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Potential of Vermicompost and Vermicompost Tea to Improve Yield and Quality of Kalamata Olive Trees Infected with Root-Knot Nematode, *Meloidogyne incognita*

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Abstract: The present experiment was conducted during two successive growing seasons 2017 and 2018 to study the effect of vermicompost (VC) (10, 15, 20 and 25 kg/tree/year) and vermicompost tea (VCT) (2, 4, 6 and 8 L/tree/month) on root-knot nematode (*Meloidogyne incognita)*, vegetative growth (shoot length, leaf area, leaves density/m and leaf dry weight), fruit and yield characteristics (fruit density, yield/tree, fruit weight, flesh weight, flesh/fruit weight, fruit length and fruit diameter) and leaf mineral content of Kalamata olive tree (30 trees) cultivated in sandy soil at private olive grove in Cairo Alex. Desert Road, Giza, Egypt. Results showed that, nematode population, root galling and egg masses number of *M. incognita* were greatly reduced by all tested treatments especially with high rates of vermicompost and vermicompost tea. In addition, trees treated with VC (25 Kg/tree/year) gave significantly highest values of shoot length, leaf area and leaf dry weight. However, the highest values of fruit density, yield/tree, fruit weight, flesh/fruit weight, fruit length and fruit diameter were induced by VC (25 Kg/tree/year) followed by VCT (8 L/tree/month) and VC (20 kg/tree/year). Moreover, the highest values of leaf mineral contents were obtained by VC (25 Kg/tree/year). Finally, it can be concluded that application of vermicompost at 25 kg VC/tree/year was the best in terms of tree vegetative growth, productivity, Kalamata fruit quality and reduce nematode population, root galling and egg masses number. Moreover, (8 L VCT/tree/month) achieved the highest net profit and economic values (32124 LE/feddan).

Key words: Olive・Kalamata・Vermicompost・Vermicompost tea・Root-knot nematode and *Meloidogyne incognita*

INTRODUCTION

Olive (*Olea europaea* L.) is one of the most important trees in the Mediterranean Basin, because it occupies significant acreage, which has longevity and adaptation to climatic conditions, also the olive fruits, are commercially valuable for oil content or for edible flesh. The olive trees productivity is generally low due to the poor soil fertility and low water holding capacity [1]. Olive trees serve as hosts to a large number of plant-parasitic nematodes, of which root-knot nematodes (*Meloidogyne* spp.), root-lesion nematodes (*Pratylenchus* spp.), spiral nematodes (*Helicotylenchus* spp.) and *Mesocriconema xenoplax* (Raski) are widely distributed [2, 3].

The root-knot nematode, *M. incognita* is the most destructive plant parasitic nematode worldwide, causing serious problems to a number of economically important agriculture crops, especially in developing countries [4]. *Meloidogyne* species known to damage olive trees are well adapted to temperate and subtropical areas, they occur in sporadic distributions in wild olive, olive nurseries and established orchards and cause heavy root galling and plant growth retardation in pathogenicity tests [5, 6].

The economic importance of these nematodes in olive cultivation has increased in recent years because most chemical agents used for the control of plant-parasitic nematodes have been banned (European legislation

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(CE 396/2005, 1095/2007, 33 and 299/2008 and 1107/2009) due to environmental and health concerns. Recently, many researches have focused on organic soil amendments, biological control, naturally occurring nematicides and plant breeding for nematode resistance [7]. The roles of organic amendments in the management of plant parasitic nematodes have been reported and reviewed [8, 9]. The mechanisms of organic matters in controlling the nematodes include the existence of toxic metabolites, the increase in activities of antagonistic microbes and the induction of plant resistance [10, 8]. The efficiency of organic fertilizers to increase soil microbiological activity has been discussed [11].

Vermicompost is a material, which is produced by the absorption of organic material by worms, are used to convert organic materials (usually wastes) into a humus-like material known as vermin-compost. The goal is to process the material as quickly and efficiently as possible that have positive effects on environment such as plant growth and soil recovery higher than compost [12, 13]. The vermicompost application affects the microbial activity in the production material and relatively, the enzyme activities positively. Vermicompost (VC) as well as vermicompost tea (VCT) significantly decreased *G. rostochiensis* propagules [14]. Many scientists have also reported that drenching VCT which is an aqueous extract of vermicompost suppressed plant-parasitic nematodes such as *Meloidogyne* spp. and *Rotylenchulus reniformis* in different crops [15, 16, 17]. The beneficial effect of vermicompost may be due to the abundant organic acids substances such as humic acids, hormones such as N-indole-3-acetic acid (IAA). Cytokinin and gibberellins found in VCT could suppress nematode infestation [10, 18]. Also, Uptake of soluble phenolic compounds from vermicompost, by the plant tissues makes them unpalatable thereby affecting pest rates of reproduction and survival [19]. Vermicompost has been found to have beneficial effects when used as soil amendments in field studies. Likewise, some studies showed that vermicompost water-extracts, used as substrate amendments, also promote the growth of strawberries [20].

Specific objectives of this research were to compare the ability of vermicompost and vermicompost tea on mitigating the damage of *M. incognita* in terms of egg hatching, vermiform stages mobility and root penetration as well as their ability to improve production and quality of Kalamata olive trees.

MATERIALS AND METHODS

The experiment was conducted with collaboration of Horticulture Res. Inst. and Plant Pathology Res. Inst., Agri. Res. Centre in private olive orchard in Cairo Alex. Desert Road, Giza, Egypt. Was located at 64 Kilometer distant from Cairo; situated at (30°268` 215``) N latitude, (30°806` 534``) E longitude at growing seasons 2017 and 2018, to illustrate the role of vermicompost and vermicompost tea to control the root-knot nematode, *M. incognita* and improving yield and quality of Kalamata olive trees (9 years old).

The trees were planted at 6×4 meter apart (175 trees/fed.), in sandy soil, under drip irrigation system with the same amount of water (2400 m^3/fed.), 2 drippers/tree and discharge 4 liters/hour. The experiment was subjected to the regularly recommended culture practices during the two years of the study. Solid compost and vermicompost derived from municipal green wastes and obtained from Central Laboratory for Organic Agriculture - ARC - Egypt. (Vermicomposting, it is a mesophilic process utilizing microorganisms and earthworms. Earthworms feeds on the organic waste material and passe it through their digestive system and give out in a granular form (cocoons) which is known as vermicompost). Compost and vermicompost was added on soil surface at the two sides of the plants and covered with 10 cm soil in the winter service and vermicompost tea derived from the same vermicompost with added water (1:10, 10% "aerobic fermentation") were applied as soil drench at various concentrations and times, VCT were added to each tree by irrigation beside the tree from January to October.

A total of 60 soil samples were randomly collected from rhizosphere of all olive trees (three samples/ treatment), at Dec. 2016 before conducting the exp. and in June during growing seasons. Samples were obtained by digging the soil to a depth of about 15-20 cm from the rhizosphere of the growing trees. Soil samples of about one kg each were placed in plastic bags and send directly to the Nematology Laboratory of Nematode Diseases Department, Plant Pathology Research Institute, ARC and kept in the refrigerator at 4°c until nematode extraction.

Soil samples were thoroughly mixed and a volume of 250g soil was used to extract nematodes according to sieving and modified Baermann technique [21]. Each soil sample was soaked in tap water for 20 minutes and then

Table 1: Mechanical and chemical analysis of the experimental soil

Mechanical analyses (%)									
Coarse sand		Fine sand			Silt		Clay		Texture class
38.4		43.3			13.0		5.3		Sandy
Chemical analyses (Anions and Cations) mg/L									
pH	EC ds /m	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
7.99	0.56	1.8	0.7	2.5	0.25	--	1.65	2.51	1.43
Available nutrients (mq/ Kg Soil)									
N					P				K
127.3					15.8				99.8

Table 2: Physical and chemical analysis of the used compost

	Bulk density	Moisture	pH	EC	Total	Ammonium	Nitrate	O. M.	O. C.	Ach	C/N	P2O5	K2O
Unit	Kg m^{-3}	%	(10:1)	(10:1)	N%	N ppm	N ppm	%	%	%	ratio	%	%
value	705	32	8.2	2.45	1.20	256	142	31.5	18	68	1:15	0.65	0.85

Table 3: Chemical analysis of vermicompost

	w. of m^3	Moisture	pH	EC	Total	Ammonium	Nitrate	O. M.	O. C.	Ach	C/N	P2O5	K2O
Unit	Kg	%	(10:1)	(10:1)	N%	N ppm	N ppm	%	%	%	ratio	%	%
value	1070	60	8.5	0.85	1.35	67	179	31.54	18.29	68.46	1:14	0.33	0.99

Table 4: Chemical analysis of vermicompost tea

Unit	pH (10:1)	EC (ds/m)	O.M. %	O.C.%	C/N ratio	Total N %	P (mg/l)	K (mg/l)
Value	7.2	1.85	14.85	8.62	1:6.54	0.45	1118	1703

the mixture was agitated. Direct sieving through 60 and 325 mesh sieves was employed. Resulting suspension was transferred on a soft tissue paper fitted on the Baermann pan for separating active nematodes from soil particles and water in the plate containing nematodes was transferred to a plastic cup 48 hr later [21]. Nematodes were extracted from soil using sieving and modified Baermann technique [21]. Roots (1g) were stained in 0.01 acid fuchsin lactic acid Byrd *et al.,* [22] and examined for the developmental stages, females, galls and egg masses under stereomicroscope. Root galling or egg masses were rated on a scale of 0-5 where 0= no galls or egg masses, 1= 1-2 galls or egg masses, 2= 3-10 galls or egg masses, 3= 11-30 galls or egg masses, 4= 31-100 galls or egg masses, 5= more than 100 galls or egg masses per root system [23].

The experiment included ten treatments, which were:

- T1: control (fertilization farm program with 25 kg compost/tree/year),
- T2: 10 kg vermicompost (VC)/tree/year
- T3: 15 kg vermicompost (VC)/tree/year
- T4: 20 kg vermicompost (VC)/tree/year
- T5: 25 kg vermicompost (VC)/tree/year
- T6: 2 L vermicompost tea (VCT)/tree/month
- T7: 4 L vermicompost tea (VCT)/tree/month
- T8: 6 L vermicompost tea (VCT)/tree/month
- T9: 8 L vermicompost tea (VCT)/tree/month
- T10: chemical nematicides "Nemaphos 40% EC" (active ingredient: Fenamephos) at 5 L/feddan by irrigation beside the tree and after 2 months the second dose 5L/feddan + fertilization farm program).

Soil, compost, vermicompost and vermicompost tea samples were analysed for various physic-chemical properties using standard methods, ICARDA manual [24] and were summarized in Tables (1, 2, 3 and 4).

The Following Parameters Were Estimated:

Vegetative Growth Measurements: Sixteen healthy one year old shoots/tree (4 in each tree direction) were selected randomly and labeled and the following measurements were carried out: Shoot Length (cm): Were measured at the end of each growing season during first of November. Leaf area (cm^2): were measured by using the Planimeter. Leaves density/m: defined as the total number of leaves per unit area. Dry leaves weight (g): fresh mature leaves samples were selected and weighted then dried at 70°C till constant weight. The average dry weight was determined [25].

Fruit and Yield Characteristics: Forty fruits from each studied replicates at maturity stage has been described and identified by morphology description of Cimato and

Attilio [26], fruit density/m: total number of fruits per meter, yield/tree (kg): the yield per tree was measured at maturity stage at mid of November, fruit weight (g), flesh weight (g), flesh/fruit weight (%), fruit dimension “length and diameter” (cm) were measured.

Chemical Analysis

Leaf Mineral Content*:* Sample of leaves was taken from middle position (4th and 5th leaves) of non-fruiting shoots from each replicate tree in July of both seasons 2017 and 2018. Samples were washed several times with tap water, thereafter with distilled water and dried at 70°C in electrical furnace until a constant weight and finally ground. Total nitrogen was determined by modified micro-Kjeldahl method as outlined by Black *et al.*, [27]; Phosphorus content was determined calorimetrically according to Chapman and Pratt [28] and Potassium content was determined by using flame photometer [29].

Defense Related Compounds:

Total Phenol (TP): In fresh leaves of olives were measured [30].

Enzymes Activity: Enzyme extracts were prepared [31]. Fresh leaves (0.5 g) of each treatment were ground in 3ml Na-phosphate buffer at pH 6.8 in a mortar and then centrifuged at 1.500 g/20 min at 6°C. The resultant supernatant fluids were processed for enzyme assays.

Peroxidase Activity (PO): Peroxidase was assayed using photochemical method [32]. The reaction mixture was added as the following sequences, 1500 ml phosphate buffer.,480 ml hydrogen peroxidase., 1000 ml pyrogallol, 20 ml sample extract. The increasing in the absorbance at 430 nm was recorded against blank with phosphate buffer instead of enzyme extract. One unit of enzyme activity was defined as the amount of the enzyme, which changing the optical density at 430 nm per min. at 25°C under standard assay conditions. Specific activity was expressed in units by dividing it to mg protein.

Polyphenol Oxidase (PPO): Polyphenol oxidase was assayed using photochemical method [33]. The reaction mixture was added as the following sequences: 2.7 ml potassium phosphate buffer 90.05M, pH 6.2, 0.25 ml of 0.25 M catechol, 0.05 ml of enzyme extract. The increasing in absorbance at 420 nm was measured. One unit of enzyme activity is defined as the amount of the enzyme that causes an increase of 0.001 absorbance unit per minute at 25°C.

Economic Evaluation: Economics feasibility/feddan of vermicompost and vermicompost tea treatments were calculated according to Heady and Dillon [34] as follows:

- Total cost of adding vermicompost/Feddan = the price of vermicompost (3 LE/kg) × amount of adding/tree × number of trees 175/Feddan.
- Total cost of adding vermicompost tea/Feddan = the price of vermicompost tea (L) × amount of adding/tree × no. of adding times a year (10) × number of trees 175/Feddan.
  1 kg vermicompost = 10 L vermicompost tea (1:10).
- The cost of chemical nematode pesticides/feddan = the price of nematode pesticides “Nemaphos” × amount of adding/feddan. = 3500 × 2= 7000 LE).
- Fixed cost of agriculture practices = (mineral fertilization, irrigation, pruning, labors, pesticides, harvesting and others) equal for all treatments = 15000 LE/feddan.
  The price of Kalamata olive fruits = 16 LE/kg in the average of 2017 and 2018 seasons, according to farm gate price.
- Total gross income = total yield (kg)/Feddan × total price.
- Net profit (LE) = total gross income-total cost.

Data Analysis: The experimental design was randomized complete block design (RCBD) with three replicates for each treatment and each replicate will represented by one tree (total 30 trees). The obtained data were statistically analyzed [35]. Duncan's multiple range tests effect was used to compare treatment means [36].

RESULTS AND DISCUSSION

Impact of Vermicompost and Vermicompost Tea on Vegetative Growth Characters of Kalamata Olive Trees Grown in Soil Naturally Infested with *Meloidogyne incognita* in 2017 and 2018 Seasons: The tested rates of vermicompost significantly affected the vegetative growth characters of Kalamata olive trees in both seasons (Table 5). The highest values of shoot length, leaf area, leaf density and leaf dry weight were induced by VC at 25 kg/tree/year while, the least values of such criteria were recorded by VC at 10 kg/tree/year, VCT at 2 L/tree/year and Nemaphos in both seasons. The same phenomenon was also described by Arshad Ullah *et al.,* [1] on olive transplant, Shukla *et al.,* [37] on Guava, Pareek *et al.,* [38] on Kinnow Mandarin and Mahmud *et al.,* [39] on pineapple, who reported that, vegetative parameters were increased with the addition of vermicompost and this may

Table 5: Impact of vermicompost and vermicompost tea on vegetative growth of Kalamata olive trees infected with *Meloidogyne incognita* in 2017 and 2018 seasons

	Shoot length		Leaf area (cm^2)		Leaves density/m		Leaf dry weight (g)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (25 kg C*/tree)	15.20^{bc}	17.33^{bc}	10.05^{ab}	7.82^{bc}	129.67^{a}	133.92^{a}	8.07^{bc}	8.04^{de}
10 Kg VC** /tree/year	11.97^{cd}	17.97^{bc}	10.24^{ab}	7.89^{abc}	121.67^{a}	122.76^{ab}	8.97^{bc}	8.75^{cde}
15 Kg VC /tree/year	17.13^{bc}	22.00^{bc}	10.53^{ab}	8.20^{abc}	92.67^{a}	122.01^{ab}	10.20^{ab}	10.68^{bc}
20 Kg VC /tree/year	18.33^{ab}	22.00^{bc}	11.04^{ab}	8.74^{ab}	112.67^{a}	124.00^{ab}	10.00^{ab}	9.62^{bcd}
25 Kg VC /tree/year	23.94^{a}	24.78^{a}	11.57^{a}	8.84^{a}	103.23^{a}	110.17^{ab}	12.33^{a}	11.71^{a}
2 L VCT***/tree/month	11.37^{cd}	16.33^{c}	9.74^{ab}	8.05^{abc}	104.23^{a}	104.30^{ab}	7.93^{bc}	7.16^{e}
4 L VCT /tree/month	13.17^{bcd}	17.93^{bc}	10.34^{ab}	8.04^{abc}	118.97^{a}	116.04^{ab}	7.97^{bc}	8.20^{cde}
6 L VCT /tree/month	13.28^{bcd}	19.80^{bc}	10.40^{ab}	8.49^{ab}	125.62^{a}	122.76^{ab}	7.13^{c}	6.48^{ef}
8 L VCT /tree/month	18.33^{ab}	24.33^{b}	10.16^{ab}	8.48^{ab}	130 87^{a}	121.55^{ab}	9.30^{bc}	10.03^{bc}
Nemaphos****	17.00^{bc}	17.83^{bc}	10.15^{ab}	7.39^{c}	100.67^{a}	101.13^{ab}	10.13^{ab}	10.86^{b}

Means in each season having the same letter/s are not significantly different at 5% level using Duncan's Multiple Range Test.

*C= compost, **VC= vermicompost, ***VCT= vermicompost tea, **** Nemaphos = chemical control

Table 6: Influence of vermicompost and vermicompost tea on yield/tree and fruit physical properties of Kalamata olive trees infected with *Meloidogyne incognita* in 2017 and 2018 seasons

	Fruit density/m		Yield/tree (kg)		Fruit weight (g)		Flesh weight (g)		Flesh/fruit weight (%)		Fruit length (cm)		Fruit diameter (cm)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	1st season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (25 kg C*/tree)	49.25 ^{ab}	45.83 $^{b-d}$	15 $^{b-d}$	11.33 ^{c}	4.79 ^{cd}	4.79 ^{cd}	4.16 $^{b-d}$	3.33 $^{b-d}$	86.72 $^{a-c}$	83.02 $^{a-d}$	2.82 ^{c}	2.72 $^{a-c}$	1.81 ^{bc}	1.65 $^{a-d}$
10 Kg VC** /tree/year	36.53 ^{b}	37.16 ^{ef}	13.33 $^{b-d}$	5.66 ^{e}	4.68 ^{d}	4.68 ^{d}	4.05 ^{cd}	3.56 $^{a-c}$	85.15 ^{cd}	83.78 ^{ab}	2.82 ^{c}	2.43 ^{cd}	1.74 ^{e}	1.55 $^{b-d}$
15 Kg VC /tree/year	49.23 ^{ab}	46 $^{b-d}$	15 $^{b-d}$	6.66 ^{e}	4.75 ^{cd}	4.75 ^{cd}	3.96 ^{d}	2.72 ^{de}	84.54 ^{d}	80.65 ^{d}	2.89 ^{b}	2.77 $^{a-c}$	1.79 ^{cd}	1.70 $^{a-c}$
20 Kg VC /tree/year	60.18 ^{a}	50.26 $^{a-c}$	21.33 ^{ab}	15.33 ^{b}	5.32 ^{a}	5.32 ^{a}	4.19 $^{b-d}$	2.87 $^{c-e}$	86.36 $^{a-c}$	84 ^{ab}	2.86 ^{bc}	2.79 $^{a-c}$	1.80 ^{cd}	1.84 ^{a}
25 Kg VC /tree/year	60.45 ^{a}	56.47 ^{a}	25 ^{a}	16.33 ^{a}	5.34 ^{a}	5.34 ^{a}	4.64 ^{a}	4.24 ^{a}	87.02 ^{a}	84.7 ^{a}	2.91 ^{a}	3.1 ^{a}	1.89 ^{a}	1.86 ^{a}
2 L VCT***/tree/month	37.32 ^{b}	40.2 ^{de}	11.66 ^{d}	7.66 ^{de}	4.97 ^{bc}	4.97 ^{bc}	4.30 ^{bc}	3.71 ^{ab}	86.53 $^{a-c}$	80.65 ^{d}	2.82 ^{c}	2.56 ^{cd}	1.80 ^{cd}	1.69 $^{a-c}$
4 L VCT /tree/month	48.55 ^{ab}	43.33 $^{c-e}$	12.33 ^{cd}	10 ^{cd}	4.71 ^{d}	4.71 ^{d}	4.36^{b}	3.46 $^{b-d}$	86 $^{a-d}$	81.93 $^{b-d}$	2.85 ^{bc}	2.68 ^{bc}	1.83 ^{de}	1.66 $^{a-d}$
6 L VCT /tree/month	50.71 ^{ab}	45.54 ^{bd}	20 $^{a-c}$	7.66 ^{de}	4.87 $^{b-d}$	4.87 $^{b-d}$	4.19 $^{b-d}$	4.01 ^{ab}	85.41 $^{b-d}$	82.57 $^{a-d}$	2.85 ^{bc}	2.72 $^{a-c}$	1.84 ^{ab}	1.74 ^{ab}
8 L VCT /tree/month	57.54^{a}	52.06 ^{ab}	22.33 ^{a}	14.33 ^{b}	5.04 ^{b}	5.04 ^{b}	4.64 ^{a}	3.72 ^{ab}	86.84 ^{ab}	84.15 ^{ab}	2.89 ^{a}	2.73 $^{a-c}$	1.86 ^{ab}	1.81 ^{a}
Nemaphos****	50.26 ^{ab}	42.03 ^{de}	16 $^{b-d}$	8.76 ^{de}	4.71 ^{d}	4.68 ^{d}	3.98 ^{d}	2.39^{e}	84.52 ^{d}	75.43 ^{e}	2.89 ^{b}	2.74 $^{a-c}$	1.81 ^{bc}	1.55 $^{b-d}$

Means in each season having the same letter/s are not significantly different at 5% level using Duncan's Multiple Range Test.

*C= compost, **VC= vermicompost, ***VCT= vermicompost tea, **** Nemaphos = chemical control

be attributed to soil fertility improvement due to the increase of humus and nutrient content, or because vermicompost addition stimulates many enzymes in plant such as peroxides and catalase, which promotes cell elongation and increase root and stem length. The application of vermicompost in Frantoio and Carolea olive cultivars, enhance vegetative characters such as stem diameter, root dry weight, stem fresh weight, stem dry weight, leaf fresh weight, leaf dry weight, shoot fresh weight, shoot dry weight, chlorophyll contents and leaf area [1].

Influence of Vermicompost and Vermicompost Tea on Fruit Density, Yield/tree and Fruit Physical Properties of Kalamata Olive Trees Grown in Soil Naturally Infested with *Meloidogyne incognita* in 2017 and 2018 Seasons: Fruit and yield characteristics, namely fruit density/m, yield/tree (kg), fruit weight (g), flesh weight (g), flesh/fruit weight (%), fruit length (cm) and fruit diameter (cm) are given in Table (6). The data reveals that fruit and yield characteristics were increased gradually with increasing vermicompost rates in both seasons. As such, the highest rate of VC (25 kg/tree/year) gave significantly gave highest fruit density (60.45 and 56.47 fruits/m), yield/tree (25 and 16.33 kg), fruit weight (5.34, 5.34 g), flesh weight (4.64 and 4.24 g), Flesh/fruit weight (87.02 and 84.7 %), fruit length (2.91 and 3.1 cm) and fruit diameter (1.89 and 1.86 cm) in both tested seasons, respectively without significant differences in most cases between those fertilized by VCT 8 L/tree/year and VC at 20 kg/tree/year. While, the least values was recorded by VCT at 2 L/tree/year and VC at 10 kg/tree/year in both seasons respectively. These findings were parallel with those obtained by Gupta and Sangma [40] on Guava and Laishram and Ghosh [41] on jackfruit. They showed that fruit and yield characteristics were increased by increasing the amount of vermicompost. Which may be due to the amelioration in soil fertility and trees can synthesize more amount of carbohydrates and sugars.

Effect of Different Rates of VC and VCT on the Infection of *Meloidogyne incognita* to Kalamata Olive Trees Grown under Field Conditions (27±3°C): Data in Table (7) illustrated the impact of applying different rates of VC and VCT on controlling *M. incognita* infesting olive trees cv. Kalamata under field conditions at 27±3°C at growing seasons 2017 and 2018. Results revealed that nematode population, root galling and egg masses and *M. incognita* population in soil greatly reduced by all tested treatments.

Table 7: Development and reproduction of *Meloidogyne incognita* on Kalamata olive trees as influenced by the addition of different rates of VC and VCT under field conditions at 27±3

	Nematode population in						
	Root						
Treatments	D.S*	Females	Soil	No. eggs/ egg mass	Total nematode population (Pf)	Red**. %	Rf***
				Season 2017			
Control (25 kg C/tree)	6.0 ^{a}	68.0^{a}	2769.0 ^{a}	364.0 ^{a}	12671.0	0.0	9.05
10 Kg VC /tree/year	1.0 ^{b}	10.0 ^{de}	799.0 ^{bc}	192.0 ^{b}	2346.0	81.5	1.68
15 Kg VC /tree/year	2.0 ^{bc}	10.0 ^{de}	726.0 $^{b-d}$	170.0 ^{bc}	1928.0	84.8	1.38
20 Kg VC /tree/year	1.0 ^{b}	10.0 ^{de}	633.0 $^{c-e}$	129.0 $^{b-e}$	1547.0	87.8	1.11
25 Kg VC /tree/year	1.0^{b}	8.0 ^{f}	718.0 $^{b-d}$	100.0 $^{b-e}$	1327.0	89.5	0.95
2 L VCT/tree/month	1.0^{b}	12.0 ^{bc}	944.0 ^{bc}	166.0 ^{b}	1787.0	85.9	1.28
4 L VCT /tree/month	2.0 ^{bc}	9.0 ^{ef}	894.0 ^{bc}	147.0 ^{b}	1346.0	89.4	0.96
6 L VCT /tree/month	1.0^{b}	9.0 ^{ef}	735.0 $^{b-d}$	90.0 $^{b-e}$	1375.0	89.1	0.98
8 L VCT /tree/month	2.0 ^{bc}	9.0 ^{ef}	635.0 ^{cd}	158.0 ^{b}	1280.0	89.9	0.91
Chemical nematicides	0.0 ^{c}	3.0 ^{g}	291.0^{ef}	51.0 ^{c}	345.0	97.3	0.25
				Season 2018			
Control (25 kg C/tree)	6.0 ^{ab}	47.0 ^{a}	1309.0 ^{a}	350.0 ^{a}	11162.0	0.0	11.1
10 Kg VC /tree/year	2.0 $^{e-h}$	16.0 $^{d-h}$	680.0 ^{c}	240.0 ^{b}	3818.0	65.8	3.8
15 Kg VC /tree/year	5.0 $^{b-d}$	20.0 ^{de}	395.0 $^{d-g}$	228.0 ^{b}	3384.0	69.7	3.4
20 Kg VC /tree/year	3.0 $^{d-g}$	12.0 $^{f-}$h	391.0 $^{d-g}$	211.0^{c}	3149.0	71.8	3.1
25 Kg VC /tree/year	3.0 $^{d-g}$	12.0 $^{f-h}$	307.0 $^{d-h}$	188.0 ^{de}	2202.0	80.3	2.2
2 L VCT /tree/month	2.0 $^{e-h}$	17.0 $^{d-g}$	551.0 $^{c-d}$	235.0 ^{b}	3390.0	69.6	3.4
4 L VCT /tree/month	2.0 $^{e-h}$	14.0 $^{e-h}$	429.0 $^{d-g}$	198.0 $^{c-e}$	3019.0	73.0	3.0
6 L VCT /tree/month	1.0 $^{d-h}$	10.0 $^{g-j}$	521.0^{cd}	200.0^{c-e}	2132.0	80.9	2.1
8 L VCT /tree/month	1.0 $^{d-h}$	9.0 $^{h-j}$	352.0 $^{d-h}$	187.0 ^{e}	1671.0	85.0	1.7
Nemaphos	0.0 ^{h}	4.0 $^{i-k}$	204.0 ^{gi}	150.0^{g}	508.0	95.4	0.5

Each value is the mean of three replicates. Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan's multiple- range test. *D.S = Development stage. **Red.= Total nematode population of treatment- Total nematode population of control / Total nematode population of control × 100

Pi (2017) =1400 juveniles of *M.* spp. Pi (2018) =1000 juveniles of *M.* spp.

***Rf= Reproduction factor = Final Population (Pf) /Initial Population (Pi)

Pf = Nematode population in soil+ no. developmental stages +no. females+ (no. eggs/egg mass x no. egg masses).

Reduction percentage in number of galls and egg masses of *Meloidogyne incognita*. as influenced by the addition of different rates of VC and VCT under field conditions at 27±3:

Among the tested applications, vermicompost tea 8 L VCT/tree/month achieved the highest reduction percentage of nematode population in soil and root with value amounted to 89.9 and 85.0 % for season 2017 and 2018, respectively followed by vermicompost 25 Kg VC/tree/year with value of 89.5 and 80.3%, respectively. Once again, vermicompost tea (8 L VCT/tree/month) ranked second to Nemaphos in suppressing nematode population density in soil and roots of Kalamata olive trees, followed by 25 Kg VC/tree/year, for two growing seasons 2017 and 2018 comparing to control. It is worthy to note that 2 L VCT/tree/month and 10 Kg VC/tree/year gave the lowest reduction percentage values for nematode population at the two season 2017 and 2018, since their values were amounted to 85.9 and 69.6 & 81.5 and 65,8 %, respectively.

Root galling was significantly reduced by all treatments of VC and aqueous VCT (Table 8). Application of 20 Kg VC/tree/year at seasons 2017 & 2018 induced minimum number of egg masses, root galls and root-knot index. Further, application of vermicompost tea, (8 L VCT/tree/month) significantly suppressed root galling with percentage of reduction ranged from 60.9 and 88.4 % at seasons of 2017 & 2018, respectively. Similar trend was noticed with number of egg masses. Nemaphos (93.5, 95.7%) showed significant reduction in root galling with RGI=2.0 & 1.3 at seasons of 2017 & 2018, respectively. However, in most treatments of vermicompost and vermicompost tea significant difference in root galling or egg masses noticed between tested rates. These results are in conformity with the findings of previous reports by Renčo *et al.,* [42], Renčo and Kováčik

Table 8: Reduction percentage in number of galls and egg masses *Meloidogyne incognita* on Kalamata olive trees as influenced by the addition of different rates of VC and VCT under field conditions at 27±3.

Treatments	No. of galls	Red. %	RGI*	No. of egg masses	Red**. %	EI***
			Season 2017			
Control (25 kg C*/tree)	46.0 a	0.0	4.0	28.0 a	0.0	3.3
10 Kg VC** /tree/year	30.0 b	34.8	3.5	27.0 a	3.6	3.3
15 Kg VC /tree/year	30.0 b	34.8	3.0	25.0 ab	10.7	3.0
20 Kg VC /tree/year	24.0 b-d	47.8	3.3	21.0 bc	25.0	3.0
25 Kg VC /tree/year	29.0 bc	37.0	3.0	25.0 ab	10.7	3.0
2 L VCT***/tree/month	20.0 d-f	56.5	3.0	18.0 c-e	35.7	3.0
4 L VCT /tree/month	23.0 c-e	50.0	3.8	19.0 b-d	32.1	2. 5
6 L VCT /tree/month	22.0 c-f	52.2	3.0	16.0 c-f	42.9	3.0
8 L VCT /tree/month	18.0 d-f	60.9	3.0	10.0 f-i	64.3	2.0
Nemaphos	3.0 ij	93.5	2.0	2.0 gk	92.9	1.8
			Season 2018			
Control (25 kg C*/tree)	69.0 a	0.0	4.0	27.0 a	0.0	3.8
10 Kg VC** /tree/year	11.0 c-e	84.1	3.0	8.0 bc	70.4	2.0
15 Kg VC /tree/year	11.0 c-e	84.1	3.0	7.0 b-d	74.1	2.0
20 Kg VC /tree/year	9.0 de	86.9	2.0	6.0 c-e	77.8	2.0
25 Kg VC /tree/year	10.0de	85.5	2.0	7.0 b-d	74.1	2.0
2 L VCT***/tree/month	10.0 de	85.5	2.0	7.0 b-d	74.1	2.0
4 L VCT /tree/month	9.0 de	86.9	2.0	4.0 de	85.2	2.0
6 L VCT /tree/month	9.0 de	86.9	2.0	5.0 c-e	81.5	2.0
8 L VCT /tree/month	8.0 e	88.4	2.0	3.0 ef	88.9	2.0
Nemaphos	3.0 f	95.7	1.3	1.0 fg	96.3	0.5

Each value is the mean of three replicates. Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan's multiple- range test.

Pi (2017) =1400 juveniles of *M.* spp. Pi (2018) =1000 juveniles of *M.* spp.

*(RGI)= Root gall index, **Red.= treatment- control/control × 100., ***(EI)= egg masses index.

[11], Gabour *et al.,* [13] and Rao *et al.,* [43], where vermicomposts produced from municipal wastes, medicinal plant wastes, cattle manure, food and paper-recycling wastes significantly reduced the populations of *M. incognita*, *Globodera rostochiensis*, *G. pallida*, *Pratylenchus sp*., *Rotylenchulus reniformis* and other plant parasitic nematodes. Tested vermicompost suppressed the numbers of *G. rostochiensis* cysts [44]. Many scientists reported that drenching VCT suppressed plant-parasitic nematodes such as *Meloidogyne* spp. in different crops [12, 14, 45]. Although the mechanisms of VCT as soil drench to suppress plant-parasitic nematodes are not completely known, there is evidence showing its consistent effect against various diseases. Further, Mishra *et al.,* [7] showed that VCT could induce host-plant resistance in cucumber against *Meloidogyne* spp. through split-root experiments. Moreover, some investigators suggested that the abundant organic acids substances such as humic acids, hormones such as N-indole-3- acetic acid (IAA), cytokinin and gibberellins in VCT could suppress nematode infestation [10, 15]. The effects of this substance are likely caused by the death of nematodes by the release of toxic substances such as hydrogen sulphate, ammonia and nitrite during vermicomposting process [46].

Impact of Vermicompost and Vermicompost Tea on N, P and K (%) in leaves of Kalamata Olive Trees Infected with *Meloidogyne incognita* in 2017 and 2018 Seasons: Based on analysis of variance (Table 9), different rates of VC and VCT at level 5% significantly affected N and P concentrations in first season (2017). The highest percentage were obtained from (25 kg VC) treatment with values 1.43 and 0.84 %, respectively. While in the second season (2018) there is no significant difference between all treatments. Regarding the K % all treatments showed that the highest percentage of K (1.73 and 1.27 %) were obtained from the previous treatment (25 kg VC) in studied seasons, respectively.

These findings go parallel with those obtained by Gupta and Sangma [40] on Guava, Laishram and Ghosh [41] on jackfruit they showed, that fruit and yield characteristics were increased by increasing the amount of vermicompost. This increasing may be due to the improving in soil fertility and trees can synthesized more amount of carbohydrate and sugars.

Resistance Related Compounds

Total Phenol: Herein, total phenol content at two growing seasons (2017 & 2018) was also increased in fresh olive leaves as a result of *M. incognita* infection (Table 10).

Table 9: Effect of vermicompost and vermicompost tea on N, P and K (%) in leaves of Kalamata olive trees infected with *Meloidogyne incognita* in 2017 and 2018 seasons

	N %		P %		K %	
Treatments	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
Control (25 kg C^{*}/tree)	1.32 ^{c}	2.04 ^{a}	0.32 ^{c}	0.42 ^{a}	1.58 ^{c}	1.19 ^{ab}
10 Kg VC^{**} /tree/year	1.11 ^{e}	1.49 ^{a}	0.11 ^{f}	0.36 ^{a}	1.36 ^{e}	1.05 ^{bc}
15 Kg VC /tree/year	1.22 ^{d}	1.52 ^{a}	0.17 ^{e}	0.33 ^{a}	1.36 ^{e}	1.01 ^{bc}
20 Kg VC /tree/year	1.36 ^{b}	1.80 ^{a}	0.21 ^{d}	0.39 ^{a}	1.45 ^{d}	1.14 ^{ab}
25 Kg VC /tree/year	1.43 ^{a}	2.22 ^{a}	0.84 ^{a}	0.43 ^{a}	1.73 ^{a}	1.27 ^{a}
2 L VCT^{***}/tree/month	0.87 ^{f}	1.49 ^{a}	0.18 ^{e}	0.31 ^{a}	0.98 ^{f}	0.99 ^{bc}
4 L VCT /tree/month	1.11 ^{e}	1.88 ^{a}	0.18 ^{e}	0.31 ^{a}	1.36 ^{e}	1 ^{bc}
6 L VCT /tree/month	1.23 ^{d}	1.87 ^{a}	0.18 ^{e}	0.32 ^{a}	1.58 ^{c}	1.13 ^{ab}
8 L VCT /tree/month	1.33 ^{c}	2.00 ^{a}	0.77 ^{b}	0.37 ^{a}	1.61 ^{b}	1.19 ^{ab}
Nemaphos	1.21 ^{d}	1.65 ^{a}	0.57 ^{b}	0.35 ^{a}	1.36 ^{e}	1.20 ^{ab}

Means in each season having the same letter/s are not significantly different at 5% level using Duncan's Multiple Range Test. *C= compost, **VC= vermicompost, ***VCT= vermicompost tea

Table 10: Impact of different rates of VC and VCT on resistance related compounds in leaves of Kalamata olive trees infected with Meloidogyne incognita under field conditions at 27±3

Treatments	Total phenolmg/100g	Red*. %	PO**activity	Red. %	PPO*** activity	Red. %
			Season 2017			
Control (25 kg C/tree)	481.3 ^{a}	0.0	0.329 ^{a}	0.0	0.458 ^{a}	0.0
10 Kg VC /tree/year	470.7 ^{b}	2.20	0.315 ^{c}	4.3	0.447 ^{c}	2.4
15 Kg VC /tree/year	415.4 ^{g}	13.69	0.311 ^{d}	5.5	0.442 ^{d}	3.5
20 Kg VC /tree/year	345.2 ^{o}	28.28	0.298 ^{f}	9.4	0.428 ^{f}	6.6
25 Kg VC /tree/year	397.8 ^{j}	17.34	0.307 ^{e}	6.7	0.436 ^{e}	4.8
2 L VCT /tree/month	458.5 ^{c}	4.73	0.281 ^{i}	14.6	0.413 ^{i}	9.8
4 L VCT /tree/month	446.5 ^{d}	7.23	0.321 ^{b}	2.4	0.453 ^{b}	1.1
6 L VCT /tree/month	377.5 ^{l}	21.56	0.295 ^{g}	10.3	0.425 ^{g}	7.2
8 L VCT /tree/month	334.9 ^{p}	30.42	0.284 ^{h}	13.7	0.419 ^{h}	8.5
Nemaphos	405.9 ^{h}	15.66	0.259 ^{l}	21.3	0.395 ^{l}	13.8
			Season 2018			
Control (25 kg C/tree)	479.5 ^{a}	0.0	0.203 ^{j}	0.0	0.220 ^{l}	0.0
10 Kg VC /tree/year	470.7 ^{b}	1.83	0.226 ^{hi}	11.33	0.230 ^{k}	3.19
15 Kg VC /tree/year	446.5 ^{d}	6.88	0.243 ^{fg}	19.70	0.290 ^{f}	33.78
20 Kg VC /tree/year	415.4 ^{i}	13.36	0.288 ^{b}	41.87	0.340 ^{b}	54.55
25 Kg VC /tree/year	416.6 ^{h}	13.11	0.277 ^{c}	36.45	0.290 ^{f}	31.82
2 L VCT /tree/month	455.5 ^{c}	5.00	0.212 ^{ij}	4.43	0.240 ^{j}	7.30
4 L VCT /tree/month	426.3 ^{g}	11.09	0.261 ^{de}	28.57	0.240 ^{j}	10.95
6 L VCT /tree/month	398.8 ^{k}	16.83	0.252 ^{ef}	24.13	0.280 ^{g}	27.27
8 L VCT /tree/month	387.3 ^{l}	19.22	0.263 ^{d}	29.55	0.340 ^{b}	54.55
Nemaphos	327.4 ^{p}	31.72	0.298 ^{a}	46.79	0.290 ^{f}	30.13

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan's multiple range test. *Red.= treatment-control/control × 100, **(PO)=Peroxidase, ***(PPO)=Polyphenol Oxidase

However, both vermicompost and vermicompost tea showed total phenol reduction in olive leaves with various extent. The highest reduction in total phenol (15.66 & 31.72%) was recorded with the conventional nematicides, Nemaphos at two growing seasons (2017 & 2018), respectively. Among vermicompost applications, the highest reduction in total phenol was recorded with (28.28 & 13.36%) with 20 kg vermicompost/tree/year application. Thus, those applied with vermicompost tea 8 L/tree/month (30.42 &19.22) at two growing seasons (2017 & 2018), respectively achieved the highest reduction in total phenol. This result reflects treated plants were metabolically cope up the infection and promoting excessive plant growth [4]. Vermicompost enhanced plant growth and disease suppression through the activities of chemical antagonists such as phenols and amino acids [47]. To summarize as a net effect introduction of growth hormones, phenols, ammonia, fatty acids amino acids have a metabolic role in the plant which improved tolerance of vigor. In view of low cost, waste, cheap and easily available, no inward residual effects on soil as well as plants parts amendments of large scale exploration in the regard is desirable towards organic farming.

Table 11: Cost and net profit/feddan of Kalamata olive trees treated with vermicompost and vermicompost tea to improve quality and production and control *Meloidogyne incognita* in average of 2017 and 2018 seasons

Treatments	Ave. of 2017 and 2018 production (kg)/feddan	Total gross income**	Price of adding/feddan	Fixed costs of Agriculture practices/feddan	Total cost (LE)	Net profit (LE)
Control (25 kg C*/tree)	2216.4	35462	1750	15000	16750	18712
10 Kg VC*** /tree/year	1661.6	26586	5250	15000	20250	6336
15 Kg VC /tree/year	1895.3	30324	7875	15000	22875	7449
20 Kg VC /tree/year	3207.8	51324	10500	15000	25500	25824
25 Kg VC /tree/year	3616.4	57862	13125	15000	28125	29737
2 L VCT****/tree/month	1690.5	27048	1050	15000	16050	10998
4 L VCT /tree/month	1953.9	31262	2100	15000	17100	14162
6 L VCT /tree/month	2420.3	38724	3150	15000	18150	20574
8 L VCT /tree/month	3207.8	51324	4200	15000	19200	32124
Nemaphos*****	2254.0	36064	7000	15000	22000	14064

*C=compost = 400 LE/ton (25 kg × 175 tree ×0.4 LE), ** Total gross income = the price of Kalamata olive fruits = 16 LE/kg. ***VC= vermicompost (the price of vermicompost = 3 LE/kg), ****VCT=. Vermicompost tea (the price of vermicompost tea = 0.30 LE/L).
*****Chemical control with nematode pesticides (Nemaphos 10 L/feddan = 2 × 3500 = 7000 LE).

Defense Related Proteins: As a result of *M. incognita* infection, peroxidase (PO) and polyphenol oxidase (PPO) activities were obviously raised in olive leaves at two growing seasons (2017 & 2018), respectively (Table 10). The least induction of PO and PPO was recorded with plants untreated and inoculated with nematodes at growing season 2017. Among tested applications, the highest reduction in total PO enzyme (9.4 & 41.87%) and PPO enzyme (6.6 & 54.55) were recorded with 20 Kg VC /tree/year treatment at two growing seasons (2017 & 2018), respectively. Meanwhile, 8 L VCT/tree/month recorded the highest reduction in total PO enzyme and PPO enzyme (29.55 & 54.55) at 2018 growing season. Chemical nematicides "Nemaphos" (21.3 & 13.8; 46.79 & 30.13%) exceeded other treatment giving the highest reduction in PO and PPO enzymes at the mention seasons. There is good evidence, vermicompost enhances soil biodiversity by promoting the beneficial microbes which inturn enhances plant growth directly by production of plant growth-regulating hormones and enzymes and indirectly by controlling plant pathogens, nematodes and other pests, thereby enhancing plant health and minimizing the yield loss [48, 46]. Owing to the effective disease suppression, VCT has become a potential alternative to chemical pesticides in agriculture You *et al.,* [49], but its potential effects against plant-parasitic nematodes has not been examined. The significant increase in soil enzyme activities such as urease, phosphomonoesterase, phosphodiesterase and arylsulphatase with vermicompost application [47].

Economic Feasibility/Feddan: Data presented in Table (11), revealed the highest production (3616 and 3208 kg/feddan) due to the vermicompost treatments i.e. 25 kg VC and 8 L VCT in the average of 2017 and 2018 seasons, respectively. However, the highest rates of vermicompost tea and vermicompost gave better net profit (32124 and 29737 LE), respectively than the other treatments and the control.

CONCLUSION

On the basis of presented data, we can conclude that, using vermicompost fertilizers is considered a good tool to reduce the nematode population, root galling and egg masses number in soil and plant roots and in the meantime get a higher quality of fruits, increase the price of marketable and thus get high profit of Kalamata olive fruits. Accordingly, organic fertilizers and amendments i.e. vermicompost would provide a good alternative of nematicides in olive trees, therefore there is a strong need to develop nematicides of biological origin and antimetabolites to reduce the costs of fertilization.

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