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Efficacy of Six Commercial Nematicides against Root-Knot Nematode, *Meloidogyne incognita* and Their Impacts on Sugar Beet Plant Growth and Chemical Constituents

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ABSTRACT

A pot experiment was conducted to assess the efficacy of six commercial nematicides with ten formulations namely ethoprophos (Todabeet®, Root Phos®, and Nemafeng®), fenamiphos (Javelin®), fosthiazate (Capsul pro®), cadusafos (Rugby®), oxamyl (Mass Tode®, Oxyle®, and Canzakel®), and bionematicide abamectin (Namazoho®) against *Meloidogyne incognita* on sugar beet plants based on numbers of galls and juveniles (J2s) as well as plant growth characteristics**.** The nematicides were applied to the soil at the recommended dosage rate. All nematicides caused a significant reduction in the number of J2s and root galls with different levels of efficacy. However, ethoprophos (Todabeet ®) and ethoprophos (Root Phos®) had the highest nematicidal effect with a 100 % reduction in the number of juveniles in soil and galls, while oxamyl (Mass Tode®) and cadusafos (Rugby®) were relatively least effective causing 63.2 and 65.91 %; 64.6 and 69.5 %; reduction in J2s population and galling, respectively. Abamectin (Namazoho®), fenamiphos (Javelin®), ethoprophos (Nemafeng®), oxamyl (Oxyle®), oxamyl (Canzakel®), and fosthiazate (Capsul pro®) ranked intermediate in descending order by 89.4 and 87.5%; 88.3 and 89.77 %; 87.2 and 95.45 %; 84.4 and 87.5 %; 70.1 and 63.64 %; 68.9 and 59.09 % reduction in J2s population and galling, respectively. Also, all of the nematicides significantly increased plant length, fresh weight, and shoot dry weight. Ethoprophos (Root Phos®) had the highest increase effect. However, all nematicides significantly decreased N, P, K, and total chlorophyll content compared to the control, while abamectin had the highest decrease effect.

Keywords: Chemical control, bionematicide, *Meloidogyne incognita*, sugar beet.

INTRODUCTION

Plant parasitic nematodes are considered a major biotic factor limiting crop production causing severe damage to a wide range of economic crops. According to Elling (2013), the annual losses in economic crop yield due to plant-parasitic nematodes in main crops have been assessed to be USD 173 billion. The root-knot nematodes (*Meloidogyne* spp.), which have over 100 species, are the most damaging ones (Trinh *et al*., 2019). The root-knot nematode, *M. incognita*, is one of the most harmful root-knot nematode species and is considered the predominant and economically important in a range of vegetable crops on lighter soil types in Egypt (Ibrahim *et al*., 2000).

Sugar beet, *Beta vulgaris* L. (Chenopodiaceae) is considered the first and most important crop for sugar production in Egypt since 2013. It is cultivated in about 40 countries of the world and it can account for 40-45% of the total sugar production in the world (El- Shafey, 2014). In Egypt, the total area of sugar beet cultivation is about 650000 Feddans in the 2020 season (Anonymous, 2021). The government encourages farmers to cultivate sugar beet in place of sugar cane to reduce water consumption (Khalifa, 2017). The sugar beet crop is attacked by numerous pests including *M. incognita* which is considered the main species attacking the sugar beet crop in Egypt, due to its high level of infestation and possible interactions with other pathogens (Maareg *et al*., 1998; Korayem, 2006; Ibrahim, 2013; Mostafa *et al*.,2014). These nematode pests proved to reduce crop quantity and quality (Bazazo and Ibrahim, 2019).

The root-knot nematodes have a wide host range and a high reproductive potential therefore, their control is relatively hard (Hussain *et al*., 2016). Generally, the best method for eradicating nematodes in a short time is using nematicides. Using nematicides for the management of nematodes becomes essential when other methods like biocontrol agents are unable to protect crops from these pests (Hague and Gowen, 1987). So, nematicides are believed to be a main nematode management approach, whether used alone or as part of an integrated management program.

Therefore, the study objective was to evaluate the efficacy of the application of different commercial nematicides and bionematicide for the control of the root-knot nematode, *M. incognita* on sugar beet plants, and their effects on the growth parameters, macro elements (N, P, K), and total chlorophyll of sugar beet plants.

MATERIALS AND METHODS

Nematicides used:

The common name of nematicides, trade name, empirical formula, and field recommended rate are shown in Table (1).

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Table 1. The common name of nematicides, trade name, empirical formula, and field recommended rate.

	Common name	Trade name	Empirical Formula	Field recommended rate
IRAC Group: 1B; organophosphate				
1	Todabeet® 40% EC	Ethoprophos	$C_8H_{19}O_2PS_2$	2.5 L/Fed
2	Root Phos® % GR			30 Kg/Fed.
3	Nemafeng® 40% EC			2.5 L/Fed.
4	Javelin® 40% EC	Fenamiphos	$C_{13}H_{22}NO_3PS$	3 L/Fed.
5	Capsul pro® 30% CS	Fosthiazate	$C_9H_{18}NO_3PS_2$	2 L/Fed.
6	Rugby® 20% CS	Cadusafos	$C_{10}H_{23}O_2PS_2$	4.5 L/Fed.
IRAC Group : 1A; carbamate				
7	Mass Tode® 24% SL	Oxamyl	$C_7H_{13}N_3O_3S$	3 L/Fed.
8	Oxyle® 24% SL			
9	Canzakel® 24%SL			
IRAC Group : 6; avermectin (bionematicide)				
10	Namazoho® 1.8% EC	Abamectin	$C_{48}H_{72}O_{14}$ (B1a) $C_{47}H_{70}O_{14}$ (B1b)	3 L/Fed.

Plant species:

Sugar beet (*Beta vulgaris* L.) var." Toro" seedlings were used in this work.

Pot experimental design:

A pot experiment was conducted under greenhouse conditions in a highly *M. incognita* infested soil at the Nematological Research Unit (NERU), Faculty of Agriculture, Mansoura University, Dakahlia Governorate, Egypt, in January 2022, to evaluate the efficacy of six commercial nematicides namely, ethoprophos (three different formulations|), cadusafos, oxamyl (three different formulations), fenamiphos, fosthiazate and bionematicide abamectin (*Streptomyces avermitilis*) against *M. incognita* on sugar beet plants. All nematicides were obtained from Agricultural Research Center, Giza, Egypt.

The initial nematode populations were 400 second-stage juveniles/250 g soil. All plastic bags of 25 cm diameter were filled with 3 kg of clayey (Clay 46.56; Silt 30.91; Fine sand 22.66; Coarse sand 3.87). Four sugar beet seedlings (30 days old) var. Toro were transplanted in each bag and irrigated with water as needed. All pots including controls(nematode only) were replicated five times and arranged in a complete randomized block design on a bench at 28-35 °C and 65-70 % RH. The nematicides were applied to the soil at the recommended dosage rate, after 30 days from transplanting time.

The experiment was divided into 11 treatments as follows:

T1 = Ethoprophos (Todabeet ®),
T2 = Ethoprophos (Root Phos**®),**
T3 = Ethoprophos (Nemafeng®),
T4 = Fenamiphos (Javelin®),
T5 = Fosthiazate (Capsul pro®),
T6 = Cadusafos (Rugby®),
T7 = Oxamyl (Mass Tode®),
T8 = Oxamyl (Oxyle®),
T9 = Oxamyl (Canzakel®),
T10 = Abamectin (Namazoho®), and
T11 = Nematode only (N) (control).

Data collection:

Plant parameters

After 45 days from transplanting time, plants were removed carefully from the bags and the roots were washed free of soil. Data on plant growth parameters, including length of shoot and root (cm), plant length (cm), fresh weight of root and shoot (g), total plant fresh weight(g), and shoot dry weight(g) were measured.

Nematode parameters

Also, the number of second-stage juveniles (J2s) / 250 g soil, reproduction factor (RF) (RF= final population/initial population), and the number of galls/root system were measured. Root gall index (RGI) was evaluated using the following scale: 0 = no galling; 1 = 1: 2 galls; 2 = 3: 10 galls; 3 = 11: 30 galls; 4 = 31: 100 galls; and 5 = more than 100 galls (Taylor and Sasser 1978). The second stage juveniles (J2) were extracted from the soil by sieving and modified Baermann technique (Goodey, 1963) and counted. The parameters changing the percentage of increase or decrease were imputed to “positive or negative” values and the current equations were used as follows:

Reduction % = {(Control−Treated) /Control} x 100

Increase % = {(Treated−Control} /Control) x 100

Chemical constituents and photosynthetic pigments of sugar beet (*Beta vulgaris* L.) leaves

Photosynthetic pigments (Chlorophyll content): Representative samples(5 leaves) were taken at random from treated and untreated leaves after 15 days of application of nematicides to determine Chlorophyll a, b, and ab according to Sadasivam and Manickam (1996).

Chemical constituents: Samples were picked up and transferred immediately to the laboratory, placed on trays, and dried at 70º c for 48 hours. The dry weight was recorded, and the dried were grounded into a fine powder and kept for further use for macronutrients (N, P, K) determinations.

1. **Total nitrogen content:** The modified Micro-Kjeldahl apparatus was employed for total N-determination (Jones *et al*., 1991).
2. **Phosphorus content:** Total phosphorus was determined spectrophotometrically by Milten Roy Spectronic 120 at wavelength 725 nm using stannous chloride reduced molybdosulphoric blue color method in the sulphuric system as described by Peters *et al*.(2003).
3. **Potassium content:** Total potassium was estimated to Flame photometrically using the Jenway Flame photometer, Model corning 400 according to the modified method (Peters *et al*., 2003).

Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) (Gomez and Gomez, 1984), followed by Duncan’s multiple range tests to compare means (Duncan, 1955).

RESULTS AND DISCUSSION

Impact of commercial nematicides and bionematicide on the number of galls and second-stage juveniles (J2s) of *M. incognita* infecting sugar beet:

Table (2) showed that all tested nematicides were effective at the recommended rate in reducing the number of J2s in the soil compared to the untreated control. The highest activities were obtained for ethoprophos (Todabeet ®) (T1) and ethoprophos (Root Phos®) (T2) causing 100% reduction and reproduction factor(RF)=0.0, whereas the lowest was observed with oxamyl (Mass Tode®) (T7), cadusafos (Rugby®) (T6), fosthiazate (Capsul pro®) (T5) and oxamyl (Canzakel®) (T9) which reduced J2s by 63.2, 64.6, 68.9 and 70.1%, respectively and RF by 0.66, 0.64, 0.56 and 0.54, respectively. On the other hand, abamectin (Namazoho®) (T10), fenamiphos (Javelin®) (T4), ethoprophos (Nemafeng®) (T3), and oxamyl (Oxyle®) (T8) were ranked intermediate, as they reduced J2s in soil by 89.4, 88.3, 87.2 and 84.4%, respectively.

Table (2) and Fig.(1) showed a significant effect for all tested nematicides in reducing the number of galls compared with untreated control. T1 and T2 caused a 100% reduction in the number of galls, followed by T3 (95.45%) and T4 (89.77%) recording RGI= 0.6 and 1.4, respectively. However, T8 and T10 were at par with a percent reduction of 87.5%. On the other hand, the lowest nematicidal effect was observed with T5 (59.09%) followed by T9, T7, and T6, respectively.

Table 2. Effects of commercial nematicides and bionematicide on the number of galls and second-stage juveniles (J2s) of *Meloidogyne incognita* infecting sugar beet under greenhouse conditions.

Treatments	No. juveniles in 250g soil	Red.%	RF*	No. galls	Red.%	RGI**
T1	0.0 j	100.0	0.0	0.0 e	100.0	0.0
T2	0.0 j	100.0	0.0	0.0 e	100.0	0.0
T3	92.0 g	87.2	0.23	0.8 e	95.45	0.6
T4	84.0 h	88.3	0.21	1.8 de	89.77	1.4
T5	224.0 d	68.9	0.56	7.2 b	59.09	1.8
T6	255.0 c	64.6	0.64	5.4 b-d	69.32	2.0
T7	265.0 b	63.2	0.66	6.0 bc	65.91	2.2
T8	112.0 f	84.4	0.28	2.2 c-e	87.5	1.2
T9	215.0 e	70.1	0.54	6.4 b	63.64	2.0
T10	76.0 i	89.4	0.19	2.2 c-e	87.5	1.6
T11	720.0 a	----	1.8	17.6 a	---	3.0
LSD	1.5	---	---	4.2	---	---

***Each value presented the mean of five 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.**

RF*= final population/initial population ; RGI=Root gall index**

T1 = Ethoprophos (Todabeet ®),T2 = Ethoprophos (Root Phos®), T3 = Ethoprophos (Nemafeng®),T4 = Fenamiphos (Javelin®),T5 = Fosthiazate (Capsul pro®), T6 = Cadusafos (Rugby®), T7 = Oxamyl (Mass Tode®), T8 = Oxamyl (Oxyle®), T9 = Oxamyl (Canzakel®),T10 = Abamectin (Namazoho®), and T11 = Nematode only (control).

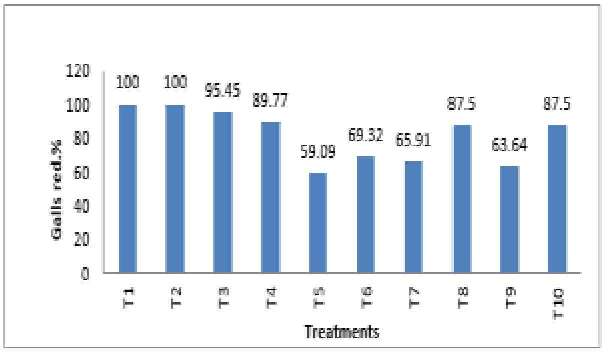

Figure 1. Effect of commercial nematicides and bionematicide on galls reduction of *Meloidogyne incognita* infecting sugar beet under greenhouse conditions.

T1 = Ethoprophos (Todabeet ®),T2 = Ethoprophos (Root Phos®), T3 = Ethoprophos (Nemafeng®),T4 = Fenamiphos (Javelin®),T5 = Fosthiazate (Capsul pro®), T6 = Cadusafos (Rugby®), T7 = Oxamyl (Mass Tode®), T8 = Oxamyl (Oxyle®), T9 = Oxamyl (Canzakel®),T10 = Abamectin (Namazoho®), and T11 = Nematode only (control).

Results on the efficacy of the tested nematicides on *M. incognita* infecting sugar beet were confirmed by those of Saad *et al*. (2017) who reported that fenamiphos, oxamyl, and ethoprophos were the highest nematicides that reduced the number of galls of *M. incognita* by 91.73, 89.53 and 83.23%, respectively. Whereas cadusafos, and fosthiazate had the least effectiveness causing 74.20, and 63.81% reduction, respectively in gall formation. On the other hand, fosthiazate, fenamiphos, and oxamyl were found to be effective treatments, which reduced J2s in the soil by 90.31, 87.81, and 83.92%, respectively. but, ethoprophos(75.90%), and cadusafos(69.49%) occupied the second rank in J2 reduction. Also, Al-Hazmi *et al.* (2017) reported that fenamiphos had relatively high effectiveness against *M. incognita* on green beans in different levels of efficacy depending on the method of treatment(alone, seed dressing, or seed dip). These results are conformism with data obtained by Acosta *et al.* (1987) who revealed that fenamiphos and oxamyl, had the maximum reduction in J2 of the *M. incognita* population in the soil. Recently, Kimenju *et al*. (2014) reported that fenamiphos has premium treatment which significantly reduced the gall index and population of J2 in the soil.

Also, Giannakou *et al*. (2005) found that fosthiazate was the most efficient nematicide studied, because of its long soil persistence, Oxamyl provided acceptable nematode control, while fenamiphos and cadusafos failed to achieve adequate nematode control, fenamiphos failure depends on its quick degradation by soil micro-organisms. Similarly, Radwan *et al*. (2012) found that cadusafos, fosthiazate and oxamyl nematicides caused a reduction in root galls and J2 of *M. incognita* in the soil. However, fosthiazate had the highest nematicidal effect, while cadusafos was relatively least effective. Oxamyl had an intermediate decrease. Also, they found that none of the nematicides tested significantly affected the growth indices of tomatoes compared to the control. Safdar *et al*. (2012) tested cadusafos (Rugby ®) 1, 0.5, and 0.25% on juvenile mortality of *M. incognita* in tomatoes, it showed 100, 72, and 57.3% mortality of juveniles, respectively. Mortality of juveniles increased with increased exposure time and concentration. The reduction of the nematode population was due to the activity of cadusafos (Rugby ®) which reduces the nematode population by contact and ingestion when the nematode penetrates the roots exposed to the soil (Putter *et al*., 1981; Faske and Starr, 2007). In the same trend, Giannakou *et al*. (2005) found that oxamyl provided some nematode control while cadusafos failed to provide suitable nematode control, even at high concentrations in soil. Also, oxamyl did not reduce potato tuber infection by *M. chitwoodi* adequately (Ingham *et al*., 2000). While El-Ashry *et al*. (2020) found that oxamyl treatment in tomato plants recorded 60.81% mortality of *M. incognita* juveniles after 2-day exposure with a significant difference, also, killed all juveniles after 4 days. Also, Mostafa *et al*. (2015) found that the oxamyl reduced root-knot nematodes on potato plants with a superior grade.

On the contrary, Khan *et al*. (2021) proved that chemical control of root-knot nematode by cadusafos (Rugby ® 100G) at recommended dose and time is a significant management technique that leads to a maximum death rate of nematode juveniles under field conditions. Also, Cadusafos was found to be the most effective nematicide against *M. incognita* on chickpea and tomatoes (Meher *et al*., 2010; Raddy *et al*., 2013). Also, cadusafos and fosthiazate proved to be active in reducing the number of tomato galls and controlling J2s of *M. incognita* (Saad *et al*., 2012).

Several authors proved that nematicides used in this study were effective against *Meloidogyne* spp. with different levels of reduction. El-Ashry *et al*. (2021) proved that juvenile mortality of *M. incognita* was 96.80 % after 10 days of treatment by abamectin and caused a % reduction in the number of galls in tomato roots and number of IJs/100 g soil 77.59 and 74.94% respectively. Likewise, this agreed with Khalil *et al*. (2012); Huang *et al*. (2014) on tomatoes and cucumbers, respectively. Otherwise, Lopez-Perez *et al*. (2011) and Muzhandu *et al*. (2014) found that abamectin was inconsistent in controlling root-knot nematodes in soil-grown tomatoes and tobacco, respectively. Also, Saad *et al*. (2017) reported that avermactin had the least effectiveness causing 66.69 and 75.34% reduction in gall formation and J2 of *M. incognita*. This may be a return to the strong adsorption and the immobility of abamectin in soil particles. Also, the time of application affects its effectiveness too.

Effect of commercial nematicides and bionematicide on plant growth response of sugar beet plants infected with *M. incognita*:

Data in Table (3) showed that the curative application of nematicides significantly promoted the growth parameters of sugar beet plants more than the control. Ethoprophos (Root Phos®) (T2) and ethoprophos (Todabeet ®) (T1) resulted in a significant induction in plant length and shoot dry weight than of other sugar beet plant treatments, while, fosthiazate (Capsul pro®) (T5) and oxamyl (Canzakel®) (T9) recorded the lowest increase in plant length, and the other treatments almost have the same effect.

Also, results showed that all tested nematicides significantly ($p \leq 0.05$) increased the shoot dry weight compared with the control. T10, T3, and T8 were recorded with the lowest increase (11.1%) followed by T7 and T6 (16.7%), then T9 and T5 (22.2%), then T1, and T4 (27.8%).

Results in Table (3) indicated that all tested nematicides increased the plant's fresh weight compared with the control. T2, T9, and T4 recorded the highest increase (69.0, 66.2, and 55.6%), respectively. While T7, T6, and T8 recorded the lowest increase (5.6, 9.9, and 19%), respectively. followed by T1, T3, T5, and T10 compared with control.

Results on the efficacy of the tested nematicides on the growth of sugar beet infected with *M. incognita* are confirmed by Saad *et al*. (2017) who reported that nematicides (ethoprophos, fosthiazate, fenamiphos, cadusafos, and oxamyl) enhanced tomato growth criteria compared to the control. Also, these results are on par with Ibrahim *et al*. (2010) who found that fosthiazate and oxamyl increased significantly the weight and shoot length of tomatoes infected with *M. incognita* shoots, Also, Khairy *et al*. (2016, 2021) reported that oxamyl significantly increased the vegetative growth of tomato and eggplant infected with *M. incognita* respectively. Hafez and Sundararaj (2006) found that fosthiazate significantly increased the whole yield of potatoes and our findings are confirmed in different crops by several scientists (Radwan *et al*., 2012; Raddy *et al*., 2013; Muzhandu *et al*., 2014; Mostafa *et al*., 2015).

Table 3. Influence of commercial nematicides and bionematicide on the growth parameters of sugar beet plants infected with *Meloidogyne incognita* under greenhouse conditions.

Treatments	Plant Growth Response									
	Length(cm)		Plant length (cm)	Inc. %	Fresh weight (g)		Plant fresh Weight (g)	Inc.%	Shoot dry weight (g)	Inc.%
	Shoot	Root			Shoot	Root				
T1	21.6 bc	14.2 ab	35.8	43.2	13.0 c-e	4.4 ab	17.4	22.5	2.3 b	27.8
T2	25.6 a	14.6 a	40.2	60.8	19.2 ab	4.8 a	24.0	69.0	2.5 a	38.9
T3	23.0 ab	11.0 bc	34.0	36.0	17.2 a-d	2.1 c	19.3	35.9	2.0 d	11.1
T4	24.0 ab	9.8 c	33.8	35.2	19.2 ab	2.9 bc	22.1	55.6	2.3 b	27.8
T5	21.6 bc	11.6 a-c	33.2	32.8	17.6 a-c	2.1 c	19.7	38.7	2.2 bc	22.2
T6	21.8 a-c	12.4a-c	34.2	36.8	13.0 c-e	2.6 bc	15.6	9.9	2.1 cd	16.7
T7	23.0 ab	11.0bc	34.0	36.0	12.4 de	2.6 bc	15.0	5.6	2.1 cd	16.7
T8	23.0 ab	11.0bc	34.0	36.0	14.4 b-e	2.5 bc	16.9	19.0	2.0 d	11.1
T9	21.2 bc	10.2 c	31.4	25.6	20.8 a	2.8 bc	23.6	66.2	2.2 bc	22.2
T10	23.2 ab	11.4 a-c	34.6	38.4	18.0 ab	3.3 a-c	21.3	50.0	2.0 d	11.1
T11	18.8 c	6.2 d	25.0	---	12.2 e	2.0 c	14.2	----	1.8 e	---
LSD	3.9	3.6	7.5	---	4.8	1.8	6.6	---	0.2	---

Each value is the mean of five 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.

T1 = Ethoprophos (Todabeet ®),T2 = Ethoprophos (Root Phos®), T3 = Ethoprophos (Nemafeng®),T4 = Fenamiphos (Javelin®),T5 = Fosthiazate (Capsul pro®), T6 = Cadusafos (Rugby®), T7 = Oxamyl (Mass Tode®), T8 = Oxamyl (Oxyle®), T9 = Oxamyl (Canzakel®),T10 = Abamectin (Namazoho®), and T11 = Nematode only (control).

Impact of commercial bionematicide, and chemical nematicide on photosynthetic pigments and chemical constituents in leaves of sugar beet infected with *M. incognita*:

Results in Table (4) found that all tested nematicides significantly ($p < 0.05$) decreased the chlorophyll (a+b), N, P, and K content compared with the control. T10 recorded the highest decrease (15.86, 34.08, 23.08, and 22.16) for chlorophyll (a+b), N, P, and K content, respectively. While T6 recorded the lowest decrease (2.75, 5.24, 3.38, and 3.49) for chlorophyll (a+b), N, P, and K content, respectively. followed by T1, T8, T7, T5, T9, T2, T3, and T4 compared with control.

Our results are supported by Haile *et al*. (1999) who showed that some insecticides within the organophosphate and carbamate class could reduce photosynthesis however other insecticides in a similar class do not. Our results contradict with those reported by Khairy *et al*. (2021) who indicated that oxamyl and abamectin increased N, P, K, and chlorophyll content in leaves of eggplant infected with *M.incognita* compared with control. Similar findings were noticed by Metwally *et al*. (2019) on cowpea infected with *M. incognita.* On the other hand, El-Sherif and Ismail (2009) found that oxamyl enhanced the N, P, and K concentrations in leaves of soybean plants inoculated with *M. incognita*, while chlorophyll content decreased. The same results were found by El-Sherif, *et al*. (2015) and Gad, *et al*. (2021) on tomato and soybean plants, respectively which support the present findings in respect to chlorophyll. Luo *et al*. (2002) showed that pesticides affected the physiology of plants depending on several factors like the active ingredient, the dosage of pesticide application, the number of sprays times, and the type of plants.

Table 4. Effect of commercial nematicides and bionematicide on the photosynthetic pigments and chemical constituents in leaves of sugar beet plants infected with *Meloidogyne incognita* under greenhouse conditions.

Treatments	Chemical constituents (macronutrients)						Chlorophyll (mg/g)			
	N%	Red.%	P%	Red.%	K%	Red.%	Chl.a	Chl.b	Chl. a+b	Red.%
T1	2.47 c	7.49	0.309 c	4.92	3.27 c	4.66	0.605	0.444	1.049 c	3.85
T2	2.04 h	23.59	0.274 h	15.69	2.92 h	14.87	0.564	0.404	0.968 h	11.27
T3	1.97 i	26.22	0.269 i	17.23	2.87 i	16.33	0.557	0.398	0.955 i	12.47
T4	1.86 j	30.34	0.260 j	20.00	2.78 j	18.95	0.548	0.389	0.937 j	14.12
T5	2.23 f	16.48	0.288 f	11.38	3.03 g	11.66	0.582	0.422	1.004 f	7.97
T6	2.53 b	5.24	0.3 14 b	3.38	3.31 b	3.49	0.611	0.450	1.061 b	2.75
T7	2.28 e	14.61	0.292 e	10.15	3.12 e	9.04	0.587	0.428	1.015 e	6.97
T8	2.39 d	10.49	0.302 d	7.08	3.21 d	6.41	0.598	0.439	1.037 d	4.95
T9	2.16 g	19.10	0.283 g	12.92	3.08 f	10.20	0.576	0.415	0.991 g	9.17
T10	1.76 k	34.08	0.250 k	23.08	2.67 k	22.16	0.540	0.378	0.918 k	15.86
T11	2.67 a	----	0.325 a	---	3.43 a	----	0.627	0.464	1.091 a	----
LSD	0.017	---	0.002	---	0.017	----	0.001	0.001	0.002	---

Each value is the mean of five 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.

T1 = Ethoprophos (Todabeet ®),T2 = Ethoprophos (Root Phos®), T3 = Ethoprophos (Nemafeng®),T4 = Fenamiphos (Javelin®),T5 = Fosthiazate (Capsul pro®), T6 = Cadusafos (Rugby®), T7 = Oxamyl (Mass Tode®), T8 = Oxamyl (Oxyle®), T9 = Oxamyl (Canzakel®),T10 = Abamectin (Namazoho®), and T11 = Nematode only (control).

From the current study, it could be concluded that all commercial nematicides and bionematicide tested significantly reduced the second-stage juveniles (J2s) in the soil and root galls of *M. incognita* as a result of a nematicidal effect on the nematodes in soil and inhibition of their penetration. Ethoprophos (Todabeet ®) and ethoprophos (Root Phos®) had the highest effect against juveniles (J2s) in soil, and root gall formation, while oxamyl (Mass Tode®) and cadusafos proved to be the least effective relatively in % reduction of J2 population. Moreover,fosthiazate (Capsul pro®), oxamyl (Canzakel®), caused the least % reduction in the number of root galls. On another hand, the bionematicide abamectin recorded a high effect on the % reduction of J2s population and no. of root galls (89.4 and 87.5%, respectively) and had the highest decrease effect on N, P, K, and total chlorophyll content compared to other chemical nematicides so, it is preferable to avoid the negative effects of chemical nematicides on some quality properties of plant and achieve acceptable management of *M.incognita.*

Finally, all chemical nematicides tested will likely continue to be used for getting rid of nematodes in a short time and highly effective until more biological approaches to management can be developed.

REFERENCES

Acosta, N., Vicente, N., Abreu, E., and Medina-Gaud, S. (1987). Chemical control of *Meloidogyne incognita*, *Rotylenchulus reniformis* and *Anthonomus eugenii* in *Capsicum annuum* and *C. frutescens.* Nematropica 17(2) : 163-169.

Al-Hazmi, A. S., Dawabah, A. A., Al-Nadhari, S. N., and Al-Yahya, F. A. (2017). Comparative efficacy of different approaches to managing *Meloidogyne incognita* on green bean. Saudi Journal of Biological Sciences 24(1): 149-154.

Anonymous (2021). Annual report of 2020 Season. Council for sugar Crops, Ministry of Agriculture and Land Reclamation, Egypt.

Bazazo, K.G., and Ibrahim, A. (2019). New record of *Diadegma oranginater* Aubert as parasitoid of *Scrobipalpa ocellatella* Boyd. in Egyptian Sugar fields. Journal of Experimental Biology 15 (2): 289- 294. http://dx.doi.org/10.5455/egysebz.20191209061731.

Duncan, D.B . (1955). Multiple ranges and multiple, F-test. Biometrics 11:1–42

El-Ashry, R. M., Ali, A. A., and Awad, S. E. (2020). Enhancing application efficiency of *Pseudomonas* spp. and *Serratia marcescens* isolates against *Meloidogyne incognita* in tomato plants. Egyptian Academic Journal of Biological Sciences, F. Toxicology & Pest Control 12(2): 127-145.

El-Ashry, R. M., Ali, M. A., Elsobki, A. E., and Aioub, A. A. (2021). Integrated management of *Meloidogyne incognita* on tomato using combinations of abamectin, *Purpureocillium lilacinum*, rhizobacteria, and botanicals compared with nematicide. Egyptian Journal of Biological Pest Control 31(1): 1-10.

Elling, A.A. (2013). Major emerging problems with minor *Meloidogyne* species. Phytopathology 103:1092–1102.

El-Shafey, A. (2014). Sugar beet cultivation in new lands Sugar Research Institute, Ministry of Agriculture and Land Reclamation, Egypt (in Arabic).

El-Sherif, A. G., and Ismail, A. F. (2009). Integrated management of *Meloidogyne incognita* infecting soybean by certain organic amendments, *Bacillus thuringiensis*, *Trichoderma harzianum,* and oxamyl with reference to NPK and total chlorophyll status. Plant Pathology Journal (Faisalabad) 8(4): 159-164.

El-Sherif, A. G., Gad, S. B., and Saadoon, S. M. (2015). Evaluation of calcium sulphate, potassium silicate and moringa dry leaf powder on *Meloidogyne incognita* infecting tomato plant with reference to N, P, K, total phenol and cholorophyl status under greenhouse condition. Journal of Entomology and Nematology 7(4): 30-38.

Faske, T. R., and Starr, J. L. (2007). Cotton root protection from plant-parasitic nematodes by abamectin-treated seed. Journal of Nematology 39: 27-30.

Gad, S. B., Aljboori, Q. H., Abido, W. A. E., Abo-El-Kheer, E. S. A., and Saadoon, S. M. (2021). Efficacy of four cruciferous germinated grinded seed on adjusting *Meloidogyne incognita* infecting soybean plants. In IOP Conference Series: Earth and Environmental Science 735 (1): p. 012030. IOP Publishing.

Giannakou, I. O., Karpouzas, D. G., Anastasiades, I., Tsiropoulos, N. G., and Georgiadou, A. (2005). Factors affecting the efficacy of non-fumigant nematicides for controlling root-knot nematodes. Pest Management Science 61(10): 961-972.

Gomez, K.A. and Gomez, A.A . (1984). Statistical procedures for agriculture research,2ndedn.Wiley, NewYork

Goodey, J.B. (1963). Laboratory methods for work with plant and soil nematodes. Ministry of Agriculture, Fisheries, and Food; Tech. Bull. 2, HMSO, London. 44 pp.

Hafez, S. L. and Sundararaj, P. (2006). Efficacy of fosthiazate for the control of *Paratrichodorus* spp. and *Meloidogyne chitwoodi* on potato. Int. J. Nematol. 16(2): 157-160.

Hague, N.M.H. and Gowen, S.R. (1987). Chemical control of nematodes. Principles and Practices of Nematode Control in Crops (Eds.), 131-178. R.H. Brown and B.R. Kerry. Academic Press, Sydney.

Haile, F. J., Peterson, R. K. D. and Higley, L. G. (1999). Gas exchange responses of alfalfa and soybean treated with insecticides. J. Econ. Entomology 92 (4): 954 – 959.

Huang, W. K., Sun, J. H., Cui, J. K., Wang, G. F., Kong, L. A., Peng, H., Chen, S. L., and Peng, D. L. (2014). Efficacy evaluation of fungus *Syncephalastrum racemosum* and nematicide avermectin against the root-knot nematode *Meloidogyne incognita* on cucumber. PLoS One 9 (2): e89717.

Hussain, M.A., Mukhtar, T., and Kayani, M.Z., (2016). Reproduction of *Meloidogyne incognita* on resistant and susceptible okra cultivars. Pak. J. Agric. Sci. 53 (02): 371–375.

Ibrahim DS (2013) Induction of resistance to root-knot nematodes in sugar-beet

Ibrahim, Dina, S.S. (2013). Induction resistance of root-knot nematode *Meloidogyne incognita* on sugar-beet plants. Ph.D. Thesis, Fac. Agric. Mansoura Univ. 124 pp.

Ibrahim, H. S., Saad, A. S. A., Massoud, M. A. and Khalil, M. S. H. (2010). Evaluation of certain agrochemicals and biological agents against *Meloidogyne incognita* on tomatoes. Alexandria Science Exchange Journal 31: 10-17.

Ibrahim, I.K.A., Z.A. Handoo and A.A. El-Sherbiny, (2000). A survey of phytoparasitic nematodes on cultivated and non-cultivated plants in northwestern Egypt. Journal of Nematology 32(4S): 478-485.

Ingham, R.E., Hamm, P.B., Williams, R.E. and Swanson, W.H. (2000). Control of*Meloidogyne chitwoodi* in potato with fumigant and nonfumigant nematicides. J. Nematol. 32: 556-565.

Jones, J.; Wolf, B. J. B. and Mills, H. A. (1991). Plant analysis Handbook: A Practical Sampling, Preparation, Analysis, and Interpretative Guide. Micro-Macro Publishing, Athens, Ga.

Khairy, Doaa, (2016). Management of root-knot nematode *Meloidogyne incognita* by the use of certain bioagents. M.Sc. thesis, Fac. Agric., Mansoura Univ. Egypt. pp. 110.

Khairy, Doaa, Refaei, A.R. and Mostafa, Fatma, A.M. (2021). Management of *Meloidogyne incognita* infecting eggplant using moringa extracts, vermicompost, and two commercial bio-products. Egyptian Journal of Agronematology 20(1): 1-16.

Khalifa A. (2017). Population dynamics of insect pests and their associated predators at different plantations of sugar beet. Journal of Plant Protection and Pathology, Mansoura University 8 (12):651- 656.

Khalil, M. S. H., Allam, A. F. G., and Barakat, A. S. T. (2012). Nematicidal activity of some biopesticide agents and microorganisms against root-knot nematode on tomato plants under greenhouse conditions. Journal of Plant Protection Research 52: 47-52.

Khan, M. A., Riaz, H., Raheel, M., Shakeel, Q., Waheed, U., Ahmed, N., ... and Khan, K. A. (2021). In-vitro and In-vivo management of *Meloidogyne incognita* (Kofoid and White) Chitwood and *Rhizoctonia bataticola* (Taub.) Butler in cotton using organic’s. Saudi Journal of Biological Sciences 28(1): 1-9.

Kimenju, J. W., Wachira, P. M., Lang'at, J. K., Otieno, W., and Mutua, G. K. (2014). Evaluation of selected methods in the control of plant parasitic nematodes infecting carnation. Journal of Agriculture Science 6: 31-38.

Korayem A.M. (2006). Relationship between *Meloidogyne incognita* density and damage to sugar beet in sandy clay soil. Egypt. J. Phytopathol 34 (1): 61–68.

Lopez-Perez, J. A., Edwards, S., and Ploeg, A. (2011). Control of root-knot nematodes on tomato in stone wool substrate with biological nematicides. Journal of nematology 43(2): 110- 117.

Luo, S. S., Wang, Z. G., Feng, X. M., Xu, J. F., Ding, H. D., Wu, J. C., Ge, C. L. and Ma, F. (2002). Study on tracer dynamics of effects of pesticides on export rate of photosynthate of rice leaves. Scienta Agric. Sinica 35 (9): 1085 – 1089.

Maareg M.F., Hassanein N.A., Allam A.I., and Oteifa B.A. (1998). Susceptibility of twenty-six sugar beet varieties to root-knot nematodes, *Meloidogyne* spp. In the newly reclaimed soils of Al-Bostan region. Egypt. J. Agronematol. 2 (1): 111–125.

Meher, H. C., Gajbhiye, V. T., Singh, G., Kamra, A., and Chawla, G. (2010). Persistence and nematicidal efficacy of carbosulfan, cadusafos, phorate, and triazophos in soil and uptake by chickpea and tomato crops under tropical conditions. Journal of agricultural and food chemistry 58(3): 1815-1822.

Metwally, W., Khalil, A.E. and Mostafa, F. M. (2019). Biopesticides as eco-friendly alternatives for the management of root-knot nematode, *Meloidogyne incognita* on cowpea (*Vigna unguiculata* L.). Egyptian Journal of Agronematology 18 (2): 129-145.

Mostafa, F. M., Ali, R. A. and Zawam, H. S. (2015). Effect of certain commercial compounds in controlling root-knot nematodes infected potato plants. Journal of Phytopathology and pest management 2: 9-19.

Mostafa, Fatma A.M., Khalil, A. E., El Deen, A. N., and Ibrahim, Dina. S. (2014). Induction of systemic resistance in sugar- beet against root-knot nematode with commercial products. Journal of Plant Pathology and Microbiology 5 (3): 1-7.

Muzhandu, R. T., Chinheya, C. C., Dimbi, S. and Manjeru, P. (2014). Efficacy of abamectin for the control of root-knot nematodes in tobacco seedling production in Zimbabwe. African Journal of Agricultural Research 9: 144-147.

Peters, J., Combs, S., Hoskins, B., Jarman, J., Kovar, J., Watson, M., and Wolf, N. (2003). Recommended methods of manure analysis. Univ. of Wisconsin Coop. Ext. Publ. A3769, Univ. of Wisconsin, Madison. Recommended methods of manure analysis. Univ. of Wisconsin Coop. Ext. Publ. A3769, Univ. of Wisconsin, Madison.

plants, Ph D Thesis. Egypt: Faculty of Agriculture, Mansoura University; p 157

Putter, I., Mac Connell, J. G., Prieser, F. A., Haidri, A. A., Ristich, S. S., and Dybas, R. A. (1981). Avermectins: Novel insecticides, acaricides, and nematicides from a soil microorganism. Experientia 37(9): 963–964.

Raddy, H. M., Ali, F. A. F., Montasser, S. A., Abdel-Lateef, M. F., and EL-Samadisy, A. M. (2013). Efficacy of six nematicides and six commercial bioproducts against root-knot nematode, *Meloidogyne incognita* on tomato. Journal of Applied Science Research 9: 4410- 4417.

Radwan, M. A., Farrag, S. A. A., Abu-Elamayem, M. M., and Ahmed, N. S. (2012). Efficacy of some granular nematicides against root-knot nematode, *Meloidogyne incognita* associated with tomato. Pak. J. Nematol. 30(1): 41-47.

Saad, A. S. A., Massoud, M. A., Ibrahim, H. S. and Khalil, M. S. H. (2012). Activity of nemathorin, natural product, and bioproducts against root-knot nematodes on tomatoes. Archives of Phytopathology and Plant Protection 45(8): 955-962.

Saad, A. S. A., Radwan, M. A., Mesbah, H. A., Ibrahim, H. S., and Khalil, M. S. (2017). Evaluation of some non-fumigant nematicides and the biocide avermactin for managing *Meloidogyne incognita* in tomatoes. Pakistan Journal of Nematology, 35(1): 85-92.

Sadasivam, S., and Manickam, A. (1996). Biochemical Methods, 2nd Ed. New age inter. India.

Safdar, H., Javed, N., Khan, S. A., ul Haq, I., Safdar, A., and Khan, N. A. (2012). Control of *Meloidogyne incognita* (Kofoid and White) Chitwood by cadusafos (Rugby®) on tomato. Pakistan Journal of Zoology 44(6): 1703-1710.

Taylor A.L., and Sasser J.N. (1978). Biology, identification, and control of root-knot nematodes (*Meloidogyne* species). Dept. of Plant Pathology, North Carolina State University, USA.

Trinh, Q., Le, T., Nguyen, T., Nguyen, H.T., Liebanas, G., and Nguyen, T., (2019). *Meloidogyne daklakensis* n. sp. (Nematoda: Meloidogynidae), a new root-knot nematode associated with *Robusta coffee* (*Coffea canephora* Pierre ex A. Froehner) in the Western Highlands. Vietnam. J. helminthology 93(2): 242–254.

تقييم فعالية ستة انواع من المبيدات النيماتودية التجارية فى مكافحة نيماتودا تعقد الجذور *Meloidogyne incognita* وتأثيرها على نمو نبات بنجر السكر ومكوناته الكيميائية

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الملخص

تم تقييم فعالية ستة مبيدات نيماتودية لعشر مستحضرات تجارية وهي ethoprophos (Nemafeng®, Root Phos® , Todabeet®) و fenamiphos و fosthiazate و cadusafos و oxamyl (Mass Tode®, Oxyle® , Canzakel®) والمبيد الحيوى abamectin لمكافحة نيماتودا تعقد الجذور *Meloidogyne incognita* على نباتات بنجر السكر تحت ظروف الصوبة بناءً على تعداد العقد الجذرية والاطوار اليرقية الثانية للنيماتودا وكذلك دراسة تأثير المبيدات على خصائص نمو النبات. تم معاملة التربة بالمبيدات بالجرعة الموصي بها, حيث ادت جميع المبيدات المختبرة الى خفض معنوى في تعداد الاطوار اليرقية الثانية للنيماتودا و العقد الجذرية بمستويات مختلفة, حيث كانت المعاملات ethoprophos (Todabeet®) و ethoprophos (Root Phos®) الأعلى تأثيرا وبلغت نسبة الخفض في اعداد الاطوار اليرقية الثانية في التربة وعدد العقد الجذرية 100 ٪ ، بينما كانت المعاملات Oxamyl (Mass Tode®) و cadusafos أقل فعالية نسبيًا محدثا انخفاض بنسبة 63,2 و 65,91 ٪ ؛ 64,6 و 69,5٪ ؛ لعدد النيماتودا فى التربة و العقد الجذرية ، على التوالي. بينما احتلت معاملة المبيد الحيوى abamectin و fenamiphos و ethoprophos (Nemafeng®) و oxamyl (Oxyle®) و oxamyl (Canzakel®) و fosthiazate المرتبة متوسطة في فى خفض تعداد الاطوار اليرقية الثانية في التربة وعدد العقد الجذرية على التوالي بترتيب تنازلي بنسبة 89,4 و 87,5٪ ؛ 88,3 و 89,77٪ ؛ 87,2 و 95,45٪ ؛ 84,4 و 87,5٪ ؛ 70,1 و 63,64٪ ؛ 68,9 و 59,09٪. كما أدت جميع المبيدات المختبرة إلى زيادة معنوية في طول النبات والوزن الرطب و الجاف حيث سجل (Root Phos®) Ethoprophos أعلى القيم كما ادت جميع المبيدات إلى خفض معنوي في محتوى النيتروجين والفوسفور والبوتاسيوم ومحتوى الكلوروفيل الكلي مقارنةً بالنباتات غير المعاملة حيث سجل abamectin أعلى معدل خفض.

الكلمات الدالة: المكافحة الكيميائية ، المبيدات الحيوية ، *Meloidogyne incognita* ، بنجر السكر