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Impact of Nano-Technology in Enhancing Nematode Biocontrol Efficiency Via Jojoba Oil and Maintaining Root Environment

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ABSTRACT
In a greenhouse belong to Pomology Department, National Research Centre, Cairo, Egypt conducted the present work during 2022/2023aims of this study was to investigate the effect of nanotechnology on improving the efficiency of jojoba oil biological control of nematodes and root environmental protection. The investigated concentrations of treatments were divided into 5 groups (Control, Starkim, Jojoba 10 ml, Nano emulsion 5 ml and Nano emulsion 7 ml). The results obtained for both seasons showed that concentrations of Jojoba oil and Nano Jojoba oil (7ml/l) compared to the control and starkim group. However, the highest values apply to fresh weight, dry weight and water content as a result of Jojoba oil and Nano Jojoba oil (7ml/l). However, jojoba oil treatment both (original and nano-emulsion) surpassed control and starkimin nutrient uptake then followed by nano-emulsion of jojoba at 5ml/l. On the other hand, a positive correlation between Jojoba oil (crude and Nano-emulsion) on nematodes population, highest reduction percentages observed with strakim, nano-emulsion jojoba oil and crude jojoba oil, respectively. Moreover, jojoba oil applications more effective in reducing of galls on root than starkim. Results revealed that the reduction percentages of egg mass obtained by crude Jojoba oil at 10ml/l followed by nano-emulsion of Jojoba oil at 7 ml/l. Besides, for soil microbial activity treating with jojoba oil resulted in encouraging most studied growth performance parameters of infected grapevine with nematode. This study concluded that using nano-emulsion of these oils (Jojoba oil with 7 & 5%) can be used as effective alternative to commercially available formulation on nematode control, and eco-friendlier.

Keywords: Jojoba oil, nano emulsion, nematodes, nano-technology

1. Introduction
In current era, onset of green revolution emerged build on nano-technology. The size of one to a hundred nanometers is nanomaterials, which used in many targets in agricultural production (Saleh, 2020). Nano-materials may play a keen role in the Agro-chemical sector expansive raising its efficiency at low doses which lead to rein pollution sources in environment. Applying of those materials, enhance nutrition compounds, safe transfer of bioactive components and micronutrients, and food conservations. Moreover, nanotechnology may address several issues in the agriculture sector and offer an essential aid to protect our environment (Vijayakumar *et al.,* 2022). Nano-materials have been used widely, due to their sole properties for diverse programs, such as catalysis, water treatment, energy storage, medicine, agriculture, etc. (Bratovcic, 2019; Gajanan and Tijare, 2018; Khot *et al*., 2012). Whereas, the properties of these nanoparticles show superior results comparing to the original particles

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of the same material like increment in the surface area and physical strength (Kumar *et al.,* 2020). There are 2 factors reasoned nano-materials to become more effective than the same materials at normal magnitudes: this due to surface and quantum effects (Roduner, 2006). These and other factors make nano-materials reveal enhancing or novel mechanical, optical, thermal, magnetic, electronic as well as catalytic properties (Buzea *et al*., 2007; Lines, 2008; Gade *et al*., 2010).

One of the most important applications of nano-technology in Agriculture sector is pesticides. Nano-pesticides are nanostructures with size ranged between 1 to 200 nm, used to carry biochemical elements. Because of their exceptionalfeatures of these nano-pesticides, nanoparticles offer benefits when compared to free pesticides (Chaud *et al*., 2021).

For instances, nano-pesticides are extensively applied due to their effective role in saving agricultural budgets, increasing agricultural products, enlightening the nutrition and shelf life of foods, and achieving precision agriculture as mentioned by Sun *et al*. (2019).

In addition, Al-Samarrai (2012) mentioned that, nonmetal-based, which applied asnano-products using silica, zinc, zinc oxide, etc. have substantial properties providing solutions for controlling environmental pollution, animal diseases, plant diseases, etc. Nanoparticles considered a new and suitable candidate for bio-pesticides producing.

Additionally, nanotechnology was identified by Bratovcic *et al*. (2021). as an interdisciplinary study area with great potential for creating new tools for treating plant diseases and identifying pathogens. Additionally, they can help to attach plant roots to the organic matter and soil structure in the area, lowering chemical runoff and addressing environmental issues. Nano-pesticides were playing a role to both manage delivery of pesticides and achieve greater effects with a lower chemical dose. Also, the treatment of nano-pesticides aims to encourage effectiveness and durability of a pesticide and simultaneously to shrink the amount of active components present and minimize or eliminate any probable threats.

Although of aforementioned above, agro-chemical (both of pesticides and nano-pesticides) considered environmental pollution sources. Meanwhile, secondary metabolites and some plant extracts may play a keen role as natural pesticides. One of these natural plant products, jojoba oil that may use as substitutesto pesticides (nematicide) as it has the capability to manage mites and many insect species' insightful, fungal diseases as well as nematode management (Mostafa *et al*., 2017). However, it efficiency may be not enough to control pests and diseases. So, converting natural pesticides in nano-form may make considerable differences in its effectiveness. Whereas, Al-Samarrai, (2012) reported that, nanoparticles have been manufactured from secondary metabolites in plants through increase the effectiveness of therapeutic compounds which could decrease the activity and spread of plant disease organisms, while lessening side effects for being: rich source of bioactive chemicals, biodegradable in nature and non-polluting (eco-friendly). Also, in study of Clerici *et al*. (2018) showed that nano-structuring of applied oils with insecticidal activities is a promising apparatus in the fight against many insects as well as termites.

The application of Nano oils would enhance earlier studies on the biological and antibacterial properties of this Nano oils. (Elumalai *et al*., 2010). Therefore, expanding the use of Nano oils in the pest management industry could have positive effects for the environment and the economy (Bixby, 2011).

El-Shewy, (2018) mentioned that nano emulsion of was more operative than crude form Jojoba oil. Also, they draw attention that Nano emulsion slow-release-formulation could present a new tool of bio pesticides and this should be considered in IPM programs.

The depression of nematode population, egg mass by Jojoba oil resulting in host resistance due to accumulation of toxic by–products of decomposition as well as increase phenolic contents. The jojoba oil contains two glycosides with toxic effects (Kamal *et al*., 2009; Nagdi *et al*., 2017).

Indeed, a comprehensive valuation of the pros and cons that influence the activity and toxicity of nano-pesticides is critical for the safe and maintainable nanoparticles application in agriculture. Thereby current work aims to assess both of the efficiency and risk of the nano-Jojoba oil as natural nematicide.

2. Methods

2.1. Plant material

Current work was carried out during2022/2023at greenhouse of Pomology Dept., National Research Centre, and Zoology Department, Faculty of Science, Tanta University, Egypt. About eighty uniform fig seedlings (one year old) that infected with nematodes *Meloidogyne incognita*) were divided into 5 groups. Each group, that contains 16 seedlings, was subjected to different treatment as the following:

Group 1: Received water
Group 2: Received nematicide (commercial product starkim) at recommended dose every month
Group 3: Received Jojoba oil as soil application at 10 ml/L every month
Group 4: Received Nano-emulsion Jojoba oil as soil application at 7 ml/L every month
Group 5: Received Nano- emulsion Jojoba oil as soil application at 5 ml/L every month

2.2. Preparation of nano oil emulsion of jojoba oils

The oil used in this study was jojoba oils of natural grades were the oils extracted from jojoba seeds by press cooling methods. The emulsifying agents used were tween 20 and triethanolamine of high purity grade, and finally distilled water.

2.3. Apparatus

The high shear mixer used in this study was HAS 2003 SV25 ATORY MIXER The HSM Series are designed specifically for emulsion processes that contain oil and water phases such as cream, lotions, silicone emulsion, ice-cream, mayonnaise, margarine, yoghurt and cheese. It is commonly used in much dispersion in which powders are mixed in water such as a carbopol dispersion (CMC) or a type of agglomerating gum, or commonly known as "fish-eye". At the core of each HSM unit lies the patented 'V' type rotor & stator in either single or double vortex design which is key in high shear mixing for efficient emulsifying or homogenizing processes. Mixing will never be the same again with Multimix® HSM mixer.

The technical data of this mixer were explained in the following table.

Table 1: Technical data of mixer.

Model	HSM2003SV25
Mixing capacity	0.1-0.5 Liters
Machine dimensions (L*W*H)	350*360*770mm
Weight	15kg
Motor	0.5HP(0.37KW)
Power Supply	Single phase, 220V,50/60Hz)
Nominal speed	1000rpm&above(6000rpm under full load)
Speed range	0-6000rpm (variable speed electronically controlled)
Motor Adjustment	Electrical
Mixing component material	Food and medical grade stainless steel 316L
Rotor diameter/stator design	25mm/Single vortex
Machine base	Corrosion resistant aluminum base with height-adjustable non-slip rubber feet

2.4. Procedure

Olic acid is saponified with sodium hydroxide to produce sodium monooleate; tween 20 is added to the produced sodium monooleate soap with ratio of 1:1 to form the target surfactant. 750 gm of jojoba oil is mixed with 250 of the surfactant solution and mixed using magnetic stirrer for 5min. the homogenized oil/surfactant solution is ten subjected to high shear mixer at 3000rpm for 15mins. The generated mixture is added to water to the desired concentration with stirring to form the target nano oil in water emulsion (Fig1).

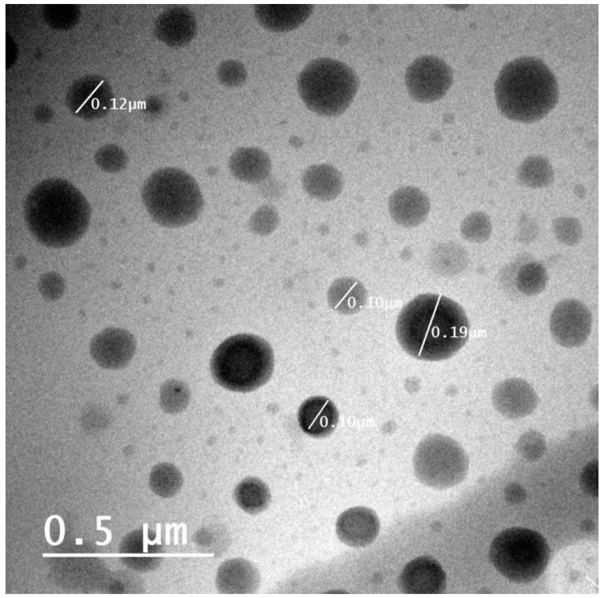

Fig. 1: particles size of nano-emulsion of Jojoba oil under electronic microscope (size ranged from 100 to 190nm).

2.5. Plant health Measurements

For measuring the effect of the different treatments on the vegetative growth, leaf fresh and dry weight (g) was measured. In the meantime, leaf water content was calculated as the difference between fresh and dry weight. Also, in a fresh sample of leaves, leaf chlorophyll content was recorded using Minolta chlorophyll meter (SPAD – 501). In addition, leaf mineral content was determined at the end of the experiment in both seasons. Leaf samples were dried and grinded for chemical analysis using digestion method according to Chapman and Pratt (1978).

Table 2: Methodology of different nutrients content assessment.

Variable			Methods used for sample preparation and analysis
Nitrogen	**(N)**	**(%)**	Micro – Kjelahl method, using boric acid modification, and distillation was done using Gerhardt apparatus
Phosphorus	**(P)**	**(%)**	**($NaHCO_3$-Extractable)** and measured using Spectrophotometer (Perkin-Elmer Lambda-2) according to Jackson (1973).
Potassium **Calcium**	**(K)** **(Ca)**	**(%)**	**(NH_4OAC-Extractable**) and measured using (EppendorofDr. Lang) Flame-photometer according to Chapman and Pratt (1978).
Magnesium **Iron** **Manganese** **Zinc** **Copper**	**(Mg)** **(Fe)** **(Mn)** **(Zn)** **(Cu)**	**(%)** **(ppm)**	**(DTPA-Extractable)** and measured using Atomic absorption (Perkin-Elmer 1100 B)according to Lindsay and Norvell (1978).

2.6. Nematodes parameters

To determine the extent of nematode reproduction and population, tumors in roots were recorded as well as egg masses/5g of roots. Hence the final number of nematodes was determined according to Barker (1985). The number of root-knot nematodes was evaluated and an average of eight readings was taken to determine the final numerical density of *M. incognita* in soil and was evaluated by the number of juveniles /250 g of soil. The Henderson and Tilton formula was used to calculate the percentage of nematode reduction (Puntener, 1981).

$$\textbf{Nematode reduction \%} = \{1 - (PTA/PTB \times PCB/PCA)\} \times 100$$

Although, **PTA** is the number present in the treated pots after treatment, **PTB** is the number present in the pots treated before treatment, **PCB** is the number present in the test dishes before treatment, and **PCA** is the number present in the test vessels after treatment.

2.7. Soil microbial activity

Soil microbial activity was investigated to evaluate the health status of the growth media. Soil samples were analyzed using the standard procedures in the laboratory at Microbial Genetics, National Research Centre (NRC).

The total microbial enzyme activities of soils were estimated based on the rate of fluorescein diacetate (FDA) hydrolytic activity according to the method described by Patel (2018) with some modifications. In brief: Two grams of Rhizosphere soil samples were placed (in triplicates) into 50-ml capped centrifuge tubes. A volume of 15 ml potassium phosphate buffer (60 mm, pH 7.6) and 0.2 mL of 0.1% FDA (in acetone) were added to initiate the reaction. Tubes were incubated horizontally at 30°C for 20 min in a rotary shaker. After incubation and color development, the reaction stopped by adding 15 mL of chloroform/methanol (2:1) and vortexing for one min. Tubes were subjected to centrifuge (5000 rpm for 10 min) to spin down soil and turbidity and separate chloroform layer. The developed colored fluorescein in the chloroform layer was spectrophotometrically measured at 490 nm against fluorescein standers. Total soil microbial activity was expressed as FDA hydrolysis values (µg of released fluorescein g^{-1} soil).

2.8. Statistical analysis

Data collected in the present experiments were analyzed as one way analysis of variance (ANOVA) and means were represented as combined analysis of both seasons. Data were statistically analyzed using the SAS (Statistical Analysis System) version 9.1 according to Gomez and Gomez (1984)**.** The least significant difference (L.S.D) at 0.05 was used to compare among the means of the different applications according to Snedecor Cochran WG (1989).

3. Results

Data in Table (3) revealed that Jojoba oil treatment (10ml/l) and Nano Jojoba oil emulsion (7ml/l) treatments produced the highest value of Fresh weight (12.82 & 10.79g respectively) comparing with control and starkim. In regard to leaf dry weight it was observed the same trend whereas both of Jojoba oil treatment (10ml/L) and Nano Jojoba oil emulsion (7ml/L) treatments produced the highest value of dry weight (4.69 &3.62 g respectively). For water content, data showed that the highest water content was observed in both of the same two treatments (nano-jojoba oil emulsion (7ml/L) followed by high level of crude jojoba oil (10ml /L). Meanwhile chlorophyll content, there were no markedly differences was observed among treatments.

Table 3: Effect of nano-emulsion of Jojoba oil on vegetative parameters of fig**.**

	F.W (g)	**D.W (g)**	**Water Content %**	**Chl.**
Control	2.82 e	1.96 e	30.5e	33.0a
Starkim	6.15 c	2.41 d	60.81c	36.1a
Jojoba 10 ml	12.82 a	4.69 a	63.42 b	33.9a
Nano emulsion 5 ml	5.12 d	2.52 c	50.78 d	33.5a
Nano emulsion 7 ml	10.79 b	3.62 b	66.45 a	35.9a
$LSD_{0.05}$	**0.06**	**0.03**	**0.06**	**n.s**

The treatment means are represented as the mean of all replicates for both seasons. Different letters within column are express for significant differences at LSD P<0.05

Data in Table 4 shown that the whole treatments that concern with nematode infection resulted in enhancement nutrient up take. However, Jojoba oil treatment (original form or nano-emulsion form) surpassed starkim (chemical nematicide) in all measured nutrients. Also, data indicated that positively reflected on nutrients content of (N, P, Ca, Mg, Fe, Mn, Zn, Cu) followed by nano-emulsion of jojoba at 5ml/l comparing with crude oil jojoba a 10ml/l.

Table 4: Effect of nano-emulsion of Jojoba oil on nutrient content in fig leaves

	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
			%				ppm		
Control	2.0d	0.46b	0.62d	1.70b	0.21c	110.7D	38d	12.6c	3c
Starkim	2.7c	0.59b	0.77c	1.80b	0.22cb	118.8C	44c	18.9b	4.5b
Jojoba oil	2.9b	1.30a	0.87cb	1.80b	0.26ba	124.2B	45c	18.9b	4.5b
Nano-Jojoba 5ml/l	3.0b	1.40a	0.95b	2.15a	0.26ba	126.9B	48b	18.9b	6.0a
Nano-Jojoba 7ml/l	3.4a	1.45a	1.10a	2.30a	0.27a	143.1A	51a	21.6a	6.0a
LSD 0.5%	**0.16**	**0.18**	**0.11**	**0.21**	**0.03**	**2.9**	**2.8**	**1.7**	**0.8**

The treatment means are represented as the mean of all replicates for both seasons. Different letters within column are express for significant differences at LSD $P<0.05$.

Results in Table (5) indicated a positive correlation between Jojoba oil (crude and Nano-emulsion) concentrations and also the times of repeat in relation to Reduction percentages.

The highest reduction percentages (in third month) were observed with starkim, nano-emulsion of Jojoba oil (90.7 & 87.2 respectively) followed with the highest concentration of crude jojoba oil (85.7). these findings indicated that Nano-emulsion of Jojoba oil at 7ml/l was more effective than crude Jojoba oil at 10ml/l against nematode (*Meloidogyne incognita*) population where the reduction percentages were (87.2 & 85.7 % respectively) and this efficiency raised by times of application.

Table 5: Effect of nano-emulsion of Jojoba oil on nematodes population Vsnematicide.

TRT	Initial	1 Month	% Red.	2 Months	% Red.	3 Months	% Red.
Control	1370a	1436a	---	1769a	---	2124a	---
Starkim	1518b	837b	47.4	640b	67.4	220c	90.7
Jojoba 10ml	1040c	177d	83.7	180e	86.6	230c	85.7
Jojoba 5ml	1130d	401c	66.1	477c	67.3	277b	84.2
Jojoba 7ml	1058c	371c	66.5	261d	80.9	210c	87.2

Each rate represents the average of three replicates. Means followed by the same letter(s) within a column are not significantly different ($P\geq0.05\%$) according to Duncan's multiple range test.

Table 6: Effect of nano-emulsion of Jojoba oil on gall/5g root population Vsnematicide

TRT	Initial	1 Month	% Red.	2 Months	% Red.	3 Months	% Red.
Control	106a	198a	---	250a	---	395a	---
Starkim	88b	120bc	27	119b	42.7	132b	59.8
Jojoba 10ml	103a	131b	31.9	106bc	56.4	115c	70
Jojoba 5ml	84b	97c	38.2	93c	53.1	115c	63.3
Jojoba 7ml	79b	95c	35.6	97c	47.9	112c	61.9

Each assessment represents average of three replicates. Means followed by the same letter(s) within a column are not significantly ($P\geq$ %0.05) different according to Duncan's Multiple range test.

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Data in table (6) presented that Jojoba oil applications were more effective than starkim in reducing of galls on root. Moreover, this reduction increased by times of repeating applications (1 to 3 times). The highest reduction was recorded with crude Jojoba oil at 10ml/l followed by nano-emulsion of jojoba oil at 5ml/l (63.3%) then by nano-emulsion at 7 ml/l.

Table 7: Effect of nano-emulsion of Jojoba oil on nematodes egg mass Vsnematicide.

TRT	Initial	1 Month	% Red.	2 Months	% Red.	3 Months	% Red.
Control	75a	174a	---	223a	---	343a	---
Starkim	62bc	91b	36.7	92b	50.1	111b	60.9
Jojoba 10ml	67ab	99b	36.3	79b	60.3	100b	67.4
Jojoba 7ml	51c	62c	47.6	80b	47.2	92bc	39.3
Jojoba 7ml	50c	70c	39.6	79b	46.9	88c	61.5

Each read represents average of three replicates. Means followed by the same letter(s) within a column is not significantly (P≥ %0.05) different according to Duncan's multiple range test.

Generally, from data in (table 7) were revealed that reduction percentages were increased by increasing times of application. And the highest reduction was achieved with crude Jojoba oil at 10ml/l followed by nano-emulsion of Jojoba oil at 7 ml/l which reached to 61.5 %.

3.1. Soil microbial activity

Extensive studies on Jojoba oil showed more effective accomplishments of biological activity as shown in Figures 2 and 3including antioxidant, antifungal, anti-rodent, insecticides and antimicrobial, activities.

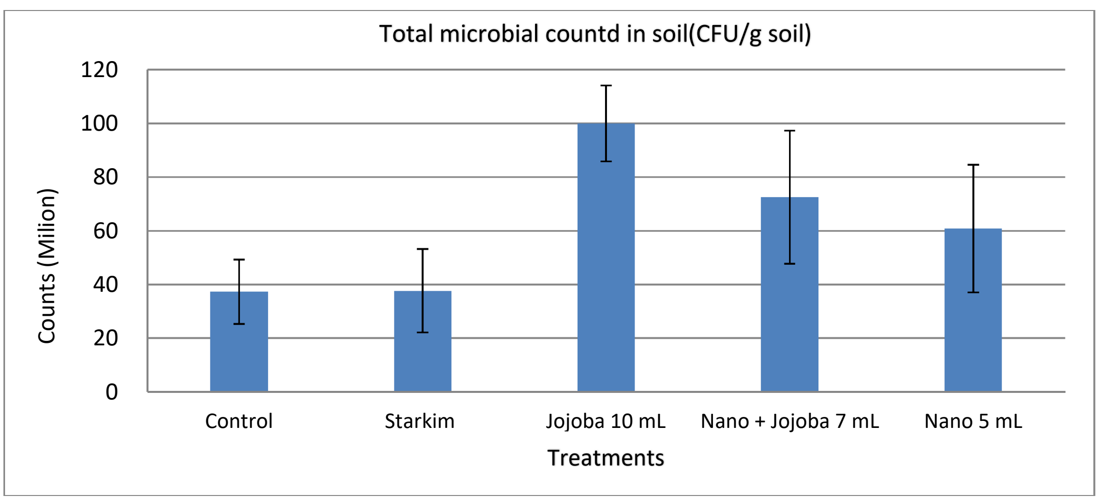

Fig. 2: The total microbial counts (CFU) of Fig Rhizosphere soils under different Jojoba oil nano-emulsion applications compared with pesticide treatment and control.

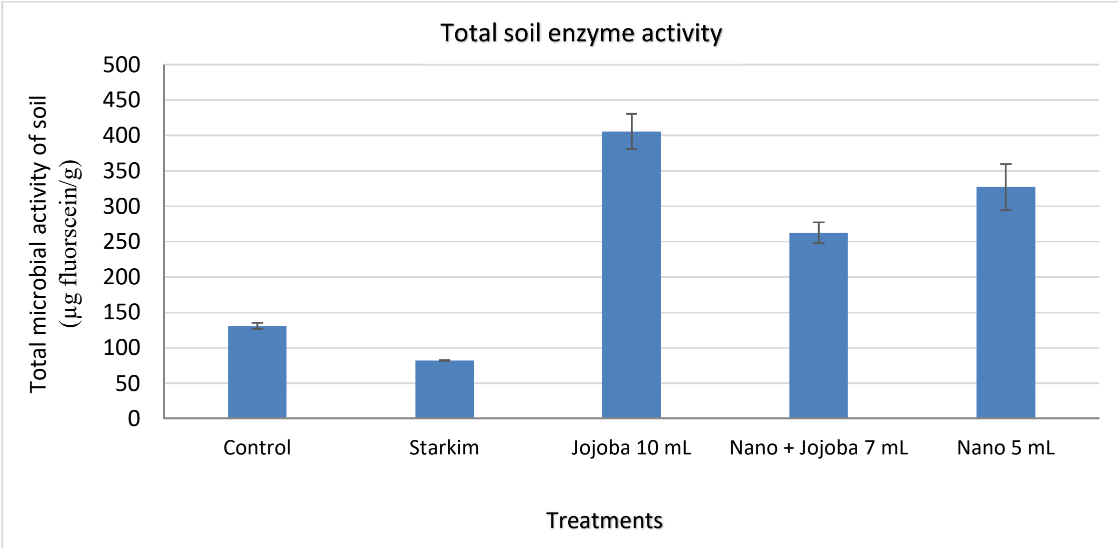

Fig. 3: The total microbial activity of Fig Rhizosphere soils under different Jojoba oil nano-emulsion applications compared with pesticide treatment and control.

4. Discussion

Jojoba oil treatment (10ml/l) and Nano Jojoba oil emulsion (7ml/l) treatments produced the highest value of Fresh weight, leaf dry weight and water content Meanwhile chlorophyll content, there were no markedly differences was observed among treatments (Table 3). Mostafa *et al.* (2017) observed that there are significant increments in all growth parameters of root knot nematode infected cucumber plants when treated with oil treatments (camphor, black seed, castor, sesame and jojoba as eco-friendly materials). Mervat *et al.,* (2012) both Jojoba and orange oils resulted in increasing of vegetative growth parameters of Thompson seedless grapevines during two studied seasons (2009 and 2010). Also, Ismail *et al.,* (2009) referred positive impact of Jojoba oil extraction that produced either by cold press or screw press on growth parameters under greenhouse conditions of cucumber to its effect on decline in *M. incognita* juveniles, galls, egg-masses and consequently, rate of nematode build-up infected chamomile. Chlorophyll results are in harmony with those obtained by Gendy *et al.* (2006); Shawky *et al.* (2010); Soliman *et al.* (2011) who mentioned that the motivating result of plant oils, bio-agents (i.e. jojoba oil) on leaf total chlorophyll content of infected Thompson seedless grapevines with nematode.

Table 4 shown that the whole treatments that concern with nematode infection resulted in enhancement nutrient up take. These data supported by findings of Mervat *et al.* (2012) who mentioned that Jojoba oil was among oils treatments that resulted in increments in percents of total N, P and K of leaves of infected Thompson seedless grapevines with nematode. Also, obtained results were in harmony of results of several studies particularly those of Hashem *et al.* (2008); El-Nagdi *et al.* (2009); El-Gendy and Shawky, (2006). Also El-Gendy and Shawky, (2006) who attributed the positive results of Jojoba to that bio-agents such as Jojoba oil caused the release of microelements and converted them to soluble forms of P, K and N which by their turn had a positive effect on the vegetative growth. Besides these bio-agents resulted in remarkable decrement in nematode population and positively reflected on the improvement observed in crop growth.

Table (5) indicate a positive correlation between Jojoba oil (crude and Nano-emulsion) concentrations and also the times of repeat in relation to Reduction percentages. The results agree with findings of Derbalah *et al.* (2014). who reported that Nano oils showed slight mortality rate against newly hatched larvae of Pectionophoragossypiella. Also, Adel *et al.* (2014) indicated that when geranium essential oil loaded Nano particles more effective on both larval and pupal development as well as longevity, female fecundity and the percentage of hatchability. Mervat *et al.* (2012) reported that of jojoba oil extract caused the highest reduction in nematode numbers in soil as well as root samples of Thompson seedless grapevines as soil application and the highest efficacy treatment reached to 83.8%, after the 3 months.

Data in table (6) presented that Jojoba oil applications were more effective than starkim in reducing of galls on root. These results were in harmony with achieved by Mervat *et al.* (2012) that Jojoba and organ oil treatments had a significant effect in reducing the total population and buildup of root-knot nematodes, *M. incognita* in both soil and off roots of "Thompson" seedless grapevines especially after the 3 months.

Data in (table 7) were revealed that reduction percentages were increased by increasing times of application. Obtained results was agreeing with findings of Refaat *et al.* (2020) who mentioned that nematode egg hatching and juvenile mortality were influenced by times of exposure to Jojoba oil. Also, Youssef & El-Nagdi (2004) reported that, jojoba oil extraction produced either by cold press or screw press successfully reduced *M. incognita* juveniles, galls, egg-masses. In addition, Mostafa *et al.* (2017) studied effect of five different plant essential oils (black seed, castor, camphor, sesame as well as jojoba as biodegradable materials) against *Meloidogyne javanica* infesting cucumber plants. All applied treatments significantly ($p \geq 0.05$) killed the nematode population, including the number of root tumors, the rate of nematode reproduction, and reduced the number of root-knot nematodes.

Extensive studies on Jojoba oil showed more effective accomplishments of biological activity as shown in Figures 2 and 3including antioxidant, antifungal, anti-rodent, insecticides and antimicrobial, activities. Generally, noted that El-Nagdi *et al*. (2017) jojoba oil is a specific kind of plant oil that contains many components that can boost development, nutritional status of plants, and resistance to nematode infection. It is one of the chemical pesticides alternatives.

Finally, they indicated that treating with jojoba oil resulted in encouraging most studied growth performance parameters of infected grapevine with nematode.

On the other hand, the effective effect of jojoba oil in killing a large number of root-knot nematodes can be due to its chemical content of specific compounds that have an exterminatory effect on nematodes such as oxygenated compounds that are characterized by their fatty properties that give them the great opportunity and ability to dissolve the cytoplasm membrane of filamentous cells and their overlapping functional groups. With nematode enzyme protein synthesis (Knoblock *et al.,* 1989). Moreover, some recent theoretical predictions regarding the mechanisms of action and effect of this group of these oils include denaturing and degrading the action of the enzyme, which helps to interfere with the electron flow in the respiratory chain of this pest or with the phosphorylation of adenosine diphosphate (Konstantopoulou *et al.,* 1994).

Mervat *et al.* (2012) showed that the good effect of jojoba oil and orange oil extract were among the most effective substances, even the most effective in reducing the total number of root-knot nematodes in both soil and roots until the time of harvesting the crop under study.

The obtained results are agreeing with El-Nagdi, (2005); El-Gendy and Shawky, (2006); Shawky *et al.,* 2010) who referred the positive effects of Jojoba oil as nematicidal may be illustrated in light of this fact (Egyptian jojoba oil is composed of Eicosenyloleate (C-38, 7%), Eicosenyleicosenoate (C-40, 30%), Docosenyleicosenoate (C-42, 52%), Eicosenyldocosenoate (C-42, 9%) and Docosenyldocoseno ate (C-44, 2%). These components can improve the biological activities against the root knot nematodes (Shawky*et al.,* 2010). As these oils have a high ability to dissolve the cytoplasmic membrane of filamentous cells, which affects their functional groups, which interferes with the protein composition of nematode enzymes (Knoblock *et al.,* 1989). In addition to this effective effect, there are some scientific hypotheses related to the mechanisms of effectiveness and effect of these vegetable oils, which include and help in changing the nature and decomposition of enzymes, as well as interfering with the electron flow in the respiratory chain of that pest or with the phosphorylation of adenosine diphosphate (Konstantopoulou *et al.,* 1994).

It also appears that these essential oils, which are incorporated into the nanoemulsions, try to enter and penetrate faster into the microbial membranes due to the increased area available per unit weight of these nanomaterials. This action and effect allows reducing the concentration, which achieves an equivalent or greater microbial effect than conventional emulsions (Odriozola-Serrano, 2014) [44].

Also, Mustafa and Bin-hussein (2020) agrochemicals based on nano-emulsions have been shown to improve the solubility of active components, agrochemical bioavailability, stability, and wet ability features during application, leading to greater efficacy for pest control and treatment.

3. Conclusion

Recently natural oils received more attention such as Jojoba oil, where it used bio-control eco-friendly agent (toxicants, repellents, growth regulators and Anti-feedant) for nematode. In addition, nano-emulsion of these oils (i.e. Jojoba oil with 7 & 5%) can be used as effective alternative to commercially available formulation on nematode control, and eco-friendlier.

Abbreviations

fluorescein diacetate (FDA), high shear mixer (HSM)

References

Adel, M., W.A. Atwa, M.L. Hassan, N.Y. Salem, D.S Farghaly and S.S. Ibrahim, 2014. Biological activity and field persistence of Pelargonium graveolens (Geraniales: Geraniaceae) loaded Solid lipid Nanoparticles (SLNs) on Phthorimaeaoperculenlla (Zeller) (PTM) (Lepidoptera: Gelechiidae). International journal of science and Research, 4(11): 514-520.

Al-Samarrai, A.M., 2012. Nanoparticles as alternative to pesticides in management plant diseases—a review. Int. J. Sci. Res. Publ., 2(4):261–264.

Barker, K.R., 1985. Nematode extraction and bioassay. In: Barker KR, Carter CC, Sasser JN (eds) Advanced treatise on Meloidogyne Vol. 11- Nematology. North Carolina State Univ. Graphics, Raleigh, 19.

Bixby, A.J.B., 2011. Biological control of the black cutworm, Agrotisipsilon (Lepidoptera: Noctuidae) and Entophyte mediated tritrophic interactions in turf grass. Doctoral Dissertations, University of Kentucky.

Bratovcic, A., 2019. Different applications of nano materials and their impact on the environment. Int J Mater Sci Eng. 5:1–7.

Bratovcic, A., W. Hikal, H. Said-Al Ahl, K. Tkachenko, R. Baeshen, A. Sabra, and H. Sany, 2021. Nanopesticides and Nanofertilizers and Agricultural Development: Scopes, Advances and Applications. Open Journal of Ecology, 11: 301-316. https://doi.org/10.4236/oje.2021.114022

Buzea, C., I.I. Pacheco, and K. Robbie, 2007. Nanomaterials and nanoparticles: sources and toxicity. Biointerphases. 2(4):MR17–71.

Chapman, H.D. and P.E. Pratt, 1978. Method of analysis for soil plant and water. University of California, Dep. Agric. Sci. USA, 1-309.

Chaud, M.V., S.B. Eliana, , Z. Aleksandra , S. Patricia , B. Fernando , O. J. Jose, and A. Thais , 2021. Nanopesticides in Agriculture: Benefits and Challenge in Agricultural Productivity, Toxicological Risks to Human Health and Environment. Toxics, 9(6):131. https://doi.org/10.3390/toxics9060131

Clerici, D.J., M.E. de Souza, M.Q. Priscilla , and W. Roger, 2018. Effects of nanostructured essential oils against subterranean termites (Coptotermes gestroi). Journal of Applied Entomology 142(4).https://doi.org/10.1111/jen.12494.

Derbalah, A.S., A.A. Khidr, Hemat, Z. Moustafa and A. Taman, 2014. Laboratory Evaluation of some Non-conventional Pest Control Agents against the Pink Bollworm Pectinophora gossypiella (Saunders). Egyptian Journal of Biological Pest Control, 24(2): 363-368.

El-Gendy, Rafaat S.S. and Shawky, Samaa M., 2006. Efficacy of some natural plants and bioagents to minimize the population of root-knot nematode; Melidogyne incognita in superior seedless vineyards and its reflection on vine growth and yield. 1st International Egyptian – Jordanian Conference on Biotechnology and Sustainable Development: Current Status and Future Scenarios, 264–280.

El-Nagdi, W.M.A., 2005. Comparative efficacy of aqueous jojoba dry leaves extract and jojoba & castor oil commercial product on the root-knot, Meloidogyne incognita infecting pepper plant. Egypt. J. Agric. Res., NRC, 2 (1): 425-437.

El-Nagdi, W.M.A., Amal, A., Ahmed and Gehan, H.S. Mahmoud, 2009. Evaluation of some medicinal plant oils and a nematicide for controlling virus-transmitted nematode and other nematodes on table grapes. Egypt. J. Hort., 36 (1): 47-69

El-Nagdi, W.M.A., O.M. Hafez, and R.A. Taha, 2017. Efficiency of jojoba oil and bio-nematicide on Meloidogyne incognita and performance of flame seedless grapevine cuttings. Special issue, Agric. EngInt: CIGR Journal Open access at http://www.cigrjournal.org, 118-124.

El-Shewy, A.M., 2018. Efficacy of Jojoba oil compared to its Nano particles on biological and physiological aspects of Agrotis ipsilon and its histological effect on albino rats. Middle East Journal of Applied Sciences, 08(04): 1404-1412.

Elumalai, K., K. Krishnappa, A. Anandan, M. Govindarajan, and T. Mathivanan, 2010. Larvicidal and ovicidal activity of seven essential oils against Spodoptera litura (Lepidoptera: Noctuidae). International Journal of Recent Scientific Research, 008-014.

Gade, A., A. Ingle, C. Whiteley, and M. Rai, 2010. Mycogenic metal nanoparticles: progress and applications. Biotechnol. Lett. 32(5):593–600.

Gajanan, K., and S.N. Tijare, 2018. Applications of nanomaterials. Mater Today Proc., 5(1):1093–6.

Gomez and Gomez, 1984. Statistical procedures for agricultural research. John Wiley and Sons, New York.

Hashem, M., A.M. Yasser, N.M. Omran, and M.A. Sallam, 2008. Efficacy of yeasts in the management of root-knot nematode Meloidogyne incognita, in Flame Seedless grapevines and the consequent effect on the productivity of the vines. Biocontrol Sci. Technol., 18 (4):357-375.

Ismail A.E., M.M. Mohamed, and S.A. Mahfouz, 2009. Effect of waste residues from black seed and jojoba seed oil extractionas organic amendments on Meloidogyne incognita, growth and oil of chamomile. Pak. J. Nematol., 27:297-307.

Jackson, M.I., 1973. Soil chemical analysis Prentice Hal Inc. N.J, U.S.A.

Kamal, A.M., A. Magd-El-Morsi, and M.A.A. Gaid, 2009. Management of tomato root-knot nematode Meloidogyne incognita by plant extract and essential oils. The Plant Pathology Journal, 25(2): 189–192.

Khot, L.R., S. Sankaran, J.M. Maja, R. Ehsani, and E.W. Schuster, 2012. Applications of nanomaterials in agricultural production and crop protection: a review. Crop Prot., 35:64–70. https://doi.org/10.1016/j.cropro.2012.01.007

Knoblock, K., A. Pauli, B. Iberl, H. Weigand, and N. Weis, 1989. Antibacterial and antifungal properties of essential oil components. Journal of Essential Oil Research, 1: 119–128.

Konstantopoulou, I., L. Vassilopoulou, P. Mavraganitispidou, and Z.G. Scouras, 1994. Insecticidal effects of essential oils. A study of essential oils extracted from eleven Greek aromatic plants on Drosophila auroria. Experientia, 48: 616–619.

Kumar, P., P. Mahajan, R. Kaur, and S. Gautam, 2020. Nanotechnology and its challenges in the food sector: A review. Materials Today Chemistry, 17: 100332.

Lindsay, W.L., and W.A. Norvell, 1978. Development of a DTPA micronutrient soil tests for Zinc, iron, manganese and copper. Soil Sci. Amer. J., 42: 421-428.

Lines, M.G., 2008. Nanomaterials for practical functional uses. J. Alloys Compd., 449(1–2):242–5.

Mervat A.A., Samaa M. Shawky, Ghada S. Shaker, 2012. Plant oil and plant aqueous extracts in controlling *Meloidogyne incognita* on growth and yield of grapevines. Annals of Agricultural Sciences, 57(1): 7-18.

Mostafa, M.A., N.A. Mahmoud, A.E. Anany, and A.M. El-Sagheer, 2017. Plant essential oils as eco-friendly management tools for root knot nematode on cucumber plants. V The Journal of Zoology Studies, 4(1): 01-05.

Mustafa, I., and M.Z. Bin-Hussein, 2020. Synthesis and Technology of Nanoemulsion-Based Pesticide Formulation. Nanomaterials, 10(8):1608. https://doi.org/10.3390/nano10081608

Odriozola-Serrano, I., G. Oms-Oliu, and O. Martin-Belloso, 2014. Nanoemulsion-based delivery systems to improve functionality of lipophilic components. Front. Nutr., 1: https://doi.org/10.3389/fnut.2014.00024.

Patel, P.N., 2018. Fluorescein Diacetate (FDA): Measure of Total Microbial Activity and as Indicator of Soil Quality. International Journal of Current Microbiology and Applied Sciences, 7(06):2103-2107. DOI:10.20546/ijcmas.2018.706.249June 2018

Puntener, W., 1981. Manual for field trials in plant protection paste. Agric. Division. Ciba-Geigy limited, Swizerland, 205.

Refaat M.M., M.E. Mahrous, R.M. El-Ashry and A. M. ElMarzoky, 2020. Nematicidal potential of some botanicals against *Meloidogyne Incognita* in vitro and in vivo. Bioscience Research, 17(1): 157-164.

Roduner, E., 2006. Size matters: why nanomaterials are different. Chem. Soc. Rev.,35(7):583–92.

Saleh, T.A., 2020. Nanomaterials: Classification, properties, and environmental toxicities. Environmental Technology & Innovation, 20: 101067.

Shawky, Samaa M., A.E. Khalil, and M. Soliman, Manal, 2010. Non chemical control of root-knot nematode; *Meloidogyne javanica* on peanut in Egypt. Zagazig J. Agric. Res. 37 (1):185–206.

Snedecor, G.W., and W.G. Cochran, 1989. Statistical methods,8thEdn. Ames: Iowa State Univ. Press Iowa, 54: 71-82.

Soliman, A., Sh. Samaa, M. Shawky, and M.N.A. Omar, 2011. Efficency of bioagents in controlling root knot-nematode on Acacia plants in Egypt. American-Eurasian J. Agric. Environ. Sci., 10 (2): 223-229.

Sun Y., J. Liang, L. Tang, H. Li, Y. Zhu, D. Jiang, B. Song, M. Chen, and Z. Guangming, 2019. Nano-pesticides: A great challenge for biodiversity?. Nanotoday, 28: 100757. https://doi.org/10.1016/j.nantod.2019.06.003

Vijayakumar, M.D., G.J. Surendhar, L. Natrayan, P. Pravin, P.M. Patil, R. Bupathi, and P. Prabhu, 2022. Evolution and Recent Scenario of Nanotechnology in Agriculture and Food Industries. Journal Nanomaterials, 1-17. https://doi.org/10.1155/2022/1280411

Youssef, M.M.A. and W.M. El-Nagdi, 2004. Cellular alteration of root knot nematode *Meloidogyne incognita* infected squash plant and intercropping sesame plant or sesame oil seed cake as control measures. Egypt. J. Phytopathol., 32: 77-85.