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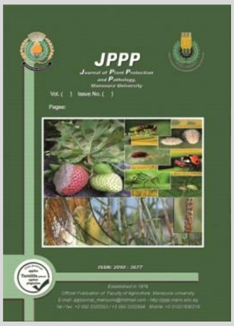
Effect of Different Soil Textures and Infestation Levels on Reproduction and Damage Potential of *Meloidogyne incognita* on Sugarbeet

Maareg, M. F. [1]; Abeer S. Yassin[1*] and K. M. Agami[2]

[1]Department of Sugar Crops Pests and Diseases
[2]Department of Agriculture Practices, Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt.



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ABSTRACT

This study was conducted to evaluate the effect of five soil textures (sandy, sandy loamy, loamy sandy, loamy, and loamy clay) and five inoculum levels (1250, 2500, 5000, 10000, and 20000 J2/pot) on the reproduction and damage potential of *Meloidogyne incognita* on sugar beet. Results indicated that both soil texture and initial population density had significant effects on nematode reproduction and sugar beet yield. The highest final population and reproduction rate occurred in sandy soil, followed by sandy loamy and loamy sandy soils, whereas loamy clay soil recorded the lowest values. Yield losses in roots, top, and raw sugar were most sever in sandy and sandy loamy soils, while loamy clay soil exhibited the least reduction. A strong positive correlation was observed between sand percentage and nematode parameters (final population, reproduction rate, and yield loss), while clay and silt percentages were negatively correlated with these factors. Regarding inoculum levels, the final nematode population increased with initial density up to 10000 J2 and then declined at 20000 J2, whereas reproduction rate consistently decreased with higher inoculum levels. Yield components were adversely affected by increasing inoculum density, with maximum losses recorded at 20000 J2. In conclusion, sandy soils were more favorable for nematode reproduction and crop loss compared to loamy clay soils. These findings highlight the importance of soil texture as a key factor for predicting risk and developing management strategies against root-knot nematodes in sugarbeet cultivation.

Keywords: *Meloidogyne incognita*, Soil texture, Nematode reproduction, Sugarbeet, Yield loss, infestation level.

INTRODUCTION

Root- knot nematodes, *Meloidogyne incognita* and *M. javanica* are considered among the most damaging pathogens attacking sugarbeet roots in Egypt, (Abd- El Massih, 1986; Maareg *et al*., 1988; Gohar, 2003 and Yassin, 2010). These nematodes are responsible for severe yield losses in both roots and sugar content (Gohar & Maareg, 2005 and Maareg *et al*., 2009). A negative relationship between soil infestation nematode levels and sugarbeet yield has been well documented (Gohar & Maareg, 2005, 2009 and Yassin, 2010). Reducing crop losses due to nematode infection is therefore a crucial step toward improving crop productivity.

Soil texture impacts on nematode movement, roots penetration overall population densities, reproduction rate and relationship between preplan population density (infestation level) and crop productivity.

This study were conducted to determine (1) The effects of soil textures and different infested levels on reproductive of *M. incognita*, (2) The damage potential of *M. incognita* on sugarbeet in different soil textures, (3) The damage potential of *M. incognita* on sugarbeet in different infestation levels and (4) The relationships between the soil solid components (sand, silt and clay particles) and both nematode reproduction and sugarbeet productivity.

MATERIALS AND METHODS

Nematodes inoculums preparation:

The *M. incognita* second stage juveniles (J_{2s}) were obtained from roots of susceptible tomato C.V. Ace as pure cultural. The fresh hatched J_{2s} were extracted using Baermann- pan method. Inoculums concentrated and stored at 4- 6. for 2 days before soil infestation.

Soil type textures used:

Five natural soil type textures i.e. sandy (91% sand, 6% silt, 3% clay; PH 7.61; E.C. 0.31, O. M. 0.6% and saturation 24%), Sandy loam (80% sand, 14% silt, 6% clay; pH 7.63; E.C. 0.51, O. M 0.9 and saturation 36.6%), Loamy sand (64% sand, 22% silt, 14% clay; pH 7.31; E.C. 1.79, O. M 1.3 and saturation 40%), Loam (38% sand, 35% silt, 27% clay; pH 7.5; E.C. 0.43, O. M 1.1 and saturation 44%) and Silty clay (5% sand, 48% silt, 47% clay; pH 8.4; E.C. 1.97, O. M 2.1 and saturation 50%) were collected from the major field crop cultivated of West Nubaryia and Bangar El- Sokar districts, and were separately steam- sterilized.

For each soil type, earthen pots (355 mm high; 300 mm diam.) were filled with steam sterilized soil and planted with susceptible sugarbeet, (Mammut variety) seeds on October, 17, 2023. The pots were irrigation every three days. After germination, seedlings were thinned to retain one vigorous plant per pot, 15 days post- emergence. A week after thinning, five different infestation levels of J_{2s} (0, 1250, 2500, 5000, 10000 and 20000) were introduced into the soil, with four replicates per treatment. The inoculum was applied using a pipette into three holes around the seedling, each receiving 10 ml water. The pots were arranged in a Randomized Complete Block Design (RCBD) on a greenhouse (20 ± 5ºc and 65 ± 5 RH). Plants were fertilized with NPK as per sugarbeet cultivation recommendations and irrigated as needed.

[*] **Corresponding author.**
E-mail address: drabeeryassin8@gmail.com
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At harvest time (after 180 days of soil infestation with J_{2s}) plant roots were cleaned, fresh weight of both top and root per plant were recorded and raw sugar percent was determined by Le Doct method as described by Mc Ginnis (1982), and raw sugar yield per plant was calculated by multiplied raw sugar percent × root weight.

The population of J_{2s} in soil of each pot were extracted by using sieving and modified Baermann- technique and counted. To asses development stages and females per root system using staining method as described by (Byrd *et al*, 1983). The final population density (P_f) and the reproduction factor (RF) of *M. incognita* nematode for each treatment were calculated {P_f = number of J_{2s} in soil + number of nematodes in root system, and RF = P_f/ infestation level (P_i)}. Data were analyses using ANOVA following Gomez and Gomez (1984), with mean comparisons conducted using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

I- Effect of different soil textures and infestation levels on reproductive of *M. incognita* on sugarbeet:

Nematode reproduction traits (P_f and RF) and sugarbeet productivity characters (root, top and raw sugar yields) were influenced by soil textures and infestation levels (Table, 1).

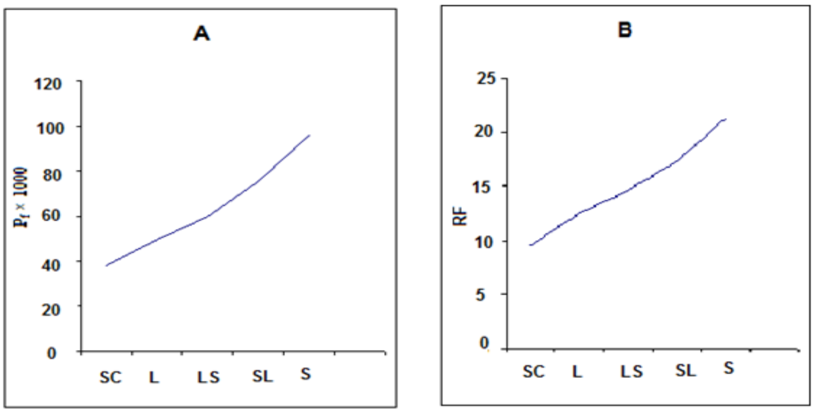
Effect of soil textures:

The nematode reproduction occurred on a sugarbeet in all soil textures tested, with variation among them as shown in Table (1). Significant variations were observed among the five tested soil textures in relation to the P_f and RF values of nematode on sugarbeet plants. The P_f and RF values were influenced ($P \leq 0.05$) significantly by soil textures. The highest value of P_f (95,959.5) was found in sandy soil, then come the sandy loam (75,725.6), loamy sand (59,437.4), loam (49,686.2) and silty clay (38,383.2), respectively. A similar trend was noted for RF values, with corresponding figures of 21.26, 17.3, 14.6, 12.5 and 9.6, respectively. These findings clearly indicate that P_f and RF values increased as the proportion of sand particles in the soil increased, with lighter- textured soils exhibiting higher nematode reproduction rates. Specifically, the highest values were recorded in sandy soil (P_f: 95959.2; RF: 21.3), followed by sandy loam (P_f: 75725.6; RF: 17.3). Conversely, silty clay soil had the lowest P_f and RF values, averaged of 38383.2 and 9.6, respectively, (Table, 1 and Fig, 1). A significant positive correlation ($P \leq 0.05$) was found between the sand content in the soil and both P_f and RF values of nematode, with correlation coefficient (r) was 0.937 and 0.956 for sand%- P_f and sand%- RF, respectively.

Table 1. The final population (P_f) and reproduction factor (RF) of *M. incognita* as influenced by soil textures and infestation population levels.

Soil textures	infestation levels (P_f)					Overall Average
	1250	2500	5000	10000	20000	
			final population (P_f)			
Sand	51250.3	67120.7	95792.0	120423.3	145211.3	95959.2
Sandy loam	41413.0	57500.7	77550.3	93435.3	10830.7	75725.6
Loamy sand	36638.3	48349.7	66367.7	82509.3	64037.7	59437.4
Loam	30188.7	43048.3	56755.7	73750.3	44689.7	49686.2
Silty clay	21687.7	35255.7	48052.7	55311.3	31610.0	38383.2
Overall average	36235.6	50255.0	68903.7	85085.9	78855.9	
			reproduction factor (RF)			
Sand	41.00	26.85	19.16	12.04	7.3	21.26
Sandy loam	33.13	23.00	15.51	9.34	5.44	17.28
Loamy sand	29.31	19.34	13.13	8.25	3.20	14.65
Loam	24.15	17.22	11.35	7.38	2.23	12.47
Silty clay	17.35	14.10	9.61	5.53	1.58	9.63
Overall average	29.0	20.1	13.8	8.5	3.9	

Within Pis | **within RF**
$LSD_{0.05}$ P_{fs} = 418.9 | **$LSD_{0.05}$ R_{fs} = 0.071**
Within average of soil types | **within average of Pi**
LSD0.005 Pf = 194.10 | **LSD0.005 Pf = 281.59**
RF = 0.033 | **RF = 0.027**



Where: SC=Silty clay, L= Loam, LS= Loamy sand, SL= Sandy loam and S= Sandy

Figure 1. Relationship between soil textures and both P_f(A), and RF (B)

While, a significant negative correlation ($P \leq 0.01$) was existed between the content of silt or clay in soil and both P_f and RF of *M.* incognita. The correlation coefficient (r) was -0.963 and -0.976 for silt% -P_f and silt% -RF, respectively, and -0.912 and -0.934 for clay% -P_f and clay% -RF, respectively.

Effect of infestation levels (P_{is}):

The P_f and RF values of M. incognita on sugarbeet plants were influenced by the tested. In general, the impact of tested P_{is} levels of M. incognita J_{2s} (1,250, 2,500, 5,000, 10,000 and 20,000) was significant among them on nematode reproduction traits on sugarbeet plants. As P_i level increased from 1250 up to 2500, 5000 and 10000 J_{2s}, the P_f value progressively increased, from 36,235.6, to 50,255.0, 68,903.7 and 85,085.9, respectively, before declining to 78,855.9 at the 20,000 J_{2s} level. Additionally, a sharp decline in the RF value was observed as P_i level increased. The RF value on sugarbeet plants decreased from 29.0 to 20.1, 13.8, 8.5, and 3.9 as P_i level increased from 1,250 to 2,500, 5,000, 10,000 and 20,000 J_{2s}, respectively, as illustrated in Table, 1 and Figure, 2.

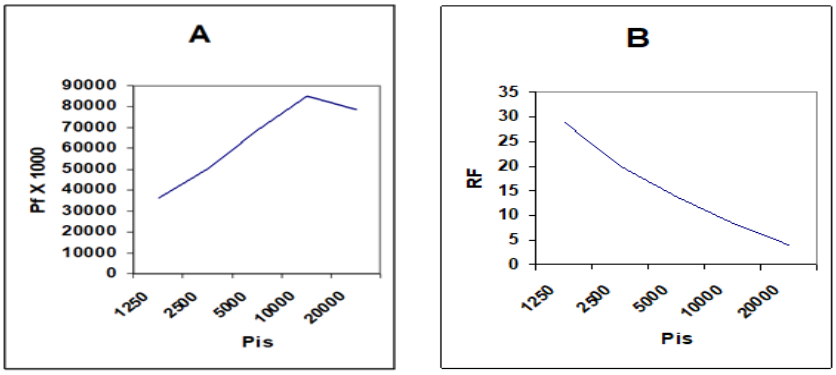


Figure 2. Relationship between infestation population (P_{is}) level and both final population P_f (A) and reproduction factors RF (B)

The P_f and RF values of nematode on sugarbeet plants were influenced ($P \leq 0.05$) by the tested P_{is} levels in all soil texture tested. The highest (145,211.3) and the lowest (21,687.7) P_f values were recorded at P_i levels of 20,000 and 1,250 J_{2s} in sandy and silty clay soils, respectively, compared to the other P_i levels tested. A positive relationship was detected between P_f values and P_i levels. In sandy and sandy loam soils, P_f value was increased significantly ($P \leq 0.05$) as the P_i level increased from 1,250 to 20,000 J_{2s}. However, in loamy sand, loam, and silty clay soil, P_f value increased significantly with increasing P_i level up to 10,000 J_{2s} but decreased ($P \leq 0.05$) significantly when the Pi level was further increased from 10,000 to 20,000 J_{2s}. Similarly, the RF values of nematode on sugarbeet were influenced ($P \leq 0.05$) significantly by the tested Pi levels. The highest RF value (41.00) found at a Pi level of 1,250 J_{2s} in sandy soil, while the lowest value (1.58) was observed at a Pi level of 20,000 J_{2s} in silty clay soil, compared to the other soil texture tested. A negative relationship was detected between RF value and Pi levels. In all tested soil texture, RF values declined significantly ($P \leq 0.05$) as the Pi level increased from 1,250 to 20,000 J_{2s} as shown in Tables, 1.

II- Effect of different natural soil textures and infestation population levels on the damage potential of *M. incognita* on sugarbeet.

The infested soil with nematode J_{2s} caused significant reduction in yield component characters, compared to non infested soils (Tables, 2, 3) yield components, root, top and raw sugar yields of sugarbeet were influenced by tested soil textures (sand, sandy loam, loamy sand, loam and silty clay) and tested infestation levels (1250, 2500. 5000, 10000 and 20000 J_{2s}). as shown in (Table, 2 and 3).

Table 2. The damage potential of *M. incognita* on yield components of sugarbeet in different soil textures

Soil type textures	Yield components					
	Root yield plant^{-1}		Top yield plant^{-1}		raw sugar yield plant^{-1}	
	g	Reduction%	g	Reduction%	g	Reduction%
Sand (con)	980.00 e	-	440.00 d	-	181.13 d	-
Sand + N	516.92	47.25	232.73	47.11	79.30	56.26
Sandy loam (con)	1010.60 d	-	455.00 c	-	184.94 c	-
Sandy loam + N	570.26	43.57	256.80	43.56	86.45	53.81
Loamy sand (con)	1194.30 c	-	538.33 b	-	217.36 b	-
Loamy sand + N	766.00	35.85	298.80	44.50	115.21	47.00
Loam (con)	1203.10 b	-	541.67 b	-	217.76 b	-
Loam + N	787.14	34.57	302.27	44.20	116.65	46.43
Silt clay (con)	1238.50 a	-	557.00 a	-	221.17 a	-
Silt clay + N	869.90	29.76	339.07	39.13	127.35	42.42
$LSD_{0.05}$	6.92		9.43		1.32	

Table 3. The damage potential of *M. incognita* on yield components of sugarbeet, with different infestation level.

Initial population densities	Yield components					
	Root yield		Top yield		Raw sugar yield	
	g plant^{-1}	Reduction%	g plant^{-1}	Reduction%	g plant^{-1}	Reduction%
0	1124.36 a	-	500.40 a	-	204.63 a	-
1250	973.90 b	13.38	438.67 b	12.34	168.28 b	17.76
2500	843.20 c	25.01	379.27 c	24.21	139.67 c	31.75
5000	555.70 d	50.58	262.60 d	47.52	78.14 d	61.82
10000	451.00 e	58.88	202.80 e	59.47	61.68 e	69.86
20000	324.50 f	71.14	146.33 f	70.76	43.07 f	78.95
$LSD_{0.05}$	6.49		8.76		1.64	

Effect of soil textures:

All soil texture had a significant ($P \leq 0.05$) impact on root yield per plant. The highest root yield (1,238.5 g plant^{-1}) was recorded in silty clay soil, while the lowest (980.0 g plant^{-1}) was observed in sandy soil. The greatest damage in root yield was found in sandy and sandy loam soils, with reduction percentages of 47.25 and 43.57%, respectively. Conversely, silty clay soil exhibited the lowest damage percentage (29.76%). Among all tested soil textures, loamy sand and loam soils showed moderate reductions of 35.85% and 34.57%, respectively, as presented in Table 2. Similarly, top yield per plant varied significantly ($P \leq 0.05$) among different soil textures. The highest and lowest top yield values were recorded in silty clay (557.00 g plant^{-1}) and sandy soil (440.00 g plant^{-1}), respectively.

Sandy loam, loamy sand, and loam soil textures had a moderate impact on top yield, with average reduction percentages of 43.56%, 44.56%, and 44.20%, respectively. In contrast, sandy and silty clay soils exhibited the highest (47.11%) and lowest (39.13%) reduction percentages, respectively. A similar trend was observed for raw sugar yield per plant across the tested soil textures. The data clearly indicated that raw sugar yield was significantly ($P \leq 0.05$) influenced by soil texture. The highest raw sugar yield (221.17 g plant^{-1}) was recorded in silty clay soil, whereas the lowest (181.13 g plant^{-1}) was observed in sandy soil. A sharp decline in raw sugar yield was noted in sandy and sandy loam soils, with reduction percentages averaging 56.26% and 53.81%, respectively. Conversely, loamy sand and loam soils exhibited moderate reductions of 47.00% and 46.43%, respectively. The least reduction in raw sugar yield was recorded in silty clay soil. Table, 2. A positive correlation was observed between sand content in soil texture and the reduction damage percentages of root, top and gross sugar yields.

Effect of infestation levels (P_{is}):

The relationship between the Pi of nematode (0, 1,250, 2,500, 5,000, 10,000, and 20,000 J_{2s}) and sugarbeet root, top, and raw sugar yields are tabulated in Table 3. The nematode infestation had a significant impact ($P \leq 0.05$) on root yield. A progressive decline in root yield was observed as the Pi level increased from 0 to 20,000 J_{2s}. The damage in root yield was significant ($P \leq 0.05$) at all tested Pi levels and became more pronounced with increasing Pi level.

The damage was 13.38, 25.01, 50.58, 58.88 and 71.14% at 1250, 2500, 5000, 10000 and 20000 J_{2s} P_i levels compared with the control treatment (P_i= 0), respectively. Similar results were obtained for top yield of sugarbeet for the same trend of P_i levels, with reduction values of 12.34, 24.21, 47.53, 59.47 and 70.76%, respectively, compared with non-infected plants (P_i= 0) treatment. A steady decline in raw sugar yield was observed as Pi increased from 0 to 20,000 J_{2s}. The reduction percentage was statistically significant ($P \leq 0.05$) at all Pi levels, with reductions of 17.76%, 31.75%, 61.82%, 69.86%, and 71.14% at Pi levels of 1,250, 2,500, 5,000, 10,000, and 20,000 J_{2s}, respectively, compared to the Pi= 0 treatment (Table 3). A significant negative regression ($P \leq 0.05$) was detected between Pi level and sugarbeet yield components, with correlation coefficients of r= -0.877, -0.875, and -0.841 for nematode-root yield, nematode-top yield, and nematode- raw sugar yield, respectively.

In general, root, top, and raw sugar yield losses were more pronounced in sandy and sandy loam soil textures, whereas lower nematode-induced damage was observed in silty clay soil. The nematode population in sandy and sandy loam soils significantly restricted yield, as high reproduction rates and nematode densities were sufficient to suppress plant productivity. Conversely, the nematode population was considerably lower in silty clay soil compared to sandy, sandy loam, and other tested soil textures.

Similarly, Windham and Barker (1986) reported that *M. incognita* exhibited higher *RF* values and greater reductions in soybean yield in sandy soil, whereas the lowest values were observed in clay soil. Koenning et al. (1996) also found that *M. incognita RF* was significantly higher in coarse-textured soils compared to fine-textured soils, with P_f values inversely related to the percentage of silt and clay. Verma and Jain (1998) reported that the P_f values of *M. incognita*, based on fecundity and reproduction on cotton plants, were highest in sandy soil, followed by loamy soil, with the lowest values recorded in clay soil, making it the least favorable for nematode development. Similarly, Hasseb et al. (1998) observed the highest P_f values in sandy loam soil, followed by sandy clay loam, loamy sand, and silty loam soils, respectively. While P_f was influenced by all tested soil types, no significant difference was found between sandy clay loam and loamy sand soils. Several other studies have confirmed the preference of *Meloidogyne* spp. for sandy soils. Dabire and Mateille (2004), Cadet et al. (2004), and Jaraba et al. (2007) reported that *Meloidogyne* spp. occurs more frequently and in greater abundance in sandy soils than in clay soils. Arevalo et al. (2007) further observed that in soils with more than 50% sand content, *Meloidogyne* spp. demonstrated increased mobility and infectivity in traditional cocoa plantations. Maareg et al, (2006) and El-Sherif et al. (2011) found significant differences among all tested soil textures regarding, the sandy soil is more favorable to high population of root- knot nematodes and cause more nematode damage on sugarbeet plants than clay soil. However, in contrast to these findings, Mario et al. (2011) reported an inverse relationship between *Meloidogyne* spp. population density and sand content, while noting a positive correlation with more structured soils.

The results demonstrated that infestation level (Pi) is a crucial factor influencing the development and reproduction of *M. incognita*. When different Pi levels were applied to sugarbeet (*Beta vulgaris*), the final populations (P_f) exhibited a positive correlation with the P_i levels. Specifically, as *Pi* increased, the P_f of *M. incognita* also increased. However, the reproduction factor (RF) value showed a gradual decline with increasing Pi. Additionally, the reduction percentages in sugarbeet yield were positively associated with Pi levels compared to the control treatment. These findings align with previous studies on various crops in different regions (Windham & Barker, 1986; Khier *et al*., 2004 and Fourie *et al*., 2010). Furthermore, the present results are consistent with those reported by Gohar & Maareg (2005, 2009), Kaurayem (2006), Maareg and Yassin (2010), Pi gradually increased on sugarbeet plants as Pi level rose. They also confirmed that RF values were inversely related to Pi level, with all Pi levels contributing to significant reductions in root, top, and sugar yields.

CONCLUSION

Soil texture was the most influential factor affecting the P_f and *RF* values of *M. incognita* and the productivity of sugarbeet in this study. A significant ($P \leq 0.005$) effect of soil texture was observed on *M. incognita* P_f and *RF* traits, and sugarbeet yield characters. The greatest yield losses occurred in sandy and sandy loam soils, while silty clay soil exhibited the least nematode-induced damage. In contrast, loamy sand soil had a moderate impact on sugarbeet yields. Additionally, P_f and *RF* values of *M. incognita* and the damage percentages in sugarbeet yields were positively and negatively correlated with sand and silt or clay contents in the soil, respectively. Therefore, sugarbeet cultivation in clay- rich soils is a priority in areas affected by root- knot nematodes, or exploring soil amendment strategies to alter the texture of sandy soils.

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تأثير أنواع من التربة ومستويات من العدوى المختلفة على تكاثروضرر نيماتودا ***Meloidogyne incognita*** على بنجر السكر

محمد فتحى معارج[1] ، عبير صلاح ياسين [1] و كمال محمد عجمى[2]

[1]قسم افات وامراض المحاصيل السكرية, معهد بحوث المحاصيل السكرية, مركز البحوث الزراعية, جيزة, مصر
[2]قسم المعاملات الزراعية, معهد بحوث المحاصيل السكرية, مركز البحوث الزراعية, جيزة, مصر

الملخص

تمت دراسة تأثير خمسة أنواع من الأراضي الطبيعية مختلفة القوام (رملية، رملية لومية، لومية رملية، لومية، لومية طينية) وخمسة مستويات من العدوى (١٢٥٠، ٢٥٠٠، ٥٠٠٠، ١٠٠٠٠، ٢٠٠٠٠ يرقة/أصيص) على تكاثر نيماتودا تعقد الجذور *Meloidogyne incognita* وحجم الضرر الناتج على محصول بنجر السكر. أظهرت النتائج أن قوام التربة كان له تأثير معنوي واضح على كل من تكاثر النيماتودا وإنتاجية بنجر السكر، حيث سجلت الأراضي الرملية أعلى تعداد نهائي ومعدل تكاثر للنيماتودا وأعلى فقد في المحصول (الجذور، الأوراق، السكر الخام)، تلتها التربة الرملية اللومية، بينما سجلت التربة الطمية الطينية أقل تعداد وأقل فقد في الإنتاجية. كما أوضحت النتائج وجود علاقة موجبة قوية بين نسبة الرمل في مكون التربة وبين كل من التعداد النهائي ومعدل التكاثر وحجم الضرر في المحصول، في حين ارتبطت زيادة نسبتي الطمي والطين بعلاقة عكسية مع هذه المؤشرات. أما بالنسبة لمستويات العدوى فقد تبين أن التعداد النهائي للنيماتودا يزداد مع ارتفاع مستوى العدوى حتى ١٠٠٠٠ يرقة ثم يتناقص عند ٢٠٠٠٠ يرقة، بينما معدل التكاثر تناقص تدريجياً مع زيادة مستوى العدوى. كما وُجدت علاقة عكسية بين مستويات العدوى ومكونات المحصول الثلاثة، حيث زاد الفقد في الجذور والأوراق والسكر الخام مع زيادة مستوى العدوى، وسجلت الأراضي الرملية أعلى قيم للفقد مقارنةً بالتربة الطمية الطينية التي سجلت أقل فقد. يتضح من النتائج أن الأراضي الرملية والقريبة منها في القوام توفر ظروفاً مناسبة لتكاثر النيماتودا وزيادة الضرر في المحصول، بينما تعمل الأراضي الطمية الطينية على تقليل التعداد والفقد. وعليه يمكن الاستفادة من خصائص قوام التربة في وضع استراتيجيات لإدارة النيماتودا على أساس نسب مكوناتها (رمل، طمي، طين).