

ORIGINAL ARTICLE

Comparative Study on the Effects of *Meloidogyne* spp. Infection on *Psidium guajava* and *Mangifera indica*

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ABSTRACT

Root-knot nematodes (*Meloidogyne* spp.) are among the most destructive plant-parasitic nematodes affecting fruit crops worldwide. Among them, *Meloidogyne incognita* and *Meloidogyne enterolobii* are important pathogens causing severe damage to guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.). The present study was conducted under greenhouse conditions to compare the pathogenic effects of these two nematode species on guava and mango plants. Healthy seedlings of both crops were transplanted into sterilised soil and inoculated with 2,000 second-stage juveniles (J2) of either *M. incognita* or *M. enterolobii*. Non-inoculated plants served as controls. Plant growth, chlorophyll content, root galling, nematode population density, and fruit yield were evaluated 120 days after inoculation. Results revealed that nematode infection significantly reduced plant height, biomass accumulation, chlorophyll content, and fruit yield in both crops compared with healthy controls. In contrast, root gall formation and nematode multiplication increased considerably in infected plants. Among the two species, *M. enterolobii* exhibited greater aggressiveness and pathogenicity than *M. incognita*, causing more severe root galling, higher nematode populations, and greater reductions in growth and yield. Guava plants showed higher susceptibility than mango plants, as indicated by increased gall indices, nematode reproduction, and yield losses. The findings highlight the economic importance of root-knot nematodes in fruit production and emphasise the need for early diagnosis, regular monitoring, and integrated nematode management strategies for sustainable cultivation of guava and mango.

Keywords: *Meloidogyne incognita*, *Meloidogyne enterolobii*, Guava, Mango, Root-knot Nematode, Fruit Yield, Plant Pathogenicity.

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INTRODUCTION

Guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) are among the most important fruit crops cultivated in tropical and subtropical regions of the world. These fruits contribute significantly to human nutrition, agricultural income, and the horticultural economy. India is one of the leading producers of both guava and mango, and these crops provide livelihood support to millions of farmers. However, their productivity is frequently affected by several biotic and abiotic constraints, among which plant-parasitic nematodes are considered major limiting factors. Root-knot nematodes (*Meloidogyne* spp.) are among the most destructive plant-parasitic nematodes causing substantial economic losses in agricultural and horticultural crops worldwide. These microscopic soil-borne pathogens invade plant roots and induce the formation of characteristic root galls, which interfere with water and nutrient uptake. As a result, infected plants exhibit stunted growth, chlorosis, wilting, reduced vigor, and significant yield losses.[1] Among the numerous species of root-knot nematodes, *Meloidogyne incognita* and *Meloidogyne enterolobii* are particularly important because of their broad host range and high pathogenic potential. *M. incognita* is one of the most widely distributed nematode species and infects a large number of cultivated crops. In

contrast, *M. enterolobii* is recognized as a highly aggressive species capable of overcoming resistance genes effective against other root-knot nematodes. Its rapid multiplication and destructive nature make it a serious threat to fruit production. In recent years, *M. enterolobii* has been identified as a major causal agent of guava decline disease. Severe infestations result in root galling, destruction of feeder roots, nutrient deficiencies, canopy thinning, branch dieback, and eventual plant death. Although mango is generally considered less susceptible than guava, nematode infestations can still significantly affect plant growth and productivity under favorable conditions. Understanding the comparative pathogenicity of different *Meloidogyne* species and the susceptibility of important fruit crops is essential for developing effective management strategies. Therefore, the present study was undertaken to compare the effects of *M. incognita* and *M. enterolobii* on guava and mango plants under greenhouse conditions. The study aimed to evaluate growth reduction, root gall formation, chlorophyll content, nematode reproduction, and yield losses caused by these nematodes, thereby providing valuable information for future nematode management programs. [2]

MATERIAL AND METHODS

Experimental Site

The present study was carried out in the Department of Botany and Plant Pathology in greenhouse conditions during the growing season. The greenhouse temperature was kept at an optimum level for plant growth and nematode development. The temperature was maintained at $28 \pm 2^\circ\text{C}$, with the relative humidity being kept between 70 and 80% during the experimental period. A natural photoperiod was supplemented with artificial light as needed to provide sufficient light and uniform plant growth.[3] Regular monitoring facilities in the greenhouse were installed, such as temperature and humidity. All the experimental units were irrigated, weeded and plant maintained in the same way. All precautions have been taken to ensure no other pests and pathogens were able to contaminate the product. A greenhouse environment allowed to evaluate the pathogenic ability of *Meloidogyne incognita* and *Meloidogyne enterolobii* in guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants, which reduced the effect of external environmental factors. The experiment was designed as a completely randomized design and the observations were made systematically throughout the experiment.[4]

Plant Material

Guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) seedlings used in the present study were healthy, vigorous and uniform. Seedlings of both fruit crops were obtained from a certified nursery for 3-4 months old which is considered genetically pure and disease free. Before the seedlings were planted, each was thoroughly checked to be sure that healthy experimental material was being used and that there were no signs of disease, especially nematodes, or root abnormalities. These seedlings were transplanted singly in plastic pots, 30 cm in diameter. The potting mixture was prepared with sand, loam soil and well-decomposed farmyard manure (FYM) at 2:1:1, and 5 kg of the mixture was put in each pot. The planting mix was well mixed to ensure sufficient air, drainage and nutrition for the growth of the plants. Soil mixture was autoclaved at 121°C for 15 psi for 30 minutes, to kill any soil-borne pathogens, weed seeds and pre-existing populations of plant-parasitic nematodes. The soil was sterilised and then incubated to stabilise it before use. All the transplanted seedlings were kept in the greenhouse and watered regularly to ensure optimum soil moisture. A uniform method of standard cultural practices, including nutrient supplementation and plant care, was used in all experimental units throughout the study period. Such measures facilitated the establishment of healthy plants and reduced the impact of non-nematode pathogen factors on the evaluation of nematode pathogenicity.[5]

Nematode Inoculum Preparation

Pure cultures of *Meloidogyne incognita* and *Meloidogyne enterolobii* were kept in a greenhouse on susceptible tomato (*Solanum lycopersicum* L.) plants. For nematodes, their purity and viability were constantly checked. The nematode species were identified by the use of the normal nematological keys and procedures based on the perineal pattern morphology, morphometric characteristics, etc. Egg masses were carefully removed with tweezers and washed with distilled water to get rid of soil particles. These egg masses were then immersed in distilled water at room temperature, allowing the eggs to hatch. Second-stage juveniles (J2), which are the infective stage of root-knot nematodes, were isolated from the soil using the modified Baermann funnel method. Juvenile suspension that was obtained was filtered and collected in clean containers for further use. The concentration of juveniles in the suspension was determined using a stereomicroscope and a nematode counting dish. Suspension was well mixed before counting to ensure uniform distribution of juveniles. To get the required number of infective juveniles, a suitable inoculum size was prepared by adjusting the number of counts with distilled water. Two weeks after transplantation, when the seedlings had become well established in the pots, nematode inoculation

was carried out. A small depression was dug around the plant root zone, and a standardised inoculum of 2,000 recently hatched second life-stage (J2) of either *M. incognita* or *M. enterolobii* was evenly distributed to each designated plant in the treatment. Caution was exercised to ensure that the inoculum was placed close to the root system to allow for infection and establishment of nematodes. The holes were filled with soil after the inoculation and the plants were lightly irrigated to encourage nematode penetration into the root zone. The distilled water with no nematodes, but the same volume, was used on control plants. All plants were then grown with the same greenhouse treatments and conditions for the duration of the experiment.

Experimental Design

The experiment was carried out in a completely randomised design (CRD) with a controlled greenhouse environment. The treatments included in the study were six, with five replications per treatment. A total of 30 experimental units were obtained, with each replication being a potted plant.

The guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants were infected with *Meloidogyne incognita* and *Meloidogyne enterolobii* and compared to the response of the plants. The following procedures were used as the 6 treatments:

T₁: Guava (non-inoculated control)

T₂: Guava inoculated with *Meloidogyne incognita*

T₃: Guava inoculated with *Meloidogyne enterolobii*

T₄: Mango (non-inoculated control)

T₅: Mango inoculated with *Meloidogyne incognita*

T₆: Mango inoculated with *Meloidogyne enterolobii*

To avoid environmental variation and position effects, the experimental units were randomly arranged within the greenhouse. The cultural and environmental conditions used for all plants were the same during the investigation. The plant growth, root galling, nematode reproduction and other related parameters were observed at predefined intervals and analyzed statistically to assess the effect of nematode infection on the two fruit crops [6]. The treatments were set up to assess and compare the pathogenicity of *Meloidogyne incognita* and *Meloidogyne enterolobii* on guava and mango plants in the greenhouse. Non-inoculated healthy plants of both species were used as controls for comparison with the nematode-inoculated plants. Growth, physiological and nematological observations were made at regular intervals during the experimental period. Data were gathered on plant growth parameters, physiological characteristics, root galling, nematode population development and other observations, until 120 days after inoculation (DAI). The recorded data were then analysed statistically to compare the pathogenicity of the two species of nematodes and their effect on the growth and development of guava and mango plants [7].

Measurement of Growth Parameters

The growth parameters were measured to evaluate the effect of *Meloidogyne incognita* and *Meloidogyne enterolobii* on the growth and development of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants at regular intervals. These observations gave useful data about the degree of damage that the nematodes caused and the relative susceptibility of the two host plants. All measurements were performed according to standard methods in order to be accurate and consistent during the experimental period. Growth was measured from the time the plants were established through 120 days after nematode inoculation. Vegetative growth parameters such as the number of leaves, shoot length, root length, plant height, stem diameter and biomass accumulation were measured at fixed time intervals. The effect of nematodes on plant growth was assessed by both the above-ground and below-ground growth parameters.

The plants were gradually removed from the soil at the end of the experiment, and soil particles were gently shaken off without root damage. Shoots and roots were harvested to determine fresh and dry weights, to evaluate biomass production. The data collected were subjected to comparisons of growth response of infected and non-infected plants, and the pathogenic effects of *M. incognita* and *M. enterolobii* were determined. Data for all observations were statistically analysed to determine if there were significant differences between treatments and to determine the severity of nematode-induced growth reduction.[8]

Plant Height

An important growth measurement of the plants was their height, and a measurement of plant vigour. A graduated measuring scale was used to measure the height of each plant, from the soil surface to the top of the main shoot. The measurements were carefully taken to ensure uniformity and accuracy of all experimental plants.

Recordings were made weekly during the experiment to assess the progress of growth and the effect of nematode infection on plant growth. Plant height was recorded in centimetres (cm), and the mean plant height per replication was the average of all replications. A decrease in plant height compared to the healthy control plants was regarded as growth suppression by *Meloidogyne incognita* or *Meloidogyne enterolobii* infection. The recorded data were statistically analysed to find out significant differences among the different treatments and also the comparative pathogenic effect of the two nematode species on guava and mango plants.

Root Length

The root length was measured to estimate the effect of nematode infection on the root growth and development. After the experimental period, plants were delicately removed from the pots and root systems were thoroughly washed to remove soil particles without damaging the roots. Great effort was made to maintain the integrity of the root system during cleaning. Root lengths of each plant were measured from the base to the tip of the longest root with a meter scale, and the total root length was obtained. All measurements were taken in centimetres (cm). The mean root length for each treatment was determined based on all replications. The extent of root damage inflicted by the root-knot nematodes is also assessed by root length; severe infections can stunt root growth, cause galls and kill the root system. The data collected were statistically analysed to compare the effects of *Meloidogyne incognita* and *Meloidogyne enterolobii* on the development of the roots of guava and mango plants.[9]

Shoot and Root Biomass

The shoot and root biomass were determined to assess the impact of nematode infection on plant growth and biomass accumulation. Plants were carefully removed and divided into shoots and roots at the end of the experimental period. The roots were delicately rinsed with water to wash away soil particles without the loss of plant material.

Fresh weight of shoots and roots was taken on a digital analytical balance after harvest, in grams (g). Fresh biomass gives an indication of the overall growth and water content of the plant. After the fresh weight measurements, the shoot and root samples were dried in a hot-air oven at 70°C, in labelled paper bags, until a constant weight was achieved. After drying, the samples were weighed by a digital analytical balance to measure their dry biomass. Dry weight measurements referred to the actual amount of plant growth, and were used as an indicator of the effects of nematode infection on plant productivity. For each treatment, the mean fresh and dry shoot and root biomass values were determined. The decrease in biomass relative to healthy control plants was taken as an indicator of the harmful effects of *Meloidogyne incognita* and *Meloidogyne enterolobii* on plant growth. Recorded data were statistically analysed to compare the effects of the two treatments and to estimate the relative *pathogenicity* of the two nematode species.[10]

Chlorophyll Estimation

The total chlorophyll content of leaves was estimated according to the method of Arnon (1949). Chlorophyll estimation was done to evaluate the effect of *Meloidogyne incognita* and *Meloidogyne enterolobii* on the photosynthetic capacity of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants. The chlorophyll content is directly related to photosynthetic efficiency and plant health, therefore any changes in chlorophyll content is indicative of physiological stress due to nematode infestation. To wash away dust and other contaminants from fresh leaf samples (0.5 g) collected from each treatment, they were washed well with distilled water before use. Samples were then crushed in 80% acetone with a chilled mortar and pestle. Homogenate was centrifuged at 5000 rpm for 10 minutes, and the clear supernatant was taken for spectrophotometric analysis. The absorbance of the extract was determined with the help of a UV-Visible spectrophotometer at wavelengths of 645 nm and 663 nm with 80% acetone as a blank. Arnon's formula was used to determine the total chlorophyll content and was expressed as chlorophyll content (mg g⁻¹ FW) [11]. Chlorophyll content was measured in all treatments and compared to the control plants for each treatment. A decrease in chlorophyll content was deemed evidence of disturbance of photosynthesis and physiological stress due to nematode attack. The results obtained were statistically analysed to assess the impact of the two *Meloidogyne* species on the chlorophyll content of guava and mango plants.

Assessment of Root Galling (Ljubej)

The root galling of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants was studied for the severity of infection by *Meloidogyne incognita* and *Meloidogyne enterolobii*. The plants were gradually removed from the pots at the end of the experimental period (120 days after inoculation), and the root system was gently washed under running tap water without damaging the roots or galls. The roots were cleaned, and gall formation was visually checked. Root galls were rated on a 0–5 gall index scale similar to that proposed by Ljubej (or cited source), with higher scores representing higher levels of nematode

infestation and root damage. The galling scale used for the study is given in Table 2 [12]. A gall index score was assigned to each plant, depending on the percentage of galls that were present on the root system. Data from all replications were used, and the mean gall index for each treatment was calculated. The root galling symptom is regarded as one of the best determinants of the pathogenicity of root-knot nematodes since it directly reflects the ability of the nematodes to penetrate the roots, establish, and feed within the roots. The gall index data were statistically analysed and compared between the severity of gall formation in guava and mango plants caused by *M. incognita* and *M. enterolobii*, also to find out the relative susceptibility of both host plants.

Nematode Population Density

To evaluate the reproduction and multiplication of *Meloidogyne incognita* and *Meloidogyne enterolobii* on guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants the final nematode population was determined at the end of the experimental period. Both soil and root samples were collected from each experimental unit after harvesting for the estimation of nematode population density. Soil samples were collected, and the nematodes were extracted by the modified Baermann funnel method, which helps to separate the active juveniles from the soil matrix. Root samples were carefully washed, cut into small pieces and processed for nematode recovery. The nematodes removed were collected and observed under a stereomicroscope. The second stage juvenile (J2) was estimated by using a nematode counting dish. This nematode population density was reported as the number of juveniles (J2/100g soil) [13].

To evaluate the reproductive potential of the nematode species on the host plants, the reproduction factor (RF) was calculated according to the following formula:

$$RF = \frac{Pf}{Pi}$$

Where

Pf = Final nematode population at the end of the experiment

Pi = Initial nematode population was inoculated at the beginning of the experiment

The reproduction factor is an estimate of the suitability of the host plant for the multiplication of the nematodes. An RF index of > 1 suggests good nematode multiplication and relative host susceptibility/tolerance, while an index of < 1 suggests poor nematode multiplication and high host resistance/susceptibility tolerance. *M. incognita* and *M. enterolobii* were compared in terms of pathogenicity and reproductive capacity under guava and mango plants based on the obtained population density and reproduction factor. All observations were statistically analysed to find significant differences between the various treatments.

Yield Assessment

Yield assessment was carried out at the time of harvest to determine the effect of *Meloidogyne incognita* and *Meloidogyne enterolobii* infection on the productivity of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants. Fruit yield is significant as an indicator of the economic effect of nematode infestation, as root damage by nematodes can negatively impact nutrient uptake, plant growth, flowering, fruit production, and ultimately yield. All fruits from each plant were harvested and measured at harvest by a digital balance. The total fruit yield per plant was measured and presented in kilograms per plant (kg plant⁻¹). Total yield and the number of fruits per plant were also recorded, and along with the average fruit weight (g), were used to assess the influence of nematode infection on fruit production and fruit quality [14]. The average fruit weight was obtained by dividing the total fruit weight by the total number of fruit produced from each plant. The amount of yield and fruit weight reduction was used as a measure of the severity of nematode damage among the various treatments. The reduction in fruit yield and the average fruit weight of infected plants compared with the healthy control plants were regarded as an indication of the negative effect of nematode infection on fruit productivity. All the yield data collected under all treatments were analysed statistically, and the results compared the effect of *M. incognita* and *M. enterolobii* on guava and mango plants, and also the relative pathogenicity of the two nematode species in terms of yield loss.

Statistical Analysis

The experimental data recorded for plant growth, chlorophyll content, root gall index, nematode population density, and fruit yield were subjected to statistical analysis using Analysis of Variance (ANOVA) under a Completely Randomised Design (CRD). Treatment means were compared at the 5% level of significance. Results are presented as mean ± standard error (SE). Statistical analyses were performed using appropriate statistical software.

RESULTS AND DISCUSSION

Effect on Plant Growth

Root-knot nematode causes infection in plants, affecting their growth and development; plant height is an important parameter to assess the impact of root-knot nematode. In the present study, a significant difference in plant height was observed between healthy and nematode-infected guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants. Veg. growth was compromised by both species of *Meloidogyne*, and the plants were clearly stunted when infected compared to healthy plants. Growth suppression was seen to be of varying severity depending on host plant and nematode species.

Table 3 showed that guava and mango plants infected by nematodes significantly decreased plant height when compared with the uninfected ones. The mean height of healthy plants was 89.4 ± 2.3 cm, while plants inoculated with *M. incognita* and *M. enterolobii* had heights of 68.5 ± 2.0 cm and 55.7 ± 1.8 cm, respectively. This reduction was more pronounced in *M. enterolobii*-infected plants, which showed higher pathogenicity [15].

Also, healthy mango plants had a mean height of 95.2 ± 2.5 cm; mangoes infected with *M. incognita* had a mean height of 82.1 ± 2.2 cm, while the height of infected mangoes with *M. enterolobii* was 73.4 ± 2.1 cm. Both nematode species had negative effects on mango growth; the reduction was less severe compared to guava [16].

Guava plants inoculated with *M. enterolobii* had the lowest plant height among all the treatments, indicating the severe effect of this nematode species on plant growth. This is likely due to root gall formation and root damage that will affect water and nutrient uptake and lead to reduced vegetative growth. The results reveal that *M. enterolobii* is more virulent than *M. incognita*, and guava is more susceptible to infection by root-knot nematode than mango.

The data of figure 1 shows the effect of various nematode treatments on the height of the plants. It is evident from a graphical presentation that healthy plants had more growth compared to infected plants. Inoculation with *M. incognita* and *M. enterolobii* resulted in a progressive decrease in plant height, and the most significant decrease occurred in guava plants inoculated with *M. enterolobii*. The trend shown in the figure corroborates the data shown in Table 3 and the strong adverse effect of root-knot nematode on plant growth. The reduction in mango plants is comparatively lower indicating a relatively higher tolerance level towards nematode infestation than guava [17].

Root Gall Formation

A symptom of root-knot nematodes (*Meloidogyne* spp.) infection is the formation of root galls. The severity of galling will depend on how far the nematodes have penetrated, established and fed in the root tissues. Significant differences were obtained in the present study between the treatment in regards to root gall formation. Pathogenicity and host susceptibility also differed as galling was more or less severe depending on the host plant and nematode species.

Table 4 showed that there was no gall formation in healthy control plants of both guava and mango, and hence, the gall index of 0.0 was recorded. All nematode-inoculated plants, however, had some degree of root galling. The plants inoculated with *M. incognita* showed a gall index of 3.8, which was considered moderate to severe formation of galls. Plants infected by *M. enterolobii*, however, had the highest gall index with 5.0, which represents an extremely severe root galling condition with over 75% involvement of the root system.

Galling severity was relatively less in mango plants as compared to guava plants. The galls caused by *M. incognita* had an average score of 2.7, and those caused by *M. enterolobii* had an average score of 4.0. Significant gall formation was noticed on mango roots, but the damage was low compared to guava [18].

In both host plants, the results clearly showed that the root galls caused by *M. enterolobii* were more severe than those caused by *M. incognita*. The fact that the extent of gall formation in *M. enterolobii*-infected plants was found to be greater than that in non-infected plants indicates that the nematodes were more established and actively feeding, thereby causing greater disruption of the root functions. In addition, guava roots had significantly higher gall indices than mango, showing that guava is more susceptible to root-knot nematode infection.

The damage to the roots in the present study by *M. enterolobii* is similar to that reported in guava orchards, where the species was known to be a very aggressive pathogen, causing extensive root injury and decline. The galling observed was probably responsible for the decrease in uptake of water and nutrients, which negatively impacted plant growth and development. In general, the results showed that *M. enterolobii* is more virulent than *M. incognita*, and guava is a more suitable host plant than mango for the development of root-knot nematodes.

The comparative root gall index is shown in figure 2 for different treatments. It is evident that the graph shows that in healthy plants, there was no gall formation, while in the nematode-inoculated plants, there

was a considerable increase in galls. The plants of guava which were infected with *M. enterolobii* showed maximum gall count, and mango plants inoculated with *M. incognita* showed the minimum galling among the infected plants. The overall trend of this graph is consistent with the higher aggressiveness of *M. enterolobii* and the higher susceptibility of guava than mango.

Chlorophyll Content

The main photosynthetic pigment, which absorbs light energy and converts it into chemical energy in photosynthesis, is chlorophyll. Chlorophyll in leaves is considered a key physiological parameter and an index of photosynthetic capacity. To investigate the effect of *Meloidogyne incognita* and *Meloidogyne enterolobii* on the physiological performance of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants, the chlorophyll content in the leaves was measured [19].

Table 5 shows that the leaf chlorophyll content was significantly affected due to root-knot nematode infection in guava and mango plants. The chlorophyll content of the healthy guava plants was 2.81 mg g⁻¹ FW, while those infected with *M. incognita* and *M. enterolobii* had 2.09 and 1.72 mg g⁻¹ FW, respectively. Guava plants infected with *M. enterolobii* showed the lowest concentration of chlorophyll, which suggested a high physiological stress inflicted by this species of nematode.

Likewise, healthy mango tree plants had the highest value of chlorophyll content (3.04 mg/g FW) when compared to all treatments. The chlorophyll content was decreased by *M. incognita* and further decreased by *M. enterolobii*, which were 2.53 and 2.12 mg g⁻¹ FW, respectively. A reduction in chlorophyll was seen in mango plants; however, the reduction was not as great as in guava.

Decreased levels of chlorophyll could be due to the interference of water and nutrient uptake by nematode damage to the roots. Root galling reduces plant uptake and transport of critical nutrients, especially N and Mg ions that play a vital role in the synthesis of chlorophyll molecules. Thus, the infected plants will have a decreased rate of chlorophyll formation, chlorosis and lesser photosynthetic activity.

The chlorophyll content was decreased by *M. enterolobii* more than *M. incognita*, indicating that *M. enterolobii* possesses a higher pathogenicity and severity to cause physiological impairment. In addition, guava plants showed a higher decrease in chlorophyll content than mango plants, which means that guava was more susceptible to nematode infestation than mango. The decrease in chlorophyll content seen in infected plants correlates with the decrease in plant growth and root health seen in the preceding sections.

The effects of the various treatments on leaf chlorophyll content are shown in Figure 3. The graph clearly demonstrates that the chlorophyll content was higher in healthy guava and mango plants as compared to nematode-infected plants. The decrease in chlorophyll content was progressive after infection with *M. incognita* and *M. enterolobii*, with the highest decrease found in the infected guava plants with *M. enterolobii*. The graphical trend corroborates the tabulated data and shows that the infection by root-knot nematodes has a negative impact on chlorophyll production and photosynthetic efficiency, which in turn affects plant growth and productivity [20].

Nematode Reproduction

Root-knot nematode suitability and aggressiveness are closely linked to their reproductive potential. For the present study, the last nematode count was made at the end of the experimental period to determine the multiplication of *Meloidogyne incognita* and *Meloidogyne enterolobii* in guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants. The final density was the number of second instar juveniles (J2) per 100g of soil.

It was found from the results shown in Table 6 that there was a significant difference in nematode reproduction in the different treatments. The guava plants inoculated with *M. incognita* had 3125 J2 per 100 g soil, while the plants infected with *M. enterolobii* had a significantly higher number of J2 per 100 g soil of 4950 J2 per 100 g soil. This suggests that the root of the guava plant is more suitable for *M. enterolobii* to reproduce than *M. incognita*.

It was seen in a similar pattern to mango plants. The final population of *M. incognita* was 2410 J2/100 g soil, and *M. enterolobii* had a final population of 3780 J2/100 g soil. Nematode multiplication was found in both hosts, but with lower overall nematode densities in mango than in guava, indicating that mango is less favourable than guava for nematode multiplication and reproduction.

The guava plants with *M. enterolobii* had the highest nematode population, while the lowest nematode population was seen in mango plants infected with *M. incognita* among all the treatments. The higher level of infectivity, faster establishment of *M. enterolobii* into the root tissues, and greater capacity to stimulate the formation of feeding sites, which allow nematode growth and reproduction, may help explain the greater reproductive capability of *M. enterolobii*. As reproduction increases, so will the root damage and the extreme pathogenic activity seen in infected plants [21].

The results clearly demonstrate that the reproductive potential of *M. enterolobii* is higher than of *M. incognita* in both guava and mango. This is consistent with more recent reports indicating that *M. enterolobii* penetrates roots more quickly and creates feeding sites more efficiently and yields more females and egg masses than *M. incognita*. The main reasons for *M. enterolobii* pathogenicity and its link with the severe decline symptoms in guava orchards are the higher multiplication rate of the fungus and its ability to infect plants during the rainy season. The higher multiplication rate of *M. enterolobii*, along with its capacity to infect plants during the rainy season, is one of the major reasons for its pathogenicity and its association with severe decline symptoms in guava orchards.

The end population of nematodes is shown in figure 4. The graph clearly indicates that population densities of *M. enterolobii* were much greater than the population densities of *M. incognita* in both host plants. The multiplication of nematodes was more in guava than in mango, which once again indicates the greater susceptibility of guava. The graphical trend reinforces the tabulated data and highlights the high reproductive capacity and aggressiveness of *M. enterolobii* relative to *M. incognita*.

Yield Reduction

Overall fruit production is the final indicator of the productivity and profitability of crops. Root-knot nematode infection can impact yield by disrupting root function, decreasing water and nutrient absorption, and interfering with plant growth and physiological processes. The present study assessed the impact of *Meloidogyne incognita* and *Meloidogyne enterolobii* on fruit yield of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants in a greenhouse [22].

As shown in Table 7, infection of the root-knot nematodes greatly reduced fruit yield of both guava and mango plants. The yield obtained from healthy guava plants of the guava treatments was the highest at 18.4 kg plant⁻¹. On average, the *M. incognita* reduced the yield to 12.3 kg/plant, and plants infected by *M. enterolobii* had an average yield of 7.8 kg/plant. This translates to a yield loss of about 33.2% and 57.6%, respectively, compared to the healthy control.

Likewise, healthy mango plants gave a production of 26.5 kg plant⁻¹. The inoculated plants with *M. incognita* had a reduced yield of 21.4 kg plant⁻¹, and the inoculated plants with *M. enterolobii* had a reduced yield of 17.2 kg plant⁻¹. These yield losses were around 19.2% and 35.1%, respectively. Losses were also heavy in mango due to nematode attack, though the losses were not as extreme as in guava [23].

The infectivity of guava plants by *M. enterolobii* was revealed by the lowest fruit production among all treatments. This significant yield loss is due to the high amount of root galling, lower chlorophyll content and reduced nutrient uptake and vegetative growth in infected plants. All of these together reduce the plant's capacity to bear and promote fruit growth.

The results also showed that *M. enterolobii* caused significantly higher loss of yield than *M. incognita* in both hosts. This result is in accordance with previous studies, which revealed that *M. enterolobii* is a very virulent root-knot nematode and causes significant economic losses in fruit crops, especially guava. The observed yield loss in guava with *M. enterolobii* is fairly similar to the previous reports, which show that *M. enterolobii* can cause yield loss of over 60% under severe infestation.

The comparative fruit productivity of healthy and guava and mango plants infested with nematodes is shown in figure 5. This decrease in yield after infection by *M. incognita* and *M. enterolobii* is evident in the graph. Guava plants with *M. enterolobii* showed the highest reduction, with healthy mango plants showing the highest yield among all treatments. The graphical trend corroborates the data in Table 7 and shows that the root-knot nematode disease has a severe negative impact on fruit productivity. The overall results suggest that *M. enterolobii* is more devastating than *M. incognita*, and guava has a higher yield reduction potential due to nematode attack than mango [24].

DISCUSSION

This present study was carried out to assess the pathogenic potential of *Meloidogyne incognita* and *Meloidogyne enterolobii* in the greenhouse on *Psidium guajava* L. and *Mangifera indica* L. plants. Root-knot nematode infection was found to be highly destructive in both crops as observed from the results, which showed significant differences in plant growth, chlorophyll content, nematode reproduction, root health and fruit yield. The extent of injury, however, was different for the various species of nematodes and host plants. All inoculated plants showed a marked decrease in plant height when compared with healthy plants. This reduction was more significant in guava plants, especially those infected by *M. enterolobii*. Root gall formation could be responsible for this reduction in growth, as it limits the uptake of water and nutrients and ultimately affects the vigour of the plant. These observations are comparable to those of other root-knot nematode-infested fruit crops studied. Root galling was the most apparent symptom of the infection. Guava plants inoculated with *M. enterolobii* had the highest gall index, showing the

increased pathogenicity of this organism. Galls severely affect root architecture and cause feeder roots to be less efficient, causing poor plant growth. A significant reduction in chlorophyll content was also seen in infected plants, particularly guava. Nutrient deficiency and/or reduced photosynthetic activity due to damage to the roots could be linked to this chlorophyll reduction. The final nematode population was highest in the guava infected with *M. enterolobii*, which shows that guava is more suitable than mango for the multiplication of nematodes. A higher rate of reproduction leads to greater root damage and greater disease severity. The yield of the fruit was significantly reduced in all infected plants, with the highest reduction seen in guava infected with *M. enterolobii*. The results were overall consistent with the increased aggressiveness of *M. enterolobii* relative to *M. incognita* and greater susceptibility of guava relative to mango towards root-knot nematode infection. The results indicate the importance of effective nematode management practices to minimise losses and maintain sustainable production of fruits.

Table 1: Experimental Treatments

Treatment	Description
T ₁	Healthy <i>Psidiumguajava</i> (Control)
T ₂	<i>Psidiumguajava</i> + <i>Meloidogyne incognita</i>
T ₃	<i>Psidiumguajava</i> + <i>Meloidogyneenterolobii</i>
T ₄	Healthy <i>Mangiferaindica</i> (Control)
T ₅	<i>Mangiferaindica</i> + <i>Meloidogyne incognita</i>
T ₆	<i>Mangiferaindica</i> + <i>Meloidogyneenterolobii</i>

Table 2: Root Gallling Index Scale

Gall Index	Description
0	No galls
1	1–10% roots galled
2	11–25% roots galled
3	26–50% roots galled
4	51–75% roots galled
5	More than 75% roots galled

Table 3: Effect of *Meloidogyne* Infection on Plant Height of Guava and Mango Plants

Treatment	Plant Height (cm)
Healthy Guava	89.4 ± 2.3
Guava + <i>M. incognita</i>	68.5 ± 2.0
Guava + <i>M. enterolobii</i>	55.7 ± 1.8
Healthy Mango	95.2 ± 2.5
Mango + <i>M. incognita</i>	82.1 ± 2.2
Mango + <i>M. enterolobii</i>	73.4 ± 2.1

Table 4: Root Gall Index of Guava and Mango Plants Infected with *Meloidogyne* Species

Treatment	Gall Index (0–5)
Healthy Guava	0
Guava + <i>M. incognita</i>	3.8
Guava + <i>M. enterolobii</i>	5.0
Healthy Mango	0
Mango + <i>M. incognita</i>	2.7
Mango + <i>M. enterolobii</i>	4.0

Table 5: Leaf Chlorophyll Content

Treatment	Chlorophyll (mg g ⁻¹ FW)
Healthy Guava	2.81
Guava + <i>M. incognita</i>	2.09
Guava + <i>M. enterolobii</i>	1.72
Healthy Mango	3.04
Mango + <i>M. incognita</i>	2.53
Mango + <i>M. enterolobii</i>	2.12

Table 6: Final Nematode Population in Different Treatments

Treatment	Population (J2/100 g Soil)
Guava + <i>M. incognita</i>	3125
Guava + <i>M. enterolobii</i>	4950
Mango + <i>M. incognita</i>	2410
Mango + <i>M. enterolobii</i>	3780

Table 7: Fruit Yield Response of Guava and Mango Plants to *Meloidogyne* Infection

Treatment	Yield (kg plant ⁻¹)
Healthy Guava	18.4
Guava + <i>M. incognita</i>	12.3
Guava + <i>M. enterolobii</i>	7.8
Healthy Mango	26.5
Mango + <i>M. incognita</i>	21.4
Mango + <i>M. enterolobii</i>	17.2

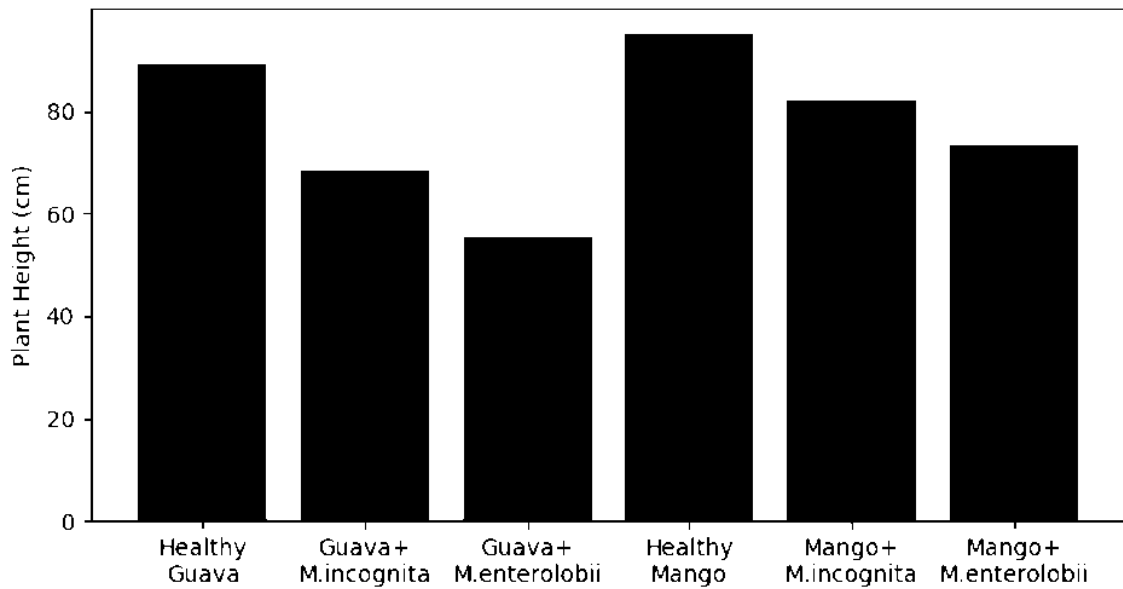


Figure 1: Influence of Various Nematode Treatments on Plant Height Reduction

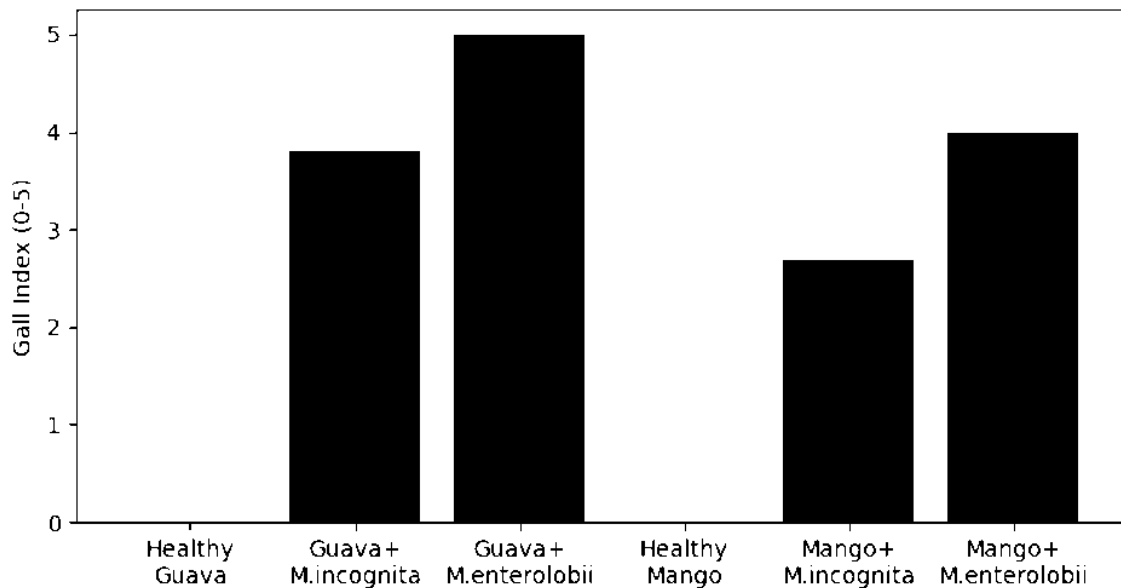


Figure 2: The Comparative Root Gall Index was Employed

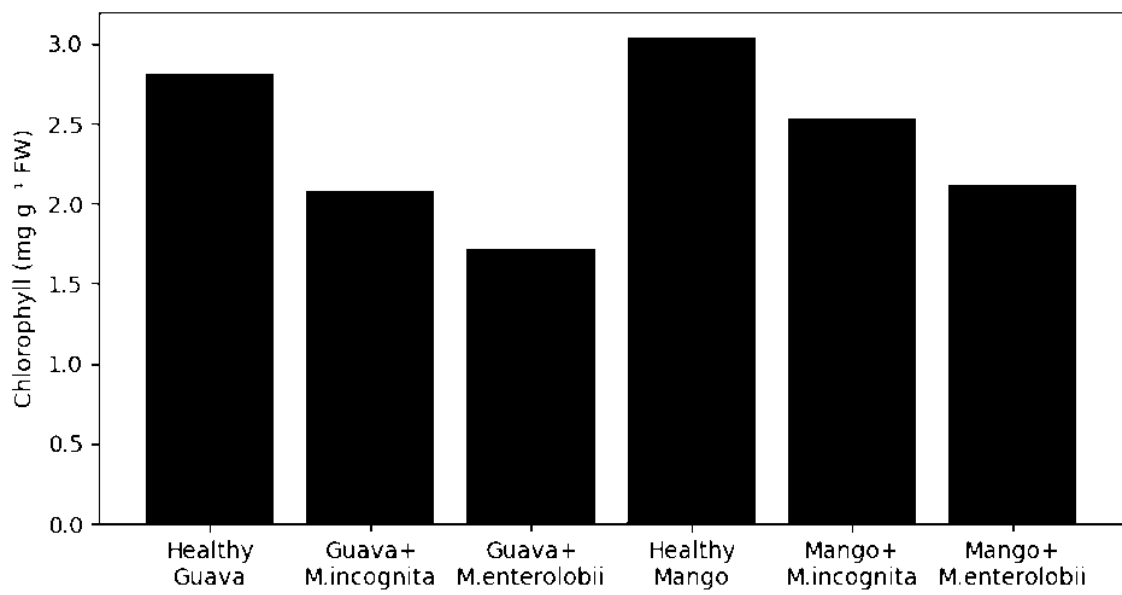


Figure 3: Chlorophyll II Variation in Infected and Healthy Plants

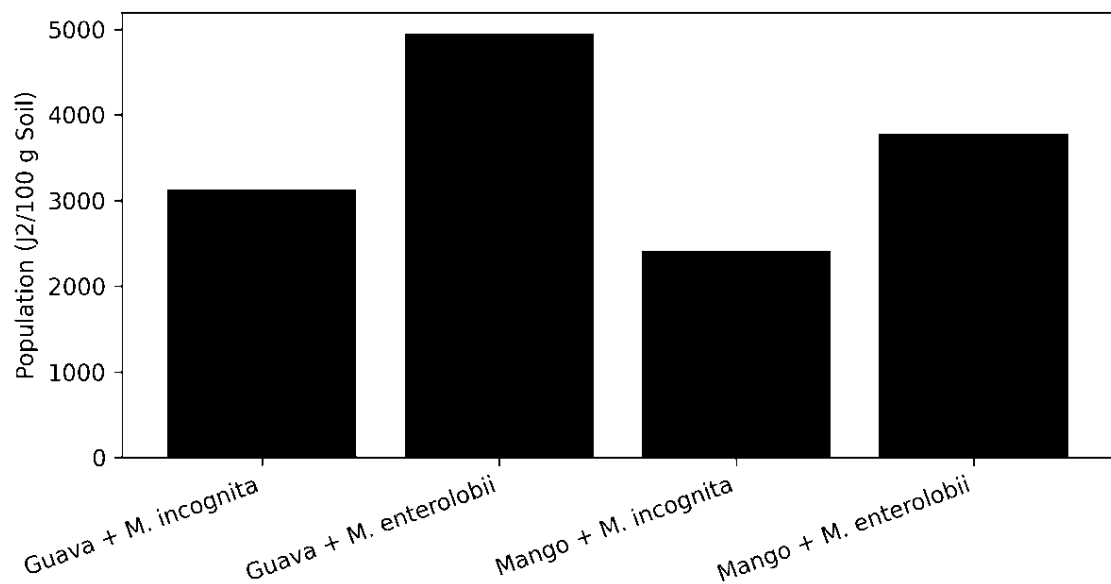


Figure 4: Comparative Nematode Population Density in Guava and Mango Plants

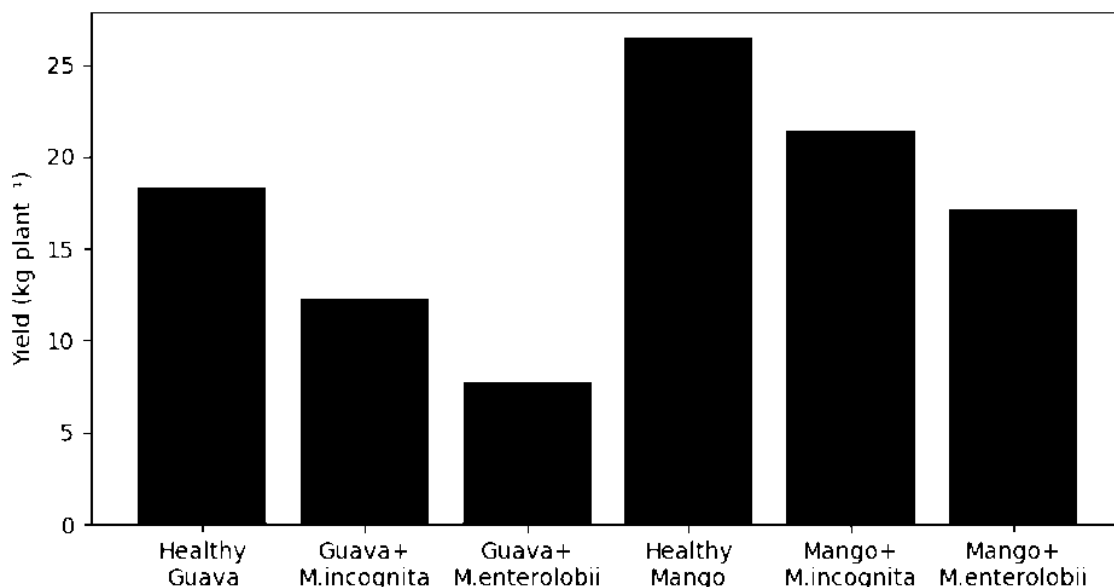


Figure 5: Reduction in Yield of Guava and Mango Plants under Different Nematode Treatments

CONCLUSION

The present study demonstrated that root-knot nematodes (*Meloidogyne* spp.) significantly affect the growth, physiological performance, and productivity of guava (*Psidium guajava* L.) and mango (*Mangifera indica* L.) plants. Infection resulted in substantial reductions in plant height, biomass accumulation, chlorophyll content, and fruit yield, while root gall formation and nematode population density increased markedly. Among the two nematode species evaluated, *Meloidogyne enterolobii* exhibited greater aggressiveness and pathogenicity than *Meloidogyne incognita*. Plants infected with *M. enterolobii* recorded higher gall indices, greater nematode multiplication, and more severe reductions in growth and yield parameters. The study further revealed that guava was more susceptible to nematode infection than mango, as evidenced by greater root galling, higher nematode populations, and greater yield losses. The findings highlight the importance of early detection, continuous monitoring, and integrated nematode management practices, including the use of resistant planting material and biological control agents, to minimize economic losses and ensure sustainable fruit production.

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