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Curtailment of root-knot nematode *Meloidogyne incognita* on sugar beet by using a novel strategy

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Abstract

Two field experiments were conducted in the west Nubaria district, located at Abu El-Matameer Center, the Northern Sector, (30°47'40"N latitude and 30°4'58"E longitude), El Behaira Governorate, Egypt 2022/23 and 2023/24 seasons to evaluate a recent strategy based on carried liquid chemical nematicides i.e., Nemakick®, Oxineem El-Nasr® and Tervigo® as well a biological one Fornem X 5® on rough wheat bran, against root-knot nematode, *Meloidogyne incognita* associated with sugar beet and its effects on yield and quality. Results included that all treatments reduced the examined nematode parameters as well as increased yield and quality characteristics. Exceptionally, Nemakick® achieved the highest reduction percent 58.9, 72.0 and 58.9 % with the number of J_2, root gall index and host efficiency respectively, and achieved the highest α amino nitrogen reduction percent 35.8 %, followed by Tervigo®. Likewise, achieved the highest increasing percent in quality chlorophyll a, chlorophyll b and charotain with 28.8, 86.3 and 37.5 % respectively, as well as total soluble solids TSS %, quality % and Sucrose % with increasing percent 19.4, 3.5 and 12.1 % respectively, furthermore the highest increasing in quantity were 24.7 and 3.5 tons / feddan by increasing percent 45.6 % with root yield and sugar yield respectively, followed by Tervigo®. Mostly, using a dose of 15 kg / feddan gave the highest reduction in *M. incognita* parameters and the highest increase in sugar beet crop quantity and quality than using 10 kg / feddan with all treatments.

Introduction

In Egypt, sugar beet (*Beta vulgaris* L.) was the second most substantial sugar crop planted in the recently recovered soil. Currently, sugar beet is considered the first sugar crop in Egypt, post forecasts harvested area in MY 2023/24 to reach 280,000 ha, almost a two percent increase (Or 5,000 ha) compared to MY 2022/23. This is attributed to the increasing demand for raw beets on the establishment of new sugar beet processing (GAIN, 2019). Sugar beet is viewed as a significant sugar crop in the world, and it is exceptionally pervaded by *Meloidogyne incognita*. This nematode makes harms the epidermis, cortex and stele districts remembering monster cells for these locales that then, at that point, consider the water and absorption of elements (El-Nagdi *et al*., 2011).

Root-knot nematodes (RKNs), *Meloidogyne* spp. are broad plant parasites that make impressive harm to the development of sugar beet. They assume a critical part in hindering plant physiology and restricting yield efficiency (Forghani and Hajihassani, 2020). Root-knot nematodes like, *M. incognita*, cause extremely rural misfortunes for some harvests as well as sugar beet (Tranier *et al*., 2014).

In Egypt, *M. incognita*, because of its occurrence frequency, elevated degree of pervasion and potential communications with different pathogens, is viewed as the dominating species infested sugar beet crop (El-Nagdi *et al.*, 2004 and Korayem, 2006).

Bio-products were assessed against *M. incognita* on sugar beet, in comparison with fenamiphos and cadusaphos were diminished the reproduction of the examined nematode characters. Besides, all treatments improved growth characteristics of sugar beet as well as the total soluble solids TSS% (El-Nagdi *et al*., 2011). The bio-product of Micronema (Containing strains of *Pseudomonas* sp., *Azotobacter* sp., *Serratia* sp., *B. thuringiensis* and *Bacillus circulans*) decreased parameters of root-knot nematode, *M. incognita* on sugar beet. Additionally, the treatment improved TSS% and plant growth criterion to varying degrees (El-Nagdi and Youssef, 2015).

When alternative approaches, such as bio-agents, fail to protect crops against these pests, nematode control requires the use of nematicides (Hague and Gowen, 1987). So, nematicides are thought to be a primary nematode control strategy, whether applied alone or as part of an integrated management program. De Leij and Kerry (1991) investigated the use of wheat bran/sand inoculum containing *Verticillium chlamydosporium* to suppress *Meloidogyne arenaria* on tomato plants. Inoculating *V. chlamydosporium* in a wheat bran/sand combination decreased *M. arenaria* infections but had no stimulating growth impact on tomato plant growth, according to research.

The research aims to: 1. Use wheat bran as a carrier material to carry the studied substances. 2. Testing the efficacy of certain chemical and biological nematicides, furthermore wheat bran as organic material for *M. incognita* and their effect on sugar beet growth and productivity.

Materials and methods

1. Sugar beet seeds:

The planted seeds of the sugar beet, *Beta vulgaris Saccharifera* L., were cv. "Oscar" (A polygerm variety) obtained from Sugar Crops Research Institute, ARC, Egypt. The degree of susceptibility/resistance of this sugar beet variety, the modified host parasite index (MHPI) scale was used as a new and appropriate scale (special approach) for assessing host (sugarbeet plant) reactions. On this basis, the screened sugar beet variety (Oscar) is categorized as moderately susceptible against root-knot nematode, *Meloidogyne incognita*.

2. Nematodes density, extract method and identification:

The densities of nematode soil populations were measured using composite soil samples. was taken from each plot after the treatments at planting to determine soil nematode densities (Pi = 1250 Larve/250 gm soil). Nematodes were isolated from samples using a modified Bearman's tray method, as reported by Barker (1985). The Pf were extracted and determined at harvest for each treatment by using the previous method. Nematodes were detected using (Hartman and Sasser, 1985), and a stereomicroscope was utilized to evaluate the perineal pattern analysis as described by Singh *et al.* (2012).

3. Carrier material (Wheat bran):

Wheat bran is the external structure of the wheat piece, which is normally eliminated during handling, and it involves the external layers of the grain including the pericarp, testa, and aleurone layer (Definition of millers), used as nematicides carrier. The weight of rough wheat bran mixed with the tested nematicides used in this study was 10 kg and 15 kg feddan^{-1} from each treatment.

4. Tested nematicides characterization and doses:

Nemakick 30% SL (Imicyafos 30% w/w, SL), Acetylcholinesterase (AChE) inhibitors (Organophosphates), Agro-Kanesho Co. LTD Japan, import by Cairo Chemical Company, the dose used for 400 ml/1 kg bran.

Oxineem El-Nasr 24% SL (Oxamyl 24% SL), Acetylcholinesterase (AChE) inhibitors (Carbamates), Sundat (S) Pte Ltd Singapore, Import by El-Nasr Intermediate Chemicals, the dose used for 250 ml/1 kg bran.

Tervigo® (Abamectin 2 % SC), Glutamate-gated chloride channel (GluCl) allosteric modulators (Avermectins), Syngenta Egypt, the dose used for 250 ml/1 kg bran.

Fornem X 5® ($2×10^3$ cuf/ml *Rhodotorula pustule*, $6×10^3$ cuf/ml *Serratia entomophila*, $9×10^8$ cuf/ml *Serratia marcescens*, $3×10^5$ cuf/ml *Pseudomonas fluorescens* and $3×10^3$ cuf/ml *Pseudomonas putida*), microbial nematicide, Bio Nano Technology for Fertilizers Development, Egypt. The dose used for 500 ml/1 kg bran.

5. Experimental site description and designation:

The experiments located at Abu El-Matameer Territory, the Northern Sector, (30°47'40''N latitude 30°4'58''E longitude), El Behaira Governorate, Egypt which was naturally infested with *M. incognita* through 2022/23 and 2023/24 seasons. The soil type was sandy soil (84.6 % sand, 5.7 % fine sand, 3.0 % silt and 4.8 % clay) containing particularly low level of natural matter (0.31 %), with a pH of 7.80. The planting dates for each field season were on 16th October 2022 and 18th October 2023. All yield agrarian practices were performed by the farmer, and preparation depended on soil supplement examination under the furrow irrigation system. Five treatments in addition to untreated check were led in a randomized complete plot design with three recreates per treatment. Preparing 10 kg of rough wheat bran for every treatment as standard weight and preparing the used doses of chemicals and biomaterials in the experiment, the bran was distributed in plastic bags, chemicals and biomaterials mixed with the bran using a plastic sprayer with stirring and spraying to complete homogeneity, then the samples were distributed and laid out on a plastic bags after mixing to dry in the laboratory on room temperature. The second dose used in the experiments was 15 kg/feddan from the standard one, all treatments equipped in solid form to apply in soil by hand planter planting directly then irrigation. Data were taken after maturity was completed after 220 days from planting.

6. Studied characters:

Nematode characters i.e, number of J_2 / 250 cm^3 soil, root gall index (GI) and host efficiency (Reproduction factor). Data were taken after 220 days from sowing for the two seasons. Gall Index (GI) was assessed on a scale of 0-5 as described by Sasser *et al.* (1984) AND reproduction factor (host efficiency) was calculated (Oostenbrink, 1966) by Eq.: host efficiency (RF) = Final population (Pf) / Initial Population (Pi). To determine the effect of the tested nematicides on nematodes and plant characteristics the reduction percent in nematode parameters and increase percent in plant characters were calculated by Eq.: Reduction % = (control - treatment) / control × 100 and Increase % = (treatment - control) / control × 100.

Physiological characteristics i.e. chlorophyll A, B, and carotenoids (mg/cm^2) according to Inskeep and Blom (1985), were taken at (80 days) for the two studied seasons.

Yield and quality i.e. α amino nitrogen, TSS (%), quality (%), sucrose (%), root yield and sugar yield were determined according to McGinnur (1971) at harvesting from 220 days after sowing in both seasons.

7. Statistical analysis:

The null hypothesis, homogeneity of changes for the two season's records analyzed by Bartlett's test (Snedecor and Cochran, 1989), consequently, the data of both seasons were consolidated for investigation of fluctuation (ANOVA) as indicated by Steel and Torrie (1981), utilizing MSTAT form 4 (1987), trailed by testing tremendous contrasts among the method for various treatments were isolated by Duncan's Different Reach Test at 0.05 likelihood as indicated by Duncan (1955).

Results and discussion

Data in Table 1 showed that the tested nematicides viz., Fornem X 5®, Nemakick®, Oxineem El-Nasr®, Tervigo® and Wheat bran as a substrate to carry the studied substances, reduced the number of J2, root gall index and host efficiency of M. incognita. The highest reduced average was 925.8 Larva / 250 cm3 soil with a reduction percent 58.9 % for Nemakick®, followed by Tervigo®. Mostly, the dose of 15 kg/feddan gave the highest reduction average of 1402.8 and a reduction percent 46.3 % than 10 kg/feddan with all treatments. The results went in the same trend with root gall index and host efficiency.

Table (1): Nematicidal effect of the tested materials on nematode characters of *Meloidogyne incognita* during 2022/23 and 2023/24 growing seasons by combine analysis.

Treatment	No. of J2/250 cm3 soil			Root gall index (GI)			Host efficiency (RF)		
	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)
	10 kg	15 kg		10 kg	15 kg		10 kg	15 kg	
Fornem X 5®	1663.3 (25.0%)*	1208.3 (47.1%)	1435.8 (36.2%)	3.00 (30.7)	2.7 (33.3%)	2.8 (31.9%)	1.3 (25.0%)	0.1 (47.1%)	1.2 (36.2%)
Nemakick®	1153.3 (48.0%)	698.3 (69.4%)	925.8 (58.9%)	1.3 (69.3%)	1.0 (75.0%)	1.2 (72.0%)	0.9 (48.0%)	0.6 (69.4%)	0.7 (58.9%)
Oxineem El-Nasr®	1496.7 (32.5%)	1041.67 (54.4%)	1269.2 (43.6%)	2.3 (46.2%)	2.0 (50.0%)	2.2 (48.0%)	1.2 (32.5%)	0.8 (54.4%)	1.0 (43.6%)
Tervigo®	1363.3 (38.5%)	908.3 (60.2%)	1135.8 (49.5%)	2.0 (53.8%)	1.3 (66.8%)	1.7 (60.0%)	1.1 (38.5%)	0.7 (60.2%	0.9 (49.5%)
Wheat bran	2183.3 (1.5%)	2276. 7 (0.3%)	2230.0 (0.9%)	3.7 (15.2%)	4.0 (0.0%)	3.8 (7.9%)	1.8 (1.5%)	1.8 (0.3%)	1.8 (0.9%)
Untreated check	2216.7 (0.0%)	2283.3 (0.0%)	2250.0 (0.0%)	4.3 (0.0%)	4.0 (0.0%)	4.2 (0.0%)	1.8 (0.0%)	1.8 (0.0%)	1.8 (0.0%)
Mean (B)	1679.4 (29.1%)	1402.8 (46.3%)	1541.1 (37.8%)	2.8 (43.0%)	2.5 (45.0%)	2.6 (44.0%)	1.3 (29.1%)	1.1 (46.3%)	1.2 (37.8%)
$LSD_{0.05}$	(A) 105.0 (B) 60.6 (AB) 148.2			(A) 0.6 (B) 0.4 (AB) 0.9			(A) 0.3 (B) 0.2 (AB) 0.5		

*** = Reduction percent %, Reproductive factor: RF = Pf/Pi where Pi = initial population density and Pf = final population density, Gall index: 0 = no gall formation; 5 = heavy gall formation source: Sasser *et al* (1984)**

The nematicidal activity of the tested nematicides in Table (2) increased sugar beet physiological characters i.e., Chlorophyll A, Chlorophyll B and Charotain with averages of 2.7, 2.4 and 1.8 by increase percentages 28.8, 86.3 and 37.5% with Nemakick®, followed by Tervigo®. The dose of 15 kg/feddan gave the highest increase, an average of 2.3 with an increase percent 11.8 % to 10 kg/feddan for all treatments. The tested nematicides also had the same effect as Chlorophyll B and Charotain and were moving in the same direction.

Table (2): Effect of the tested materials on *Meloidogyne incognita* management and their impact on sugar beet physiological characters during 2022/23 and 2023/24 growing seasons by combine analysis.

Treatment	Chlorophyll A			Chlorophyll B			Charotain		
	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)
	10 kg	15 kg		10 kg	15 kg		10 kg	15 kg	
Fornem X 5®	2.2 (9.4%)*	2.2 (4.3%)	2.2 (6.8%)	1.7 (29.9 %)	1.7 (30.2 %)	1.7 (30.1%)	1.3 (4.8%)	1.4 (6.1%)	1.4 (5.5%)
Nemakick®	2.6 (30.7%)	2.7 (27.0%)	2.7 (28.8%)	2.4 (86.6 %)	2.4 (86.1 %)	2.4 (86.3%)	1.7 (39.2%)	1.8 (35.9%)	1.8 (37.5%)
Oxineem El-Nasr®	2.3 (12.9%)	2.3 (10.4%)	2.3 (11.6%)	1.7 (33.1 %)	1.7 (34.1 %)	1.7 (33.6%)	1.6 (28.0%)	1.6 (22.1%)	1.6 (25.0%)
Tervigo®	2.4 (16.3%)	2.4 (12.8%)	2.4 (14.5%)	1.7 (34.7 %)	1.8 (35.7 %)	1.8 (35.2%)	1.7 (34.4%)	1.7 (32.1%)	1.7 (33.2%)
Wheat bran	2.1 (3.5%)	2.2 (4.3%)	2.2 (3.9%)	1.3 (0.0%)	1.3 (0.8%)	1.3 (0.4%)	1.3 (1.6%)	1.3 (0.0%)	1.3 (0.8%)
Untreated check	2.0 (0.0%)	2.1 (0.0%)	2.1 (0.0%)	1.3 (0.0%)	1.3 (0.0%)	1.3 (0.0%)	1.3 (0.0%)	1.3 (0.0%)	1.3 (0.0%)
Mean (B)	2.3 (14.6%)	2.3 (11.8%)	2.3 (13.1%)	1.7 (36.9 %)	1.7 (37.4 %)	1.7 (37.1%)	1.5 (21.6%)	1.5 (19.2%)	1.5 (20.4%)
$LSD_{0.05}$	(A) 0.4 (B) 0.2 (AB) 0.6			(A) 0.3 (B) 0.2 (AB) 0.4			(A) 0.4 (B) 0.2 (AB) 0.5		

*** = Increase percent %**

Table (3) shows the effect of the tested nematicides on the quality characteristics of sugar beet. Nemakick® achieved the highest α Amino nitrogen reduction average of 3.1 with a 35.8 % reduction percent for followed by Tervigo® . As for the total soluble solids and quality, Nemakick® gave the highest increase averages 23.3 and 86.4 with the highest reduction percent 19.4 and 3.5%, respectively followed by Tervigo®. Generally, there are no significant differences between doses 10 and 15 kg/feddan on reduction of α amino nitrogen and increase of total soluble solids and quality for all treatments.

Table (3): Effect of the tested materials on *Meloidogyne incognita* management and their impact on sugar beet quality characters during 2022/23 and 2023/24 growing seasons by combine analysis.

Treatment	α Amino nitrogen			Total soluble solids TSS (%)			Quality (%)		
	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)
	10 kg	15 kg		10 kg	15 kg		10 kg	15 kg	
Fornem X 5®	4.4 (- 5.0%)*	4.3 (- 14.4%)	4.3 (- 9.9%)	20.3 (3.1%)**	20.2 (4.3%)	20.3 (3.7%)	84.4 (1.1%)	84.7 (1.5%)	84.5 (1.3%)
Nemakick®	3.1 (- 31.7%)	3.0 (- 39.6%)	3.1 (- 35.8%)	22.7 (15.6%)	23.9 (23.3%)	23.3 (19.4%)	86.2 (3.2%)	86.6 (3.8%)	86.4 (3.5%)
Oxineem El-Nasr®	4. (- 6.1%)	3.7 (- 26.4%)	4.0 (- 16.7%)	20.6 (4.5%)	21.4 (10.6%)	21.0 (7.5%)	85.2 (2.1%)	85.8 (2.8%)	85.5 (2.4%)
Tervigo®	3.5 (- 24.45%)	3.7 (- 25.8%)	3.6 (- 25.2%)	21.3 (8.3%)	23.8 (22.9%)	22.6 (15.6%)	85.4 (2.3%)	85.8 (2.8%)	85.6 (2.5%)
Wheat bran	4.5 (- 2.4%)	4.7 (- 6.4%)	4.6 (- 4.5%)	19.7 (0.1%)	20.3 (4.9%)	20.0 (2.4%)	83.6 (0.1%)	83.5 (0.1%)	83.5 (0.1%)
Untreated check	4.6 (0.0%)	5.0 (0.0%)	4.8 (0.0%)	19.7 (0.0%)	19.4 (0.0%)	19.5 (0.0%)	83.5 (0.0%)	83.5 (0.0%)	83.5 (0.0%)
Mean (B)	4.1 (- 13.9%)	4.1 (- 22.5%)	4.1 (- 18.4%)	20.7 (6.3%)	21.5 (13.2%)	21.1 (9.7%)	84.7 (1.7%)	85.0 (2.2%)	84.8 (2.0%)
LSD0.05	(A) 0.8 (B) 0.5 (AB) 1.1			(A) 1.1 (B) 0.6 (AB) 1.5			(A) 1.1 (B) 0.6 (AB) 1.6		

*** = Reduction percent %, ** = Increase percent %**

Finally, the results illustrated in Table (4) explain the effect of the tested materials on sugar beet yield and quality, so Nemakick® and Tervigo®, respectively, achieved the highest increasing averages and percent with sucrose, root and sugar yield. Also, there are no significant differences between doses 10 and 15 kg/feddan on increasing of sucrose, root and sugar yield for all treatments.

Table (4): Effect of the tested materials on *Meloidogyne incognita* management and their impact on sugar beet yield and quality characters during 2022/23 and 2023/24 growing seasons by combine analysis.

Treatment	Sucrose (Su %)			Root Yield (Tons/Feddan)			Sugar Yield (Tons/Feddan)		
	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)	Dose/Feddan (A)		Mean (B)
	10 kg	15 kg		10 kg	15 kg		10 kg	15 kg	
Fornem X 5®	19.0 (2.2%)*	19.9 (5.8%)	19.4 (4.0%)	19.7 (15.4%)	20.4 (20.8%)	20.1 (18.1%)	2.8 (15.4%)	2.9 (20.8%)	2.9 (18.1%)
Nemakick®	20.3 (9.4%)	21.6 (14.8%)	20.9 (12.1%)	23.67 (38.8%)	25.8 (52.4%)	24.7 (45.6%)	3.4 (38.8%)	3.7 (52.4%)	3.5 (45.6%)
Oxineem El-Nasr®	19.5 (5.0%)	20.2 (7.3%)	19.8 (6.2%)	20.4 (19.3%)	21.9 (29.7%)	21.2 (24.5%)	2.9 (19.3%)	3.1 (29.7%)	3.0 (24.5%)
Tervigo®	19.9 (7.3%)	20.5 (9.3%)	20.2 (8.3%)	22.5 (31.9%)	23.5 (39.2%)	23.0 (35.5%)	3.2 (31.9%)	3.3 (39.2%)	3.3 (35.5%)
Wheat bran	18.6 (0.7%)	19.0 (0.9%)	18.7 (0.1%)	17.4 (1.9%)	17.7 (4.8%)	17.6 (3.4%)	2.5 (1.9%)	2.5 (4.8%)	2.5 (3.4%)
Untreated check	18.4 (0.0%)	18.8 (0.0%)	18.7 (0.0%)	17.1 (0.0%)	16.9 (0.0%)	17.0 (0.0%)	2.4 (0.0%)	2.4 (0.0%)	2.4 (0.0%)
Mean (B)	19.3 (4.9%)	20.0 (7.6%)	19.6 (6.1%)	20.1 (21.5%)	21.1 (29.4%)	20.6 (25.4%)	2.9 (21.5%)	3.0 (29.4%)	2.9 (25.4%)
$LSD_{0.05}$	(A) 0.9 (B) 0.5 (AB) 1.2			(A) 1.2 (B) 0.7 (AB) 1.7			(A) 0.7 (B) 0.4 (AB) 1.0		

*** = Increase percent %**

Our results indicated that, the tested chemical nematicides i.e., Nemakick®, Oxineem El-Nasr® and Tervigo® as well as microbial one Fornem X 5®, furthermore wheat bran as organic carrier material had a nematicidal activity against nematode parameters of *M. incognita* and improved sugar beet growth parameters and productivity. Nemakick® gave the highest reduction of the number of J_2, root gall index and host efficiency of *M. incognita* as well a high exceptionally in the improvement of growth characteristics and quality of sugar beet followed by Tervigo®, due to Imicyafos, equally showed a significant effect on infective juvenile hatching rates so, this was reflected other nematodes parameters in this study. More notably, it had a similar significant effect on plant parasitic nematodes *Meloidogyne* spp. (Kim *et al*., 2015). Moreover, Tervigo (Abamectin 2%) the highest poisonous against the J_2 of *M. incognita* in vitro and reducing galls, egg masses, eggs and soil nematodes density essentially. Additionally, the plant growth parameters were improved (Radwan *et al*., 2019). The capability of abamectin is credited to its go about as blocker of the conveyance of electrical movement in nerves and muscle cells by animating the delivery and restricting of γ-aminobutyric corrosive (GABA) at sensitive spots. This prompt led to Cl ion into the cells and lead to hyper polarization and ensuing loss of motion of the neuromuscular frameworks (Bloomquist, 2003). Accordingly, this is reflected in the improvement of crop characteristics and quality of sugar beet. Fornem X 5® contains, *serratia marcescens* and Ahmed *et al*. (2022) affirmed that the bio-product containing

Serratia marcescens was viable against *M. incognita* and amended pepper growth parameters, so it is likely that Fornem X 5® improved sugar beet yield and quality. Finally, Oxineem El-Nasr® (Oxamyl® 24% SL) significantly reduced *Meloidogyne* ssp. female root system^{-1}, gall index, disease severity. Seeds treated with Oxamyl® 24 % show enhanced growth and protection against soil borne diseases. These treatments promote quick germination, strengthen root systems, and improve plant health and enhancing disease resistance (Hassan *et al*., 2024).

The efficacy of some nematicides on root-knot nematode using a novel strategy through carrying the tested nematicides on wheat bran to increase the exposure period of the tested nematicides on sugar beet during 2022/23 and 2023/24 growing seasons by combining analysis considered the most authentic means to conclude and recommend successful management strategy to reduce *M. incognita* infestation and improve sugar beet crop yield and quality. So, in this research, all treatments reduced the number of J2, root gall index and host efficiency of M. incognita and increased yield and quality characteristics, exceptionally Nemakick® and Tervigo® achieved the highest results in reducing nematode characteristics and increasing sugar beet crop productivity and quality, so we recommend using them in root-knot nematodes control programs.

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