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Scientific Article

Effect of organic amendments on the control of *Meloidogyne incognita* and on the physicochemical properties of the soil

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ABSTRACT

Background/Objective. Organic amendments applied in agricultural systems commonly provide nutrients to crops. However, there are few studies on their simultaneous differential response to *Meloidogyne incognita* control and soil physicochemical characteristics. In this study, three organic amendments (vermicompost, cow dung, and neem green manure) were compared for root-knot nematode control and their influence on soil edaphic characteristics.

Materials and Methods. Agricultural soil, previously sterilized and mixed with the organic amendments individually, was placed in 4-L plastic pots. A treatment with a mixture of the three amendments, a synthetic fertilizer, and the water control were added and established in a randomized complete block design with 15 replicates. Each pot was inoculated with 500 juvenile *M. incognita*. Physicochemical parameters were analyzed 20 days later, and the nematode population and reproduction factor were determined 90 days later.

Results. The vermicompost amendment significantly influenced ($P = 0.0001$) the *M. incognita* population (≤80%) compared to the control (100%). It also significantly influenced soil variables, such as organic matter (1.11%) compared to the other treatments (0.27%).

Conclusion. The effective reduction in nematode populations was primarily recorded with vermicompost (111 nematodes/g of soil) and manure (505) amendments compared to the control (1,037). These results provide important information on the impact of the amendments on plant pathogenic nematode control and soil characteristics.

Keywords: Biocomposts, Soil Science, Nematodes, Control

INTRODUCTION

Currently, in the production of plant-based foods, there is a continuous demand and request for quality in products worldwide (Dong *et al*., 2022). However, multiple factors could reduce their quantity and quality. For example, the root knot nematode (*Meloidogyne incognita*), is considered of great importance within the agricultural systems, due to the wide range of crops it affects. It causes the formation of root galls that interrupt the flow of water and nutrients, which reduces crops yields (Mesa *et al.*, 2020). The level of damage generally depends on the population density of the nematode, the plant susceptibility and edaphic conditions. Although the constant application of synthetic nematicides is the traditional method for the control of nematodes, this approach leads to important environmental consequences. In particular, the toxic residues that these products leave behind directly affect the soil, since they alter the chemical molecules that are related to the structures or crystals that determine their different textures, leading to an imbalance in their formation and quality (Reyes-Palomino and Cano-Ccoa, 2022; Watson *et al*., 2020). These alterations can lead to high erosion, low humidity retention, reduction of organic matter, alteration of pH and electrical conductivity, as well as the reduction of the beneficial microbiota, which leads to a loss in the quality of the soil (Mandal *et al.,* 2020).

In this context, the current social demands regarding the production of safe foods have led to new agricultural tendencies being carried out with the use of alternatives that guarantee the quality of the product, efficiency in the control of *Meloidogyne* spp., compatible with the environmental niches and to a lower impact on soil characteristics (Ntalli *et al.,* 2020). In this regard, several studies have confirmed that amendments are an efficient option for the improvement of fertility, structure and water retention capacity of the soil, promoting plant growth and productivity (Meghvansi and Varma, 2015). Additionally, some amendments, such as cattle manure and worm humus increase the population of beneficial organisms that act in the suppression of phytopathogens, while others have shown little or no effect (Hu *et al*., 2018). Currently, common organic amendments in the control of nematodes are animal and green fertilizers, compost, nematicides plants and protein residues (Oka, 2010). This variability in response may be due to the type, dose and frequency of application of the amendments (Ouyang *et al*., 2022).

Some possible mechanisms involved in the control of nematodes are the release of nematicides compounds, the production of ammonium and fatty acids during the introduction of microbial antagonists, increase in the resistance of plants, and changes in the soil physiology that are inadequate for the behavior of nematodes (Oka, 2010). However, one of the problems in the application of amendments for the control of nematodes is inconsistent efficiency, influenced by the amendment and the type of soil. Therefore, understanding the responses of different types of amendments in the suppression of nematodes in modified soils is essential to improve its use and obtain the greatest control efficiency. Due to this, the aim of this study was to evaluate the suppression of *Meloidogyne incognita* populations using organic amendments and their effect on the physicochemical quality of the soil.

MATERIALS AND METHODS

Site of study and soil. This investigation was carried out between February and July, 2022. The experimental site was a field belonging to the Universidad Autónoma de Baja California Sur (UABCS), in La Paz, B.C.S, (24° 06’ 03” N - 110° 19’ 01” W). A region with a dry climate, represented in 93% of the surface and semi-dry (7%). Average annual rainfall of 265 mm in the basin (CONAGUA, 2020).

Sample selection and preparation. Soil samples with galled roots caused by *Meloidogyne incognita* were obtained from an agricultural plot in the town of Melitón Albañez, B.C.S (23° 39' 16" N - 110° 26' 03" W). In this area, earlier studies had molecularly identified *M. incognita* populations. 10 plant samples with root gall were collected at random, placed un plastic bags and transported in fresh conditions in ice chests to the phytopathology laboratory.

Organic amendments. Three organic amendments were used in this investigation. The earthworm humus Vermicompost (V) and cattle manure (CM) were provided by the Academic Department of Agronomy of the UABCS. The green fertilizer (AV) was obtained by gathering fresh Neem (*Azadirachta indica*) leaves in trees located in green areas of La Paz. 50 kg of each amendment were transported to the Phytopathology Laboratory belonging to the Academic Department of Agronomy of the UABCS, in La Paz. They were stored in several 20 L plastic containers at room temperature (25 °C) for five days until use.

Establishing the experiment. Two experiments were carried out from February to July, 2022. The first was an evaluation of soil with amendments and the second one evaluated soil, amendments and nematodes. Both were conducted under the same initial procedure, which consisted of the random collection of 20 kg of 10 samples of sandy-loam agricultural soil from a depth of 30 cm and stored in plastic bags with a capacity of 2 kg to be sterilized in an autoclave at 121 °C for 25 min. After 24 h, 2 kg of sterile soil were placed in 4 L plastic pots (20 × 30 cm). Each one was added a dose of 30 g kg^{-1} of the organic amendments individually and in mixtures and the content was homogenized. Likewise, a sample of soil without amendments was included, which contained T17 fertilizer (1 g kg^{-1}) or synthetic nematicide (Rugby; 10% a.i.) applied at a dose of 1 mL kg^{-1}, in addition to the control treatment (soil only). Subsequently, the content of each mixture was moistened with 500 mL of tap water. The treatment groups of both experiments were kept under greenhouse conditions (70% HR, 27 °C and 12 h light/darkness). These were watered twice a week.

Experiment 1 consisted of a group of 60 pots containing only soil with the organic amendments prepared earlier during the beginning of the experimental establishment. Once all treatments were obtained, they were irrigated with 500 mL of tap water twice a week (30 weeks, 60 irrigations in total) and it was left to act for 20 days. After the time of evaluation, the variables described below were determined to evaluate the direct effect of the organic amendments on the physical and chemical characteristics of the soil.

Experiment 2 was based on a group of 60 pots containing the mixture of sterile soil with the amendments, which were inoculated with 500 juveniles of the root-knot nematode previously extracted from tomato roots with galls and morphologically identified under the microscope. For this purpose, 15 days after applying the amendments, a population of nematodes was extracted from root galls (100 g), and from 1 mL of a nematode solution placed on a watch glass, it was counted under the microscope with the aid of a manual counter, where the solution was adjusted to 500 juveniles mL^{-1} and inoculated in pots, in a central hole at a depth of 3 cm. Three months later, the nematode population was determined and the nematocidal effect of the amendments was evaluated.

Experimental design. The experiments were established under a complete randomized block design, which consisted of seven treatments (1) Green fertilizer, 2) Cattle manure, 3) Vermicompost, 4) Mixture of the 3 1:1:1, 5) Fertilizer, 6) Rugby nematicide; 10% a.i./dose of 1 mL kg^{-1} and 7 Control (soil only). Each treatment consisted of 15 repetitions, each one of which was considered an experimental unit.

Physical and chemical characterization of the soil. In experiment 1, to determine the direct influence of the amendments on the physicochemical quality of the soil, 20 days after having incorporated the treatments, non-inoculated soil was taken from the pots to the edaphology laboratory of the Department of Agronomy of the Universidad Autónoma de Baja California Sur. The samples were died in the open at room temperature and sieved with a 2 mm mesh before the corresponding analyses. Subsequently, a complete 1 kg soil sample of each treatment was used to determine the following variables: Organic matter (OM), Electrical conductivity (EC), Field capacity (FC), Apparent density (AD), Phosphorous (P), Potassium (K), pH and Ca^{2+} and Mg^{2+} exchangeable bases.

The organic matter was measured using the potassium dichromate oxidation heating method (Walkley and Black, 1934). The electrical conductivity was determined from the saturated soil extract using a conductometer (Rhoades *et al*., 1989). Likewise, field capacity was obtained using the column method by Colman (1946), whereas the apparent density was obtained using the paraffin method (Blake and Hartge, 1986). Total phosphorous was determined using Mo-Sb colorimetry (Olsen and Sommers, 1982) and total potassium, using Pech's method (Sadzawka, 1990). Soil pH was obtained using a potentiometer (VWR scientific products model sp20). To determine the exchangeable Ca^{2+} and Mg^{2+} bases, the EDTA method was used EDTA (Jackson, 1982).

***M. incognita* population density.** In experiment 2, 90 days after the inoculation of *M. incognita* in the treatments, the infested soil from each pot was homogenized and 100 g were obtained from each repetition. The nematode population density was evaluated by extraction with Baerman's funnel method 48 h later (Southey, 1986). The microscopic counting of *M. incognita* individuals was carried out under a light microscope (LABOMED 400X) at a magnification of 40x, using a manual counter.

Reproduction factor (RF). This variable was determined by counting the final population density in each pot. The reproduction rate was expressed as the ration between the final (FP) and initial (IP) of *M. incognita*, using the formula by Oostenbrink (1966), where RF = FP/IP.

Statistical analysis. The data from both experiments underwent an analysis of variance (ANOVA) and Tukey's means comparison test was conducted in the GraphPad Prism 8.4.3 statistical software. In all analyses, a significance level of p = 0.05 was used.

Results and Discussion

Organic amendments and soil edaphology

Chemical characteristics. The effect of the organic amendments displayed significant differences (P = 0.0000186) with the synthetic agrochemicals and the control (Table 1). The concentration of P was high (≥13 ppm) in the soil containing the organic amendments, mainly in cattle manure, followed by green fertilizer, vermicompost and the mixture of the three, in comparison with the nematicide and the control (≤ 1.8 ppm). The highest concentration of K was recorded in the mixture of the three amendments and in the synthetic fertilizer (≥ 110 ppm). Meanwhile, in the Mg^{2+} and Ca^{2+} exchangeable bases, content was high in cattle manure and the mixture of amendments, in comparison with the control, where its concentration was extremely low.

The important reduction of these chemical elements in the soil, mainly in the control treatment, confirmed that these arid soils are deficient in organic matter, which is also related to a deficient edaphic microbiome population, which in turn explains their erosion. In addition, the increase of these chemical elements was observed to be related to the application of organic amendments, which shows that these play a crucial role in the quality of organic soils, by improving their fertility. The result of the effect of the amendments on the increase of P, K, Mg and Ca was similar to that reported by Su *et al*. (2022), who determined the effect of synthetic fertilizers and eight manures such as cow, chicken and pig manure compost, neem (*Azadirachta indica*) cake, rapeseed meal (*Brassica napus*), soybean meal (*Glycine max*) and tea seed meal (*Camellia sinensis*) on the chemical properties of soil, such as exchangeable P, K, Ca and Mg; furthermore, they determined that the chemical fertilization treatment displayed the most available P. Meanwhile, the application of manure displayed the highest contents of K and Mg, but did not increase Ca. This response was associated to a correlation between the contents of these compounds, with the proportion of organic matter, increase of the microbiota and the optimum development of the plant.

In this study, in the synthetic fertilizer treatment, Ca^{2+} displayed no significant differences in comparison with the vermicompost, green fertilizer and nematicide amendments, since they provided a similar concentration of these compounds. However, although this synthetic product facilitates the availability of chemical elements in the soil to improve plant growth, it has also been shown to deteriorate soil quality, as its active molecule affects the microorganisms present, which are key in the degradation and mineralization of compounds. In this regard, Zhou *et al*. (2015) report that the application of inorganic fertilizers causes soil acidification, which leads to a decline in the diversity of microorganisms.

Table 1. Comparison of the total content of phosphorous and potassium, and exchangeable bases in soils treated with organic amendments.

Treatment	P	K	Mg^{2+}	Ca^{2+}
	----------------(ppm)----------------			
Vermicompost	12.2 ± 0.8^{a}	66.7 ± 31.7^{bc}	84.3 ± 12.9^{abc}	189.7 ± 86.2^{ab}
Green manure	13.1 ± 1.4^{a}	87.2 ± 9.77^{abc}	56.9 ± 14.5^{bc}	157.6 ± 16.7^{ab}
Cow manure	13.1 ± 1.2^{a}	70.9 ± 19.9^{abc}	144.6 ±1.1^{a}	264.5 ± 90.6^{a}
Mix	9.2 ± 4.8^{a}	112.8 ± 18.4^{a}	134.1 ± 48.6^{a}	205.7 ± 58.0^{a}
Fertilizer	8.0 ± 1.5^{ab}	110.8 ± 3.7^{ab}	90 ± 31.4^{ab}	113.5 ± 30.1^{ab}
Nematicide	1.8 ± 1.4^{c}	104.8 ± 6.2^{ab}	105.7 ± 18.7^{ab}	126.9 ± 20.0^{ab}
Control	2.44 ± 1.0^{bc}	48.4 ± 31.7^{c}	16.9 ± 13.1^{c}	46.76± 11.6^{b}

Means followed by the same letter in columns are not significantly different using Tukey, with a reliability level of 95%.

pH physical characteristics. The amendments reduced the pH of the soil from 7.63 to 7.13 20 days after being applied (Figure 1). Despite no significant differences in the treatments (P = 0.23), a lower pH range was observed in the nematicide treatment (7.12), followed by the green fertilizer (7.13), cattle manure (7.17), vermicompost (7.22) and the mixture of these three (7.34), compared with the treatments related to the fertilizer (7.01) and the control (7.63). The pH value derived from the amendments favors soil quality, as it tendency near the value of neutrality, with the fertilizer having the same tendency. In regard to this, Wichem *et al*. (2020) pointed out that the organic amendments modify the soil pH by mineralizing with the release of NH^{4+} and OH^{-}. The response of presenting a pH similar to the control treatment can be related to the fertilizers not having been completely dissociated or at the same level of degradation as the green fertilizer. This response is consistent with that reported by Rusli *et al*. (2022), who indicated that some organic amendments require more time to disintegrate completely, react with the soil and maintain their pH level. Likewise, Lou *et al.* (2022) mentioned that the assimilation of organic matter is not only influenced by factors such as humidity, temperature and edaphic microbiome, but also by their type of material, the time taken for them to degrade and the dose applied. Soils in arid areas such as those used in this study stand out for their sandy texture, and generally have a pH that ranged from neutral to alkaline (INEGI, 2021). Its use in agricultural activities is a constant challenge for crop production, where intensive agriculture also intensifies the problem due to the indiscriminate exploitation of resources. Therein lies the relevance of the application of organic amendments to improve soil quality.

Organic matter (OM). The amendments increased organic matter in the soil significantly, in comparison with the control ($P = 0.00038$). The control treatment presented an OM content of 0.27 %, whereas in the soil with amendments, it reached a value of up to 1.11% (Figure 1). The mixture of the three amendments (V+CM+GF) and the cattle manure (CM) presented the highest percentage of organic matter (1.11 and 1.09% respectively), followed by vermicompost (0.95%) and green fertilizer (0.70%), in comparison with the control. Meanwhile, the nematicide and the fertilizer presented 0.91 and 0.67% respectively. The treatment with cattle manure presented the highest organic matter content, since its percentage was similar, both individually and in a mixture. In this regard, Pino *et al.* (2008) indicated that cattle manure has a higher content in the C/N ratio than other amendment types and high values of total and soluble carbon have been confirmed. This response may be key in the improvement of soil quality for those with extremely poor in organic matter, such as those found in arid zones. Das *et al*. (2017) proved that the incorporation of livestock waste compost is a feasible agricultural practice to improve soil fertility and productivity and mitigate degradation, hence the importance of applying different types of organic matter in the soil. In this regard, Marín-Benito *et al.* (2019) evaluated that applying amendments as organic biofertilizers improve soil quality. Likewise, Mohammad *et al.* (2019) reported that the use of manures, compost and plant residues is widely accepted to improve soil characteristics, as well as the production of different crops. In addition, Cox *et al*. (2000) concluded that organic matter plays an important part in the adsorption and reduction of synthetic agrochemicals.

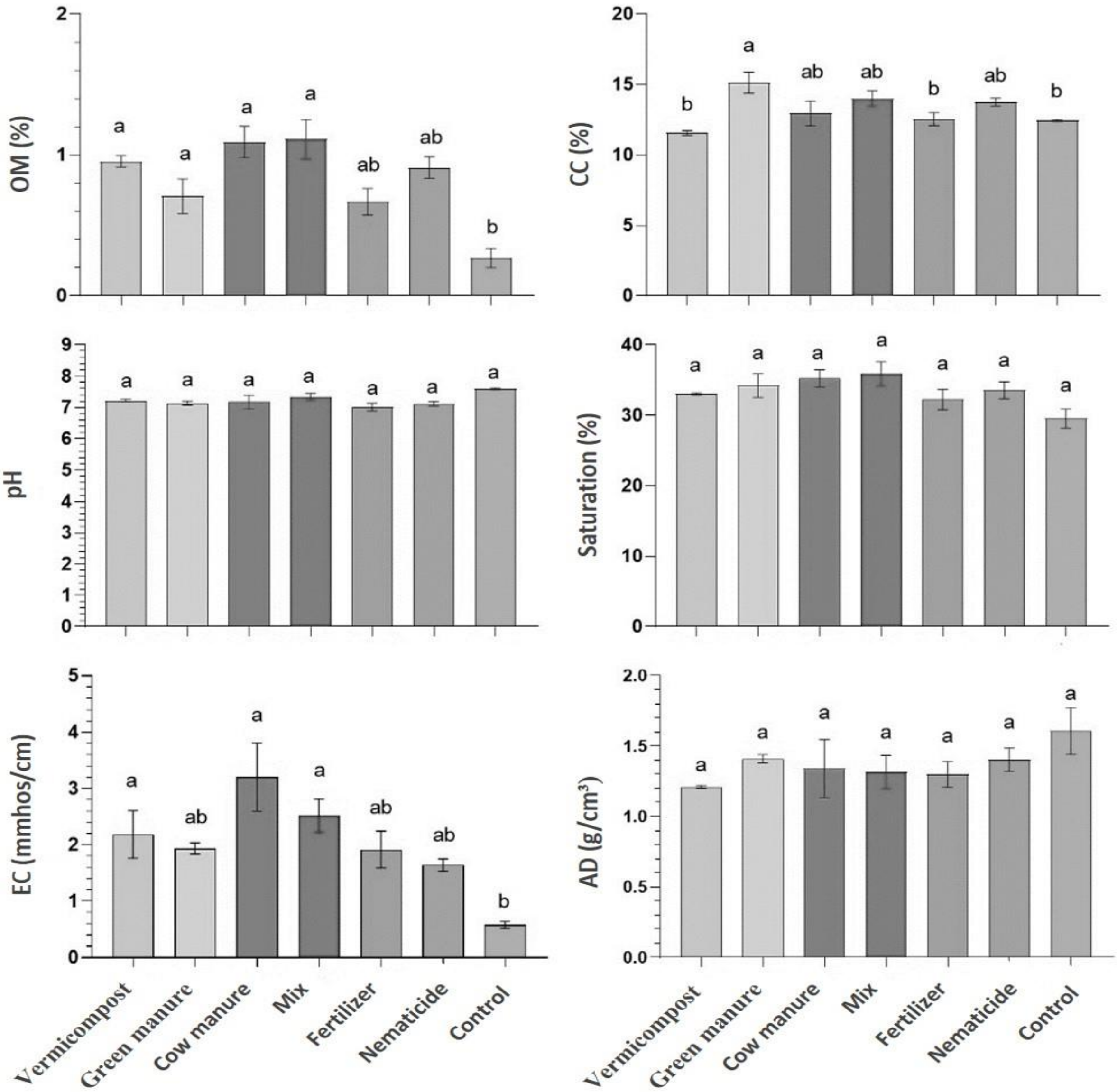

Figure 1. Physical characterization of the soil with the different organic amendments. Error bars indicate standard deviation; different letters on the bars indicated significant differences between amendments for each parameter (Tukey test, $p < 0.05$).

Field capacity and humidity saturation. The organic amendments presented no significant differences in the percentage of saturation, yet they did in the field capacity (Figure 1). However, in saturation, a slight reduction was registered in the fertilizer, nematicide and control treatments. Meanwhile, in the CC, the difference between treatments was noticeable. This variable represents the water available in the soil, whether for the plants and/or the edaphic biome. The highest percentage of humidity was registered in the treatment derived from green fertilizer (15.13%), whereas in the vermicompost, the fertilizer and the control, the percentage of humidity was lower (11.55, 12.52 and 13.26 % respectively). The results show that the amendments can have different effects on the humidity content of the soil, depending on the conditions of the site. Li *et al.* (2017) reports that maintaining adequate soil humidity benefits microbial communities, which improves its structure, along with the nutrient cycle and the resistance of plants to stress.

Apparent density (Ad). This variable generally depends on the degree de soil compaction and composition. This factor affects the storage of water in the soil, the nutrient absorption of plants, root growth and crop yield. According to these results, there were no significant differences (P = 0.9943). However, the organic amendments evaluated such as vermicompost registered the lowest value (1.21 g cm^3), whereas the fertilizer, the mixture and the manure presented an apparent density of 1.30, 1.32 and 1.34 respectively (Figure 1). The Ad in the nematicide (1.40) and the control (1.61) was higher. Cuevas *et al.* (2006) pointed out that the lowest apparent density is the result of the highest macroporosity in the soil and therefore the least compaction, which will depend on the added organic material. However, research by Ayoubi *et al.* (2020) pointed out that the persistence of composts is low and, because no aggregates were formed, the organic matter quickly mineralized and stopped. This makes the continuous application of amendments in the soil highly important to maintain an optimum soil structure; therefore, the adequate management of the adding of organic matter is considered a crucial factor to increase the stability of the aggregates. In the results of this study, the low Ad values registered for the amendments were in the range of a mostly fine texture, tending toward clay soils. Meanwhile, in the case of the nematicide and the control, its value was closer to textures between loamy and sandy. These characteristics were related to the type and content of organic matter evaluated. This response is consistent with the report by Scharge and Delgado (1990), who indicated that the soils with fine textures, well-structured and with high organic matter contents, display lower values for apparent density than soils with coarse textures, less structured and with low organic matter contents. In addition, they indicate reference values for fine-textured or clay soils (1.00-1.30 Mg m^3), medium or loamy soils (1.30-1.50 1.00-1.30 Mg m^3) and coarse or sandy soils (1.50-1.70 1.00-1.30 Mg m^3).

Electrical conductivity (EC). Applying organic amendments and chemical treatments on the soil significantly increased the EC (Figure 1) in comparison with the control (P = 0.02). The cattle manure significantly increased the salinity, since it presented a value of 3.20 dS m^{-1}, followed by the mixture of amendments (2.52 dS m^{-1}), vermicompost (2.18 dS m^{-1}) and green fertilizer (1.93 dS m^{-1}). García-Terrazas *et al.* (2022) pointed out that most crops absorb nutrients best when electrical conductivity does not surpass 2.5 dS m^{-1}. In this sense, although most of the amendments in this study increased EC, they stayed within an optimum range required for plant growth, with the exception of the cattle manure, which did surpass the suggested level. This is supported by Michelon *et al*. (2021), who concluded that after 3 dS m^{-1}, water and nutrient absorption decreases, leading to lower productivity. The increase in EC within this experiment may be related to the type of compounds every amendment is composed of, which in some cases are more dissociable than others. Nassar *et al.* (2017) pointed out that the increase in EC is due to the release of inherent soluble salts, mainly to the ionic types (K+, Cl-, SO4 2- and NO3 -) and the mineralization of others during the process of decomposition of the organic sources.

Prevalence, population and reproduction factor of *Meloidogyne incognita.* The initial presence of *M. incognita* found was 100% in the soil of the pots before the treatment, and after 90 days, it decreased to less than 80% in the vermicompost treatment, followed by the rest of the amendments with significant differences between the nematicide (P = 0.0001) (Figure 2). The *M. incognita* population density in the control increased at the end of the study, whereas in the amendments, this index fell considerably. Out of the treatments evaluated, the soil containing the vermicompost registered the lowest nematode population, with 111 nematodes/100 g of soil, followed by cattle manure (366), the mixture (505) and green fertilizer (902). Meanwhile, the fertilizer and nematicide drastically reduced the population, with 66 and 0 nematodes respectively, in comparison with the control (1,037), in which the population increased significantly. The response of the amendments in the reduction of the nematode population, particularly in vermicompost, may be due to the large diversity of chemical substances it produced and the antimicrobial action reported (Hu *et al*., 2018; Ouyang *et al*., 2022). In this regard, Ohri and Pannu (2010) point out that the vermicompost induces the production of metabolites (phenols and polyphenols), which damage the plasma membrane of the nematodes. In addition, Ayvar *et al*. (2018) mentioned that the secondary metabolites of the amendments such as sesquiterpenes, flavonoids, alkaloids and saponins inhibit the hatching of eggs, with a reduction in nematode populations. Additionally, the results of this study are similar to those reported by Gandariasbeitia *et al.* (2021), who verified the nematocidal effect of organic fertilizers against *M. incognita* in lettuce, where they observed that the compounds released during the degradation of these subproducts and the temperatures reached during biodisinfestation (<42 °C) were key to develop suppressor soils.

The effect of the amendments on the soil characteristics had an influence on the *M. incognita* population. The vermicompost amendment reduced the population in a greater extent, and also caused the lowest value in CC, modified the soil pH slightly, and its EC was high. Likewise, it provided the highest OM and P contents. It also had an influence on the exchangeable Mg and Ca bases. In this context, Calvo-Araya (2021) reported that the suppression of edaphic pathogens is influenced by organic matter, the apparent density, pH, humidity and electrical conductivity, since they exert an influence on the microbiology of the soil. Additionally, they achieve a reduction in the population or in the infectivity of pathogens (Mohammed, 2021). Likewise, Un *et al.* (2021) mentioned that the diversity of nematodes depends on the geographic location, due to the environmental changes and edaphic factors, in which pH is essential to the structure of the nematode community. Guzmán and Alonso (2008) mentioned that pH has a direct influence on the reproduction of phytopathogenic nematodes when the pH ranges of the soil range between 5 and 7.6. Alongside this, Matute *et al.* (2013) pointed out that a lo pH affects the nematological community. In this context we can mention that the amendments of this study maintained an optimal pH, so that the nutrients can be used by plants, although it can also have an influence on the reproduction of *M. incognita*. In the case of the CC and the saturation of humidity, these parameters have been determined as having a direct influence on the population of nematodes such as *M. incognita*. In the cases in which humidity is high, the nematode population is favored, since the higher the water content is, the greater the hydration of nematodes and the easier the distribution will be in the soil. Nevertheless, when this humidity is saturated, it limits oxygen availability, which harms nematode reproduction and acts to suppress them (Calvo-Araya, 2021). Sandy soils have a low percentage of saturation due to the infiltration of water, which helps nematodes in their movement (Hu *et al*., 2018). In this context, applying organic amendments such as vermicompost improves the texture while maintaining an optimal percentage of humidity for the plants and edaphic microbiota, though not enough to favor the increase and displacement of the phytopathogenic nematodes. In the case of the EC, it was observed that, as this variable increases, nematode populations decline. Mendoza *et al*. (2008) and Shokoohi *et al.* (2019), in their study on the diversity and population of phytopathogenic nematodes in soil associated to the planting of alfalfa (*Medicago sativa*) and edaphological properties, found that they had a positive correlation, mainly in EC.

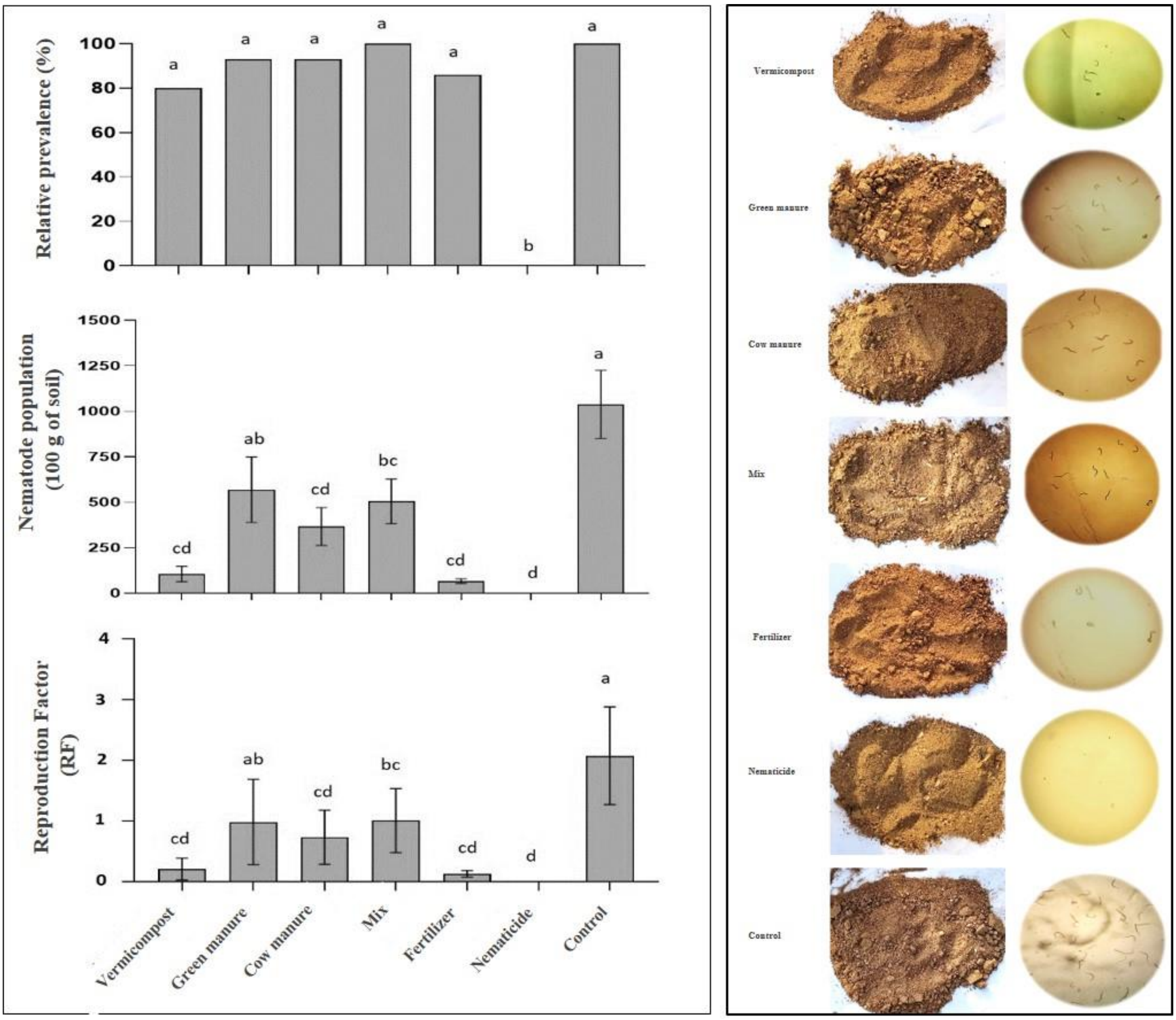

Figure 2. Relationship between the evaluated organic amendments and the population response of *Meloidogyne incognita*. Equal alphabet means indicate no significant differences among treatments according to Tukey's test, with $p < 0.05$.

Wolcott *et al.* (2004), in his study related to electrical conductivity and the *M. incognita* population, determined that these populations tended to decrease as the amount of clay increases, and simultaneously, the clay content had a positive relation with electrical conductivity (EC).This response is consistent with the results from this investigation, in which amendments were related to an increase in organic matter, which in turn reduced the Ad displaying a slight tendency towards clay, which led a high EC, which led to a lower *M. incognita* population. Although the treatment of the synthetic nematicide reduced the nematode population by 100%, this action has a negative impact on the soil microbiome, since it affects phytopathogens and the edaphic microbiota (Mandal *et al*., 2020). The green fertilizer used displayed an important reduction, with nod statistical differences with the control, possibly due to its degradation process being slow.

M. incognita reproduction was greater in the control, where significant differences were found between treatments (Figure 2). The vermicompost (0.21) and the fertilizer (0.13) presented the lowest value in the reproduction factor, followed by cattle manure (0.73) and the green fertilizer (0.98). The three amendments reduced this parameter, which indicates the effectiveness of these treatments in the reduction of phytoparasitic nematodes in comparison with the control (2.07), in which its reproduction factor was high. This increase is mainly related, not only to the susceptibility of the host, but also to the favorable conditions for the nematode (Méndez *et al.,* 2020). El-Nagdi *et al*. (2017) reported that the exact mechanism of the amendments may be due to the secondary products of their decomposition causing direct toxicity on the nematodes. This action may lead to the death of the nematodes and/or suppress the reproduction or hatching of eggs.

CONCLUSIONS

Organic amendments displayed efficiency in the reduction of the *M. incognita* population and the physicochemical properties of the soil such as the content of P, K, Mg^{2+}, Ca^{2+}, MO, CC and CE, since they modify their content and/or condition. The vermicompost was consistent in increasing the content of OM, EC, pH, FC and in reducing the nematode population (111 nematodes/100 g of soil) and the reproduction factor. Future studies could investigate the relationship of organic amendments and the increase in fungal and bacterial populations with antagonistic ability against phytopathogenic nematodes. In Baja California Sur, this is the first report related to the effect of organic amendments on certain physicochemical properties of the soil and the control of phytopathogenic nematodes.

Limitations

The investigation was presented without limitations.

Conflict of interest

The authors declare the existence of no conflict of interest in this investigation.

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Contributions of the authors

María de Jesús Briseño-López; research, preparation of the original draft and statistical analysis of data. Sergio Zamora-Salgado; supervision and revision. Gregorio Lucero-Vega; Supervision and revision. Mirella Romero-Bastidas; Validation, revision and editing.

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