh}	131.4 ^g	158.0 ^h
		(45.7)	(76.7)	(79.3)	(73.8)	(79.8)
	S/2	54.6 ^{cde}	113.0 ^e	125.8 ^e	190.4 ^e	249.0 ^f
		(26.0)	(60.4)	(65.5)	(62.1)	(68.2)
	S/4	62.4 ^b	140.2 ^d	171.0 ^d	275.2 ^d	345.2 ^d
		(15.4)	(50.9)	(53.0)	(45.2)	(56.0)
Distilled water		73.8 ^a	286.0 ^a	365.4 ^a	502.8 ^a	784.8 ^a

*Reported numbers represent cumulative means of 5 replicates.

** Means in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

*** Numbers in parenthesis are percentages of egg hatching inhibition in comparison with control of distilled water.

Table 2. Effect of certain commercial oils on free eggs of the root-knot nematodes, *Meloidogyne incognita* at five intervals during 7 days of exposure

Treatment	Concentration	Mean number of juveniles emerged after				
		1	2	3	5	7
Castor bean, <i>Ricinus communis</i>	Stock solution (S)	4.8 ^{fg}	15.6 ^d	44.2 ^d	50.8 ^d	54.6 ^d
		(71.0)	(44.6)	(41.2)	(39.8)	(40.2)
	S/2	9.4 ^c	17.8 ^c	50.4 ^c	56.2 ^c	60.2 ^c
		(43.3)	(36.8)	(32.9)	(33.4)	(34.1)
	S/4	11.4 ^b	22.8 ^b	59.6 ^b	66.2 ^b	72.8 ^b
		(31.3)	(19.1)	(20.7)	(21.5)	(20.3)
Colocynthus , <i>Citrullus colocynthis</i>	Stock solution (S)	95.1	5.0 ⁱ	23.4 ⁱ	28.8 ^k	33.0 ^j
		(82.2)	(68.8)	(65.8)	(63.8)	
	S/2	1.6 ^{ij}	7.8 ^h	23.2 ⁱ	34.8 ^j	40.2 ⁱ
		(90.3)	(72.3)	(69.1)	(58.7)	(56.0)
	S/4	3.6 ^{gh}	10.0 ^{fg}	24.4 ⁱ	43.8 ^{fg}	49.8 ^{ef}
		(78.3)	(64.5)	(67.5)	(48.1)	(45.5)
Jojoba, <i>Simmondsia chinensis</i>	Stock solution (S)	2.0 ^{ij}	7.8 ^h	31.4 ^h	36.2 ^{ij}	41.6 ^{hi}
		(87.9)	(72.3)	(58.2)	(57.1)	(54.4)
	S/2	4.6 ^{fg}	10.2 ^f	35.6 ^{fg}	41.6 ^{gh}	45.6 ^{fgh}
		(72.2)	(63.8)	(52.6)	(50.7)	(50.1)
	S/4	6.8 ^{de}	13.8 ^e	42.2 ^{de}	47.0 ^{ef}	49.4 ^{ef}
		(59.0)	(51.0)	(43.8)	(44.3)	(45.9)
Moringa, <i>Moringa oleifera</i>	Stock solution (S)	2.8 ^{hi}	8.6 ^{gh}	33.8 ^{gh}	38.8 ^{hi}	43.4 ^{ghi}
		(83.1)	(69.5)	(55.0)	(54.0)	(52.5)
	S/2	5.4 ^{ef}	11.0 ^f	38.6 ^{ef}	43.4 ^g	47.8 ^{fg}
		(67.4)	(60.9)	(48.6)	(48.5)	(47.7)
	S/4	7.2 ^d	16.4 ^{cd}	46.0 ^d	49.4 ^{de}	52.4 ^{de}
		(56.6)	(41.8)	(38.8)	(41.4)	(42.6)
Distilled water		16.6 ^a	28.2 ^a	75.2 ^a	84.4 ^a	91.4 ^a

*Reported numbers represent cumulative means of 5 replicates.

** Means in each column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

***Numbers in parenthesis are percentages of egg hatching inhibition in comparison with control of distilled water.

Results in Fig. 1 were designed to compare the sensitivity of egg-masses and free eggs of *M. incognita* to the tested oils at the three tested concentrations after 7 days post treatment. It was concluded that, egg-masses were more sensitive to the tested oils compared to free eggs. Average of hatching inhibition of the three concentrations when 5 egg-masses treated with colocynth, jojoba, moringa and castor bean oils after 7 days were 82.5, 81.2, 68.0 and 43.5%, respectively. However, the parallel values when 100 free eggs treated with the respective oils at the same period were 55.1, 50.1, 47.6 and 31.5%, consequently.

Larvicidal Activity of Three Concentrations of Commercial Oils, Castor Bean, Colocynth, Jojoba, and Moringa on Second Stage Juveniles of *M. incognita* *In vitro*

Likewise, the tested oils were found to be significantly ($P \leq 0.05$) effective against juveniles of *M. incognita*. Among which, jojoba and colocynth were the most effective oil followed by moringa while castor bean was the lowest toxic one. As exposure time increased from 1 to 7 days after treatment, larvicidal effect of the tested oils was increased at all the tested concentrations (Table 3). The highest value of juvenile mortality was detected with jojoba at the standard solution after 7 days of exposure (48.6%) followed by colocynth (43.0%) and moringa (31.0%) while castor bean (17.4%) was the lowest toxic one at the same concentration and exposure time. The respective values for these oils at S/2 and S/4 concentrations after the same period were 37.4 (28.8), 37.0 (25.2%), 29.8 (20.8) and 13.2 (6.8)%, consequently. Generally, the nematocidal effect of the tested oils on *M. incognita* juveniles was directly proportioned to concentration and exposure time. As the concentration and exposure time increased, percentage mortality was increased also. After 3 days, standard dilution of colocynth, jojoba, moringa, and castor bean caused 25.2, 19.8, 22.0 and 12.4% while half and quarter dilutions after the same period gave 20.4 (14.8), 17.6 (12.8), 18.0 (12.2) and 9.2 (5.0)%, respectively. The same trend was observed after the fifth day of application. However, after the seventh day, jojoba surpassed all the tested compounds followed by colocynth, moringa and castor bean (Table 3).

DISCUSSION

The recent European legislation has restricted the application of synthetic nematicides on agricultural crops due to their harmful effect on human and environment. On the other hand, as organic farming is gaining popularity, alternative control strategies need to be developed, since chemical nematicides are not acceptable in organic farms. Moreover, resistant cultivars are not available for the most of economic crops. Therefore, it has been become an important matter to find new alternative control practices. In addition, medicinal plants as botanical nematicides are available in most places, cheaper compared to chemical nematicides, safe to human and environment and easy to prepare by farmers (Renco *et al.*, 2004; Ononuju and Nzenwa, 2011).

The results of the present study revealed that three concentrations (S, S/2 and S/4) of castor bean, colocynth, jojoba and moringa oils showed significantly ($P \leq 0.05$) inhibitory effect on egg hatch and increased juvenile mortality of *M. incognita in vitro*. These results are in conformity with other investigators who studied nematocidal properties of castor bean (Abdel-Aty, 2010; Chaudhary and Kaul, 2013; Mostafa *et al.*, 2017), colocynth (Desheesh and Abdel-Aty, 2008; Rizvi and Shahina, 2014; Tarraf *et al.*, 2019), Jojoba (Gomaa *et al.*, 2016; El-Nagdi *et al.*, 2017; Hafez *et al.*, 2017), and moringa (El-Shrief *et al.*, 2014; Gomaa *et al.*, 2016; Bello *et al.*, 2019). The inhibitory effect of the tested oils may be attributed to the presence of chemicals with nematocidal effect. These chemicals either influenced embryonic development or killed the eggs or dissolved the egg-masses (Asif *et al.*, 2013). Also, the plants exhibit nematocidal activity due to the presence of compound such as isothiocyanates, thiophenics, glucosides, alkaloids, phenolics, tannins and fatty acids (Akhtar, 2000). Moreover, Tarraf *et al.* (2019) determined the fatty acids, linoleic acid methyl ester, oleic acid, erucic acid methyl ester, palmitic acid and searic acid in *C. colocynthis* oil which showed highly toxic effect on juveniles and eggs of *M. incognita in vitro*. They recommended this oil for formulation as new nematicide that could be used in controlling plant parasitic- nematodes.

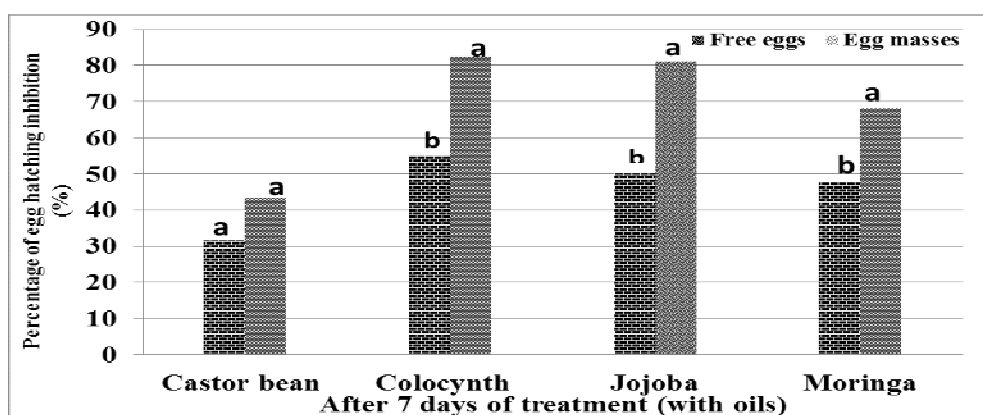


Fig. 1. Comparison between percentages of egg hatching inhibition in egg-masses and free eggs of *M. incognita* resulted after immersion in castor bean, colocynth, jojoba and moringa oil solutions at the seventh day post treatment. Results are average of the 3 concentrations.

** Different letters over bars in each of the tested oils indicate significant differences at $P \leq 0.05$ according to Duncan's multiple range test.

Table 3. Effect of certain commercial oils on juvenile mortality of the root-knot nematode, *M. incognita* at different interval periods during 7 days of exposure.

Tested oil	Concentration	Mortality (%) after exposure time				
		1	2	3	5	7
Castor bean	Standard solution (S)	0.0 ^d	5.2 ^{cd}	12.4 ^d	15.2 ^d	17.4 ^d
<i>Ricinus communis</i>	S/2	0.0 ^d	4.2 ^{de}	9.2 ^{de}	11.8 ^{de}	13.2 ^{de}
	S/4	0.0 ^d	1.2 ^e	5.0 ^c	8.6 ^e	6.8 ^e
Colocynth,	Standard solution (S)	2.4 ^a	10.0 ^a	25.2 ^a	36.4 ^a	43.0 ^a
<i>Citrullus colocynthis</i>	S/2	1.6 ^b	8.2 ^b	20.4 ^{bc}	29.2 ^b	37.0 ^b
	S/4	1.2 ^a	5.0 ^{cd}	14.8 ^d	22.8 ^c	25.2 ^c
Jojoba,	Standard solution (S)	1.6 ^b	8.2 ^b	19.8 ^{bc}	27.6 ^b	48.6 ^a
<i>Simmondsia chinensis</i>	S/2	1.4 ^{ab}	6.2 ^{cd}	17.6 ^{bc}	25.4 ^b	37.4 ^b
	S/4	1.0 ^c	3.8 ^{de}	12.8 ^d	20.0 ^c	28.8 ^{bc}
Moringa,	Standard solution (S)	2.4 ^a	10.0 ^a	22.0 ^b	28.2 ^b	31.0 ^{bc}
<i>Moringa oleifera</i>	S/2	1.0 ^c	8.0 ^b	18.0 ^{bc}	26.8 ^b	29.8 ^{bc}
	S/4	0.8 ^c	5.0 ^{cd}	12.2 ^d	16.4 ^d	20.8 ^d
Distilled water		0.0 ^d	1.4 ^e	3.4 ^f	4.2 ^f	5.2 ^f

*Reported numbers represent means of 5 replicates.

** Tested nematode was observed daily for mortality but only table contains data of 1,2,3,5 and 7 days.

***Different letter in the same column indicate significant differences ($P \leq 0.05$) according to Duncan's multiple range test.

These results revealed that colocynth and jojoba oils gave the best effects in reducing egg hatching and increasing juvenile mortality of *M.incognita* followed by moringa oil, while castor bean oil was the least effective oil. The study also showed that the ovicidal and larvicidal activities of the tested oil were dependent on concentration and time of exposure. These findings are in harmony with many authors who studied the nematicidal properties of the tested oils. However, these results are not completely confirmed with those reported by **Mostafa et al. (2017)**. They showed that castor oil gave the best results against *M. javanica* compared to camphor, black seed, sesame and jojoba oils. However, results in this study revealed that castor oil was the least effective oil.

The nematicidal mechanisms of medicinal plants as nematicides are not clear. Many plant extracts have been shown to inhibit acetylcholinesterase. Another possibility is that plant extracts or essential oils cause disruption in cell membrane of nematodes and affected its permeability (**Kayani et al., 2012**). Generally, the results of this present study are not conclusive. There is need for further research to ascertain the nematicidal ability of the tested oils under greenhouse and field conditions.

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خصائص زيوت البذور التجارية لبعض النباتات الطبية كمبيدات نيماتودية ضد فقس البيض وموت اليرقات لنيماتودا تعقد الجذور ميليدوجيني انكوجنيتا فى المختبر

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أظهرت التركيزات الثلاثة (القياسى ونصف القياسى وربع القياسى) لزيوت البذور التجارية المستخلصة بالضغط على البارد لكل من الخروع *Ricinus communis* والحنظل *Citrullus colocynthis* والجوجوبا *Simmondsia chinensis* والمورنجا *Moringa oleifera* تأثيرا كمبيدات نيماتودية ضد كتل البيض والبيض المفرد ويرقات الطور الثانى لنيماتودا تعقد الجذور *Meloidogyne incognita* تحت ظروف المعمل، فقد تأثر فقس البيض وموت اليرقات معنويا بنوع الزيت المختبر والتركيز وفترة التعريض حيث كانت النسبة المئوية لتثبيت الفقس عند تعريض خمسة من كتل البيض الحديثة والمتساوية فى الحجم أو ١٠٠ بيضة حرة للتركيز الموصى به لكل من زيت الحنظل والجوجوبا والمورنجا والخروع بعد ٧ أيام من المعاملة تعادل ٨٩,٧ (٦٣,٨) و ٨٨,٨ (٥٤,٤) و ٧٩,٨ (٥٢,٥) و ٤٣,٤ (٤١,٢) % على التوالي، وتناسب تثبيط الفقس عكسيا مع تخفيف الزيت المختبر، ومن ناحية أخرى كلما زادت فترة التعريض من يوم إلى سبعة أيام زاد بوضوح تأثير هذه الزيوت كمبيدات ضد البيض مع كل التركيزات المستخدمة فى معاملات أكياس البيض فى حين كان العكس صحيحا فى معاملات البيض المفرد، وأظهر التحليل الاحصائى أن كتل البيض أكثر حساسية للزيوت المختبرة مقارنة بالبيض الحر مع جميع الزيوت المستخدمة عند التركيزات الثلاثة، وبالمثل أظهرت الزيوت المختبرة فعالية معنوية ضد يرقات الطور الثانى لنيماتودا تعقد الجذور *M. incognita*، وكان زيت الجوجوبا هو الأكثر فعالية من بين الزيوت المختبرة يليه زيت الحنظل ثم زيت المورنجا بينما كان زيت الخروع هو أقل الزيوت فعالية، حيث كانت أعلى نسبة مئوية لموت اليرقات مع زيت الجوجوبا بعد ٧ أيام من المعاملة بزيت الجوجوبا هي ٤٨,٦ % يليه زيت الحنظل (٤٣,٠) % ثم زيت المورنجا (٣١,٠) % بينما كان زيت الخروع هو أقل الزيوت سمية بنسبة مئوية مقدارها (١٧,٤) %، واعتمدت نسبة موت اليرقات على التركيز ومدة التعريض أيضاً، وبصفة عامة كشفت هذه النتائج عن وجود تأثير قوى للزيوت المختبرة ضد أكياس البيض والبيض الحر والطور اليرقى الثانى لنيماتودا تعقد الجذور معمليا وهناك حاجة الى مزيد من الدراسات على هذه الزيوت تحت ظروف الصوبة والحقل.

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