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# RESPONSE OF *DAUCUS CAROTA* PLANTS UNDER *MELOIDOGYNE INCOGNITA* INFECTION TO *BLUMEA AURITA* COMPOST, POWDER, AND ESSENTIAL OIL

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ABSTRACT

*Meloidogyne incognita* is a common pest of carrots grown in hot climates. Existing control methods using synthetic nematicides are associated with contamination and intoxication of plants and the production environment. Recent research trends in pest control include investigations on the use of plant materials. In the present study, *Blumea aurita* compost, powder, and essential oil were assessed in comparison with Furadan for mitigating the effects of *M. incognita* on carrot plants. The essential oil was applied at 10, 20, and 30 mg·ml$^{-1}$, while the compost and powder were applied at 1.0, 2.0, and 3.0 kg·m$^{-2}$. The characteristic components of *B. aurita* essential oil were trans-α-bergamotene (18.04%), caryophyllene epoxide (15.01%), eugenol (11.59%), carvacrol (11.02%), geraniol (10.13%), 1-octen-3-ol (7.03%), 1,8-cineole (7.02%), δ-elemene (7.01%), and α-copaene (6.20%). The reproduction of *M. incognita* on carrot roots and the level of *M. incognita* soil infestation were significantly reduced by *B. aurita* compost and essential oil. The effect of *B. aurita* compost was comparable to that of the standard nematicide – Furadan. Therefore, materials derived from *B. aurita* may prove to be an interesting alternative in inhibiting *M. incognita* populations.

**Key words**: bioprotection, gall index, nematicide, nematode population, plant height, carrot root yield

## INTRODUCTION

Plant parasitic nematodes (PPN) cause significant yield reduction and visible damage to agricultural crops (Khan et al. 2023). More than 4,300 PPN species have been reported as pests of economic importance (Decraemer & Hunt 2006), causing yield losses ranging from 8% to 15% depending on climate, location, and crop type (Singh et al. 2013, 2015). In budgetary terms, crop losses caused by PPNs are calculated at over USD 150 billion (Ali et al. 2015; Kantor et al. 2022). *Meloidogyne incognita* is a major pest among PPNs, responsible for biotic limitations in many crops worldwide (Hussey & Janssen 2002; Garcia et al. 2022).

Carrot (*Daucus carota* L.), a good source of sundry minerals, vitamins, and antioxidants, is particularly susceptible to *M. incognita* infection. Synthetic nematicides are the basic method of nematode control in agriculture. Undoubtedly, this method is effective, however, soil microbial consortia are destabilized, residues remain in the soil and products, and the overall environmental stability is widely compromised (Fabiyi & Olatunji 2021). This requires a global reduction in the use of synthetic nematicides. Due to this, some nematicides are banned and withdrawn from use, which has led to the search for plant materials for the control of nematode pests. The use of plant active substances and metabolites has proven particularly beneficial in the control of the genus *Meloidogyne* and has been widely used on several crops with good efficacy, particularly on *M. incognita* (Fabiyi 2021, 2022).

*Blumea aurita* (L.f.) DC., an herb about 1.50 m high, of the family Asteraceae, which is widely scattered throughout West Africa, is strongly aromatic, rarely grazed by cattle and mainly used as an insecticide (Andrews 1956; Burkill 1985). The extensive application of this herb in folk medicine as an analgesic, anesthetic, antibacterial, and anti-inflammatory agent has been widely documented (Okafor 2002; Abdulla et al. 2013; Olurishe & Mati 2014). Nevertheless, it is necessary to collect data on the possibilities of practical use of *B. aurita* in the control of *M. incognita*. Therefore, this study aims to assess the feasibility of using *B. aurita* essential oil (EO), powder, and compost in comparison with Furadan in the control of *M. incognita* infecting carrot plants. Although Furadan is banned in the European Union, Canada and other countries, its use is allowed in Nigeria.

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## MATERIALS AND METHODS

**Preparation of plant materials**

A considerably large amount of the whole *Blumea aurita* plant was collected from the habitat and divided into three parts. One part was extracted for essential oil, the other was dried into powder, and the last part was used for composting. A square pile was formed on the concrete floor. The size of the pile was 150 × 150 cm. The first layer, the base, was made of maize stalks up to 10 cm, then 5 cm of fresh sheep manure, then 15 cm of *B. aurita*, and then 5 cm of dry mango leaves. The layers were repeated until the pile reached 150 cm. Each layer was doused with rabbit urine and water in a 1 : 1 ratio and then sprinkled with mango wood ash. The layer was covered with 5 cm thick humus soil, collected from under the shade of trees. Finally, the pile was covered with a thick, transparent 0.254 mm polyethylene foil to heat and decompose quickly. To ensure oxygen and proper mixing of materials, turning took place four times every two weeks, with materials at the edges being moved to the center and conversely. The pile was watered each time it was turned over with rabbit urine and water (1 : 1). The temperature in the center of the pile rose to 53–61 °C and then dropped to 27 °C. Harvesting was carried out at this point after 120 days. The compost was dark brown in colour and granular in shape. Air-dried *B. aurita* plant material was ground into powder, and EO was obtained from fresh *B. aurita* plants by standard methods (Fabiyi et al. 2020). *B. aurita* materials were coded as follows: BMAT/PWD – powder, BMAT/EO – essential oil, BMAT/CPST – compost, and FRD – Furadan (carbofuran). A list of treatment methods is provided in Table 1.

**Planting experiment**

The experiment was conducted from November 2019 to February 2020 and repeated from November 2020 to February 2021. The field was divided into 5 × 2 m plots. The study included four treatments, allocated at four levels with five individual replicates, assigned to a randomized complete block design with 80 experimental plots. Before planting, soil samples were randomly collected from each experimental plot to a depth of 25 cm to estimate the population of native nematodes, in particular *M. incognita*. Ten subsamples were taken from each plot, mixed thoroughly and combined as composite samples. For extraction of nematodes, 200 cc of soil was collected from each sample using the procedure established by Jenkins (1964).

The direct sowing method was used for planting with a spacing of 40 cm between rows and 25 cm between carrot plants (‘Touchon Mega’). *B. aurita* compost and powder were mixed into the top 10 cm of soil at rates of 1.0, 2.0, and 3.0 kg·m$^{-2}$ on the plots 30 days before planting to ensure proper decomposition. For *M. incognita* inoculum, juveniles (J$^2$) were extracted from root galls using the technique described by Baker (1985). Freshly hatched *M. incognita* juveniles were inoculated into the central hole at the base of each carrot seedling with 50 ml of a 30 per ml suspension six days after sprouting to increase the initial population. The EO was predissolved in hydroxypropyl-β-cyclodextrin and applied to the soil around each plant at 10, 20, and 30 mg·ml$^{-1}$ in 200 ml of solution one week after inoculation. Furadan was applied at 1.0, 1.5, and 2.0 kg a.i. per ha. Recommended agronomic practices such as fertilization and weeding for carrot production were applied in all plots during the study period. Carrot root damage was assessed using the Bridge and Page (1980) scale and expressed as a gall index. A carrot plant was marked for further sampling in each plot, resulting in a total of 80 plants. The height of carrot plants was measured two to eight weeks after treatment. During harvest, the weight of carrot roots was measured. Soil nematode population, root, and gall indices were assessed in the first and second experiments. Data from two trials were analyzed using R software version 3.1.0 (R Core Team 2013). Time was considered as the main factor and *B. aurita* materials as subfactors. The interaction between data sets was not significant ($p < 0.05$), therefore the data were combined and analyzed. Tukey’s HSD was used to separate means ($p \leq 0.05$).

Table 1. Treatments used in the experiment

| Treatment | Concentration | | | |
|---|---|---|---|---|
| | control | level 1 | level 2 | level 3 |
| Furadan (FRD) | 0 | 1.0 kg a.i.·ha$^{-1}$ | 1.5 kg a.i.·ha$^{-1}$ | 2.0 kg a.i.·ha$^{-1}$ |
| *B. aurita* powder (PWD) | 0 | 1.0 kg·m$^{-2}$ | 2.0 kg·m$^{-2}$ | 3.0 kg·m$^{-2}$ |
| *B. aurita* essential oil (EO) | 0 | 10 mg·ml$^{-1}$* | 20 mg·ml$^{-1}$ | 30 mg·ml$^{-1}$ |
| *B. aurita* compost (CPST) | 0 | 1.0 kg·m$^{-3}$ | 2.0 kg·m$^{-3}$ | 3.0 kg·m$^{-3}$ |

*in 200 ml

## RESULTS

**Essential oil composition**

Thirteen compounds were identified, among which nine was above 5%: trans-α-bergamotene (18.04%), caryophyllene epoxide (15.01%), eugenol (11.59%), carvacrol (11.02%), geraniol (10.13%),1-octen-3-ol (7.03%), 1,8-cineole (7.02%), δ-elemene (7.01%), and α-copaene (6.20%). The others were ascertained in trace amounts.

**Initial nematode population**

In the sampled plots, the following plant parasitic nematodes were identified in 200 cc of soil: *Pratylenchus* spp. (83), *Tylenchulus* spp. (79), *Scutellonema* spp. (102), and *Meloidogyne* spp. (607) on average from three counts.

**Effect of *B. aurita* materials on *M. incognita* multiplication**

The multiplication of *M. incognita* in soil and on carrot roots was significantly suppressed by each tested concentration of Furadan and each tested amount and formulation of *B. aurita* materials compared to the untreated control (Table 2). The decrease was related to concentration. The greatest reduction in the *M. incognita* population in roots and soil was recorded at the highest concentration of Furadan and plant materials. The highest concentration of Furadan reduced the population of juveniles in the soil by 148 times and the population in the roots by 69 times. The highest reduction effect was recorded for compost (43 and 17 times less than in the control, respectively), followed by EO (30.5 and 7.4 times less), and the weakest reduction effect was recorded for powder (18.5 and 7.4 times less). Carrot root damage by *M. incognita*, characterized by the gall index, decreased with all types of treatments and their concentrations, most in the plots where Furadan and compost were applied.

**Effect of *B. aurita* materials on plant growth and yield**

Furadan and *B. aurita* materials notably enhanced the growth of carrot plants. Plant height increased significantly with increasing doses (Table 3). After eight weeks of Furadan application, the height was 2.4 times greater than in the control. At the highest dose of *B. aurita* powder, plants were 1.6 times higher than the control, whereas these increases in the EO-treated plots were 2.2 times higher. The height of plants grown in plots treated with compost increased 2.4 times, which was equal to the Furadan results. At harvest, both Furadan and *B. aurita* materials led to significant increases in carrot yield, providing practical benefits. Plant height and root yield increased in all treatments compared to the control and increased with concentration. The highest increase was recorded in plots with compost (8.5 times higher), followed by plots with Furadan (7.1 times higher), plots with EO (4.7 times higher), and plots with powder (2.5 times higher) (Table 3).

Table 2. Average population of juveniles in the soil, root and gall index of harvested carrot roots depending on the treatment

| Treatments | Juvenile population in 200 cc of soil at harvest | Nematodes population in 10 g root sample | Gall index |
|---|---|---|---|
| $FRD_0$ | 1932±66[ab] | 413±18.9[ab] | 10±2.2[a] |
| $FRD_1$ | 115±4[c] | 56±4.9[de] | 3.2±0.5[c] |
| $FRD_2$ | 35±2[de] | 12±1.8[e] | 1.3±0.5[d] |
| $FRD_3$ | 13.3±1.3[e] | 6±1.3[e] | 0.8±1.3[e] |
| $BMAT/PWD_0$ | 2038.3±78.7[a] | 398.8±12.5[b] | 9.7±0.9[a] |
| $BMAT/PWD_1$ | 353±13.9[c] | 133.2±7.6[c] | 6.2±1.3[b] |
| $BMAT/PWD_2$ | 204.5±7.2[c] | 88.4±9.4[cd] | 5.3±0.9[b] |
| $BMAT/PWD_3$ | 110.2±3.6[c] | 54±4.5[de] | 3.4±1.3[c] |
| $BMAT/EO_0$ | 1893±19.2[b] | 461.4±19.7[a] | 10±0.9[a] |
| $BMAT/EO_1$ | 137.8±0.9[c] | 106.8±7.2[c] | 4.3±0.5[bc] |
| $BMAT/EO_2$ | 97.4±1.8[cd] | 71.4±4.0[d] | 3.9±0.5[bc] |
| $BMAT/EO_3$ | 61.7±2.2[d] | 49.4±0.9[de] | 3.1±0.5[c] |
| $BMAT/CPST_0$ | 2243.1±5.09[a] | 371.2±16.1[b] | 9.8±1.3[a] |
| $BMAT/CPST_1$ | 103.5c±6.3 | 93.8±3.1[c] | 3.7±0.5[c] |
| $BMAT/CPST_2$ | 88.1±4.0[cd] | 38.5±2.2[de] | 2.6±0.9[d] |
| $BMAT/CPST_3$ | 51.7±2.1[d] | 22.3±1.8[de] | 1.7±0.5[d] |

FRD – Furadan, BMAT/PWD – *B. aurita* powder, BMAT/EO – *B. aurita* essential oil; BMAT/CPST – *B. aurita* compost

Table 3. Average height of carrot plants and yield depending on the treatment

| Treatments | Time of measurement (weeks after treatment) | | | | Carrot root yield |
|---|---|---|---|---|---|
| | 2 WAT | 4 WAT | 6 WAT | 8 WAT | ($kg \cdot ha^{-1}$) |
| FRD$_0$ | $6.2\pm0.7^{c}$ | $7.3^{e}\pm1.1^{e}$ | $8.1\pm1.0^{e}$ | $9.4\pm1.1^{f}$ | $385.9\pm6.0$ |
| FRD$_1$ | $8.7\pm1.1^{b}$ | $10.6^{cd}\pm1.1^{cd}$ | $11.9\pm1.3^{d}$ | $12\pm1.4^{e}$ | $1017\pm16.2^{cd}$ |
| FRD$_2$ | $10.3\pm1.7^{ab}$ | $13.2^{bc}\pm1.3^{be}$ | $16.3\pm1.6^{b}$ | $17.8\pm2.3^{c}$ | $2514.4\pm13.9^{b}$ |
| FRD$_3$ | $13\pm2.1^{ab}$ | $16.2^{ab}\pm1.9^{ab}$ | $18\pm1.9^{b}$ | $22.1\pm2.2^{a}$ | $2748.1\pm29.4^{b}$ |
| BMAT/PWD$_0$ | $6.4\pm0.7^{c}$ | $7.9^{e}\pm0.6^{e}$ | $8.6\pm0.9^{e}$ | $9.2\pm1.2^{f}$ | $402.1\pm19.1^{ef}$ |
| BMAT/PWD$_1$ | $7.2\pm0.0^{bc}$ | $8.2^{de}\pm1.3^{de}$ | $10.3\pm1.3^{de}$ | $10.9\pm1.2^{ef}$ | $621\pm12.1^{de}$ |
| BMAT/PWD$_2$ | $8.3\pm1.2^{b}$ | $9.8^{d}\pm1.1^{d}$ | $11\pm1.1^{d}$ | $11.8\pm1.0^{e}$ | $810.7\pm4.0^{d}$ |
| BMAT/PWD$_3$ | $9.1\pm1.5^{b}$ | $11.4^{c}\pm0.0^{c}$ | $13\pm1.2^{e}$ | $14\pm2.0$ | $1006.3\pm11.0^{cd}$ |
| BMAT/EO$_0$ | $6\pm0.6^{c}$ | $7.2^{e}\pm0.0^{e}$ | $8.3\pm0.5^{e}$ | $9.1\pm1.1^{f}$ | $396.4\pm25.4^{f}$ |
| BMAT/EO$_1$ | $7.3\pm1.2^{bc}$ | $8.9^{d}\pm1.0^{d}$ | $11.1\pm1.1^{d}$ | $13.3\pm1.7^{e}$ | $968.8\pm18.5^{d}$ |
| BMAT/EO$_2$ | $9.6\pm1.5^{b}$ | $10.4^{cd}\pm0.0^{cd}$ | $12.1\pm1.3^{cd}$ | $14.3\pm2.4^{d}$ | $1028.2\pm6.9^{cd}$ |
| BMAT/EO$_3$ | $12.7\pm1.9^{ab}$ | $15.3^{b}\pm1.1^{b}$ | $19.1\pm1.9^{ab}$ | $19.8\pm1.2^{b}$ | $1864.5\pm7.5^{c}$ |
| BMAT/CPST$_0$ | $6.3\pm0.8^{c}$ | $7.4^{e}\pm0.8^{e}$ | $8.7\pm1.0^{e}$ | $9.9\pm0.8^{f}$ | $428.3\pm5.2^{e}$ |
| BMAT/CPST$_1$ | $9.2\pm1.4^{b}$ | $11.3^{c}\pm0.8^{c}$ | $13.1\pm1.1$ | $13.9\pm2.0^{de}$ | $1274.2\pm6.9^{cd}$ |
| BMAT/CPST$_2$ | $11.5\pm1.9^{ab}$ | $14.1^{b}\pm1.5^{b}$ | $17.1\pm1.5^{b}$ | $18.6\pm2.1^{bc}$ | $1779.6\pm6.4^{c}$ |
| BMAT/CPST$_3$ | $15\pm2.3^{a}$ | $17.3^{a}\pm1.8a$ | $21.3\pm2.2^{a}$ | $23.6\pm3.1^{a}$ | $3628.9\pm11.0^{a}$ |

Note: see Table 2

## DISCUSSION

*Blumea aurita* materials in this study significantly minimized the multiplication of *M. incognita* on carrot plants, which was accompanied by increased carrot growth and yield. The highest dose of Furadan and compost containing *B. aurita* were most inhibitory. Composting has previously been reported to be effective and provide consistent benefits to soil and crop health. Among others, Leroy et al. (2007) found an increase in the population of bacteriophagous nematodes, while the population of plant parasitic nematodes decreased in soil amended with garden waste compost and this was accompanied by higher maize yield. Moselhy (2009) found a significant impairment of *M. incognita* developmental stages on sunflower roots amended with agro-industrial wastes, while Cayuela et al. (2008) in their study of olive mill waste compost also reported a strong inhibition of *M. incognita* egg hatching, as well as weakening of $J^2$ motility.

Abou El Atta et al. (2012) reported that compost from municipal waste incorporated one week before transplanting eggplants effectively inhibited egg mass, eggs per root, and galls on eggplant roots. Abdel-Bary et al. (2014), who evaluated animal and tea composts and their extracts, proved that both compost are capable of inhibiting the reproduction of *M. incognita*. In the *in vitro* experiment, the activity of plant compost extracts exceeded that of animal compost. After 72 hours, 58.8% mortality of *M. incognita* $J^2$ was observed in the plant compost, while in the animal compost the mortality rate was 55.4%. Moreover, in screenhouse trials using solid composts applied at 25, 50, and 100 $g \cdot kg^{-1}$ of soil, significant inhibition of egg masses, juveniles, and galls was recorded, on average by 71.9%, 88.0%, 92.5% (plant compost) and 73.6%, 85.1%, 91.7% (animal compost), depending on the concentration. Similarly, Atungwu et al. (2012) reported lower populations of *M. incognita* in soybean plots treated with compost. It should be emphasized that in addition to its nematicidal effect, compost also improves soil fertility and structure, which affects plant yields.

The success of *B. aurita* EO in reducing the multiplication of *M. incognita* is consistent with the reports of El-Habashy et al. (2022) who found that *Artemisia judaica* EO was highly effective and superior to oxamyl in inhibiting *M. incognita* developmental stages in *in vitro* and screenhouse studies. Similarly, Ntalli et al. (2023) found that *Carlina acaulis* essential oil hindered the developmental cycle of *M. incognita*. It showed remarkable nematicidal activity against *M. incognita* $J^2$, and its penetration into tomato roots was significantly inhibited.

The use of *B. aurita* powder also inhibited the multiplication of *M. incognita*. For example, powdered material of *Eupatorium adenophorum* (Spreng.) dried roots, stems, and leaves reduced the survival of *M. incognita* in cucumber plants (Parsiaaref et al. 2023). The authors obtained high mortality of juveniles, increased shoot length of cucumber plants, and abundant yield of cucumber fruit compared to the control. Comparatively, the powdered material of *Lawsonia inermis* showed significant activity against *M. incognita* parasitizing lettuce plants (Fabiyi 2024). The results of this study indicate the relative effectiveness of *B. aurita* in *M. incognita* control.

## CONCLUSION

Application of *Blumea aurita* materials in the form of powder, essential oil, and compost helps to reduce the occurrence of *Meloidogyne incognita* in soil and carrot roots and is associated with better plant growth and higher root yield. The effect of *B. aurita* compost was comparable to the use of the standard nematicide Furadan, so it can potentially serve as a reasonable replacement for synthetics. Future research is recommended to investigate the effect of compost on the physical and chemical properties of soil and on the quality of carrot roots.

## REFERENCES

Abdel-Bary N.A., Hendy H.H., Ashoub A.H., Yassin M.Y., Abdel-Razek G.M. 2014. Evaluation of compost and compost tea as promising method for *Meloidogyne incognita* management. Egyptian Journal of Agronematology 13(2): 50–66. DOI: 10.21608/ejaj.2014.63617.

Abdulla M.A., Lutfi M.F., Baket A.O., Mohamed A.H. 2013. Evaluation of the anti-inflammatory effects of *Blumea aurita.* Global Journal of Medical Research 13(B4): 23–29.

Abou El Atta D.A.M., Mostafa F.A.M., Taha H.A. 2012. Effectiveness of certain botanical and city waste composts on *Meloidogne incognita* infecting eggplant. Egyptian Journal of Agronematology 11(1): 90–105.

Ali M.A, Abbas A, Azeem F, Javed N, Bohlmann H 2015. Plant-nematode interactions: from genomics to metabolomics. International Journal of Agricultural Biology 7: 1071–1082. DOI: 10.17957/ijab/15.0037.

Andrews F.W. 1956. The flowering plants of the Sudan, vol. 3. T. Buncle, Arbroath, Scotland, 579 p.

Atungwu J., Lawal O., Afolami S., Adejuyigbe C. 2012. Appraisal of compost for suppression of *Meloidogyne* species and enrichment of micro-arthropods in soybean fields. Biological Agriculture and Horticulture 28(2): 101–110. DOI: 10.1080/01448765.2012.681348.

Baker K.R. 1985. Sampling nematode communities. In: Baker K.R., Carter C.C., Sasser J.N. (Eds.), An advanced treatise on *Meloidogyne*, vol. 2. Methodology. North Carolina State University, USAID, Raleigh, USA, pp. 3–17.

Bridge J., Page S.L.J. 1980. Estimation of root-knot nematodes infestation levels on roots using a rating chart. Tropical Pest Management 26(3): 296–298. DOI: 10.1080/09670878009414416.

Burkill H.M. 1985. The Useful Plants of West Tropical Africa. Royal Botanical Gardens, Kew, UK, pp. 452–453.

Cayuela M.I., Millner P.D., Meyer S.L.F., Roig A. 2008. Potential of olive mill waste and compost as biobased pesticides against weeds, fungi, and nematodes. Science of the Total Environment 399(1–3): 11–18. DOI: 10.1016/j.scitotenv.2008.03.031.

Decraemer W., Hunt D.J. 2006. Structure and classification. In: Perry R.N., Moens M. (Eds.), Plant nematology, vol. 32. CABI, Wallingford, UK, p. 3–40. DOI: 10.1079/9781845930561.0003.

El-Habashy D.E., Adss I.A., Abdelrasoul M.A., Abdelgaleil S.A.M. 2022. Efficacy of six essential oils for the management of *Meloidogyne incognita* in eggplant and their effect on the expression of plant defense genes. International Journal of Pest Management, 10 p. DOI: 10.1080/09670874.2022.2145520.

Fabiyi O.A., Atolani O., Olatunji G.A. 2020. Toxicity effect of *Eucalyptus globulus* to *Pratylenchus* spp. of *Zea mays*. Sarhad Journal of Agriculture 36(4): 1244–1253. DOI: 10.17582/journal.sja/2020/36.4.1244.1253.

Fabiyi O.A., Olatunji G.A. 2021. Environmental sustainability: bioactivity of *Leucaena leucocephala* leaves and pesticide residue analysis in tomato fruits. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 69(4): 473–480. DOI: 10.11118/actaun.2021.042.

Fabiyi O.A. 2021. Evaluation of *Terminalia glaucescens* chromatographic fractions on *Meloidogyne incognita* infecting chili pepper (*Capsicum chinense*). Journal of Horticulture Research 29(1): 67–74. DOI: 10.2478/johr-2021-0006.

Fabiyi O.A. 2022. Evaluation of weeds against root-knot nematode (*Meloidogyne incognita*) in vegetables. Sarhad Journal of Agriculture 38(4): 1289–1299. DOI: 10.17582/journal.sja/2022/38.4.1289.1299.

Fabiyi O.A. 2024. Management of *Meloidogyne incognita* damaging lettuce: potential of chromatographic fractions and extracts from *Lawsonia inermis.* Journal of Animal and Plant Science 34(3): 671–680. DOI: 10.36899/japs.2024.3.0753.

Garcia N., Grenier E., Buisson A., Folcher L. 2022. Diversity of plant parasitic nematodes characterized from fields of the French national monitoring programme for the Columbia root-knot nematode. PLoS One 17(3); e0265070; 16 p. DOI: 10.1371/journal.pone.0265070.

Hussey R.S., Janssen G.J.W. 2002. Root-knot nematodes: *Meloidogyne* species. In: Starr J.L., Cook R., Bridge J. (Eds.), Plant resistance to parasitic nematodes. CABI, London, UK, pp. 43–70. DOI: 10.1079/9780851994666.0043.

Jenkins W.R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48(9): 692.

Kantor M., Handoo Z., Kantor C., Carta L. 2022. Top ten most important U.S.-regulated and emerging plant-parasitic nematodes. Horticulturae 8(3); 208; 26 p. DOI: 10.3390/horticulturae8030208.

Khan M.R., Haque Z., Sharma R.K. 2023. Novel biotechnological interventions in plant nematode management technologies. In: Khan M.R. (Ed.), Novel Biological and Biotechnological Applications in Plant Nematode Management. Springer, pp. 167–186. DOI: 10.1007/978-981-99-2893-4_7.

Leroy B.L.M.M., Bommele L., Reheul D., Moens M., De Neve S. 2007. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: Effects on soil fauna and yield. European Journal of Soil Biology 43(2): 91–100. DOI: 10.1016/j.ejsobi.2006.10.005.

Moselhy M.A. 2009. Bioconversion of rice straw and certain agro-industrial wastes to fertilizers for organic farming systems. Ph.D. Thesis, Faculty of Agriculture, Cairo University, 221 p.

Ntalli N., Zochios G., Nikolaou P., Winkiel M., Petrelli R., Bonacucina G. et al. 2023 *Carlina acaulis* essential oil nanoemulsion for managing *Meloidogyne incognita.* Industrial Crops and Products 193; 116180; 6 p. DOI: 10.1016/j.indcrop.2022.116180.

Okafor J.C. 2002. Tropical plants in health care delivery in Nigeria: Contributions of some members of Compositae (Asteraceae). Journal of College of Medicine 7(2): 129–131.

Olurishe T.O., Mati F.G. 2014. Anti hyperalgesic potentials of *Laggera aurita* in Swiss Albino mice. Pakistan Journal of Pharmaceutical Science 27(1): 169–172.

Parsiaaref S., Cao A., Li Y., Ebadollahi A., Parmoon G., Wang Q. et al. 2023. Nematicidal and toxicity effects of *Eupatorium adenophorum* Spreng against the root-knot nematode *Meloidogyne incognita* in soil producing cucumber. Agriculture 13(6); 1109; 12 p. DOI: 10.3390/agriculture13061109.

R Core Team 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Singh S.K., Hodda M., Ash G.J. 2013. Plant-parasitic nematodes of potential phytosanitary importance, their main hosts and reported yield losses. EPPO Bulletin 43(2): 334–374. DOI: 10.1111/epp.12050.

Singh S., Singh B., Singh A.P. 2015. Nematodes: a threat to sustainability of agriculture. Procedia Environmental Sciences 29: 215–216. DOI: 10.1016/j.proenv.2015.07.270.