APLICAÇÃO DO FERTILIZANTE ORGANOMINERAL UFV-TM100 NO DESENVOLVIMENTO DE PLANTAS DE ALFACE, PEPINO, BANANA E DE CAFÉ E NO CONTROLE DE *MELOIDOGYNE* SPP.

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Resumo:
O uso de fertilizantes organominerais é uma possibilidade inovadora de veicular resíduos orgânicos e fertilizantes minerais que podem atuar no manejo de nematoides e no desenvolvimento das plantas. No entanto, existe escassez de informações sobre o uso desses produtos em diferentes culturas e no controle de fitonematoides. Sendo assim, o trabalho teve como objetivo selecionar doses do fertilizante organomineral a base de torta de mamona (UFV-TM100) a ser utilizado em plantas de alface, pepino e banana, visando ao controle de *Meloidogyne javanica* e em cafeeiro arábica, para o manejo de *Meloidogyne exigua*. Os experimentos foram montados de forma independente para cada cultura e o UFV-TM100 foi incorporado ao substrato 14 dias antes do transplantio das mudas, nas doses de 0, 6, 12, 18, 24 e 30 g L^{-1} de substrato. No mesmo período de incorporação, o substrato foi infestado com 5.000 ovos de *Meloidogyne* sp. Ao final dos experimentos, foram avaliados o desenvolvimento vegetativo das plantas e a população dos nematoides nas raízes. O UFV-TM100 se mostrou como uma boa alternativa de controle de nematoides e de promoção de crescimento nas diferentes plantas, sendo que as doses do produto selecionadas para o controle de *M. javanica* em plantas de alface, pepino e banana foram 18, 15 e 30 g L^{-1} de substrato, respectivamente. Para o cafeeiro, a dose do UFV-TM100 selecionada para o controle de *M. exigua* foi 12 g L^{-1} de substrato.

Palavras-chave:
Torta de mamona. Matéria orgânica. Nematoide das galhas.

APPLICATION OF THE ORGANO-MINERAL FERTILIZER, UFV-TM100, ON THE DEVELOPMENT OF LETTUCE, CUCUMBER, BANANA AND COFFEE AND THE CONTROL OF *MELOIDOGYNE* SPP.

Abstract:
The use of organo-mineral fertilizers represents an innovative possibility to exploit organic residues and mineral fertilizers that may influence the management of nematodes and the

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development of plants. However, there is limited information concerning the use of such products in different crops and their potential to control plant parasitic nematodes. Therefore, this work had the objective to determine dosages of the organo-mineral fertilizer based on castor cake, UFV-TM100, to manage *Meloidogyne javanica* in plants of lettuce, cucumber and banana and to manage *Meloidogyne exigua* in *Coffea arabica* plants. The experiments were set up for each crop independently and the UFV-TM100 was incorporated to the substrate 14 days before seedling transplantation, at dosages of 0, 6, 12, 18, 24 and 30 g L^{-1} of substrate. During incorporation the substrate was infested with 5,000 eggs of *Meloidogyne* sp. At the end of the experiments, the vegetative development of plants and the nematode population within plant roots were evaluated. The product, UFV-TM100, showed potential to control plant parasitic nematodes and to promote plant development. Dosages of 18, 15 and 30 g L^{-1} of substrate were found to control *M. javanica* in plants of lettuce, cucumber and banana, respectively. In coffee plants, the dosage of UFV-TM100 found to control *M. exigua* was of 12 g L^{-1} of substrate.

Keywords:
Castor cake. Organic matter. Root-knot nematodes.

APLICACIÓN DEL FERTILIZANTE ORGANOMINERAL UFV-TM100 EN EL DESARROLLO DE PLANTAS DE LECHUGA, PEPINO, PLÁTANO Y CAFÉ Y EN EL CONTROL DE *MELOIDOGYNE* SPP.

Resumen:
El uso de fertilizantes organominerales es una posibilidad innovadora para transportar residuos orgánicos y fertilizantes minerales que pueden actuar en el manejo de nematodos y en el desarrollo de plantas. Sin embargo, existe escasez de información sobre el uso de estos productos en diferentes cultivos y en el control de los fitonematodos. Por lo tanto, el objetivo de este trabajo fue seleccionar dosis de fertilizante organomineral a base de ricino (UFV-TM100) para usar en plantas de lechuga, pepino y plátano, con el objetivo de controlar *Meloidogyne javanica*, y café arábica para el manejo de *Meloidogyne exigua*. Los experimentos se establecieron independientemente para cada cultivo y se incorporó UFV-TM100 al sustrato 14 días antes de trasplantar las plántulas, a dosis de 0, 6, 12, 18, 24 y 30 g L^{-1} de sustrato. En el mismo período de incorporación, el sustrato se infestó con 5.000 huevos de *Meloidogyne* sp. Al final de los experimentos, se evaluó el desarrollo vegetativo de las plantas y la población de nematodos en las raíces. UFV-TM100 demostró ser una buena alternativa para el control de nematodos y la promoción del crecimiento en diferentes plantas, siendo las dosis de producto seleccionadas para el control de *M. javanica* en plantas de lechuga, pepino y plátano de 18, 15 y 30 g L^{-1} de sustrato, respectivamente. Para el café, la dosis de UFV-TM100 seleccionada para el control de *M. exigua* fue de 12 g L^{-1} de sustrato.

Palabras clave:
Tarta de ricino. Materia orgánica. Nematodos de las agallas.

Introduction

In Brazil, as in many countries around the world, root-knot nematodes (*Meloidogyne* spp.) are reported in association with economic significant crops and are considered a major limiting factor for the production of some of those, as for example cotton (*Gossypium* sp.), potatoes (*Solanum tuberosum* L.), coffee (*Coffea arabica* L.), sugar cane (*Saccharum* sp.), carrots (*Daucus carota* L.), tobacco (*Nicotiana tabacum* L.), soy bean (*Glycine max* (L.) Merr.), tomato (*Solanum lycopersicum* L.) and others (LORDELLO, 1992; PERRY et al., 2009) . Roots of such crops infected with nematodes exhibit galleries that serve as an entrance for fungal and bacterial plant pathogens (WHITEHEAD, 1997), or results in the development of galls, thus reducing plant's water and nutrient availability (ZIMMERMANN; MCDONOUGH, 1978), that ultimately will reduce plant growth and leaf area, cause mineral deficiency and severe wilt during the hotter periods of the day, besides the consequently yield reduction (GONÇALVES et al., 1995; FERREIRA et al., 2012).

Management of plant parasitic nematodes is costly and several times the results are not suitable. The core method for nematode control is to avoid their entrance into new growing areas. From the moment the nematodes are present in a given area, all the potential control measures to be implemented will only reduce its population (FERRAZ et al., 2001; FERRAZ et al., 2010). Among control measures, the use of organo-mineral fertilizers is a novel procedure to introduce organic residues and mineral fertilizers that may be used in conventional or organic agriculture, in order to assist in the control of nematodes and enhance plant development. These fertilizers are formulated from industrial, urban and agricultural residues, making them environmentally and economically interesting products that favor agricultural sustainability (RITZINGER et al., 2008).

However, when planning the use of organo-mineral fertilizers aiming to control plant nematodes, one faces with the lack of technical information concerning their use in crops (AKHTAR; MAHMOOD, 1997; BERNARDO et al., 2011; RITZINGER et al., 2011; HINDS et al., 2013). Moreover, a tendency for focusing only on the effects of such fertilizers over the soil microfauna and microbiota were observed in the last years, as for example studies concerning free living nematodes, micro-arthropods, fungi and bacteria inhabiting soils (AKHTAR; MAHMOOD, 1997; EO; NAKAMOTO, 2007; NDUBUISI-NNAJI et al., 2011).

The Biological Control of Phytonematodes Laboratory (BIONEMA), Department of Phytopathology at Universidade Federal de Viçosa, Brazil, has developed some organo-mineral fertilizer formulation based on castor cake and coffee husk (UFV-TMC10), and castor cake exclusively (UFV-TM100), which exhibits nematicidal activity over *Meloidogyne* spp., and has been registered as a Patent Document at the Industrial Property National Institute, n° PI0904349-7.

Therefore, the objective of the present work was to determine doses of the organo-mineral fertilizer based on castor cake (UFV-TM100), to control *Meloidogyne javanica* (Treub) Chitwood on lettuce (*Lactuca sativa* L.), cucumber (*Cucumis sativus* L.) and banana (*Musa cavendishii* L.) plants, and the management of *Meloidogyne exigua* Goeldi in coffee plants.

Material and Methods

All the experiments were performed under greenhouse conditions at the Department of Phytopathology at Universidade Federal de Viçosa, Minas Gerais state – Brazil.

Inocula for the experiments consisted of *M. javanica* and *M. exigua* eggs, obtained from pure populations, collected from roots of tomato "Santa Clara" and coffee plants "Catuaí Vermelho IAC 144", respectively, and kept under greenhouse with mean maximum and minimum temperatures of 33.5 and 18 ºC, respectively. Isoenzymes analysis were performed to confirm the species and verify the absence of contamination by other nematodes. Eggs were extracted according to Hussey and Barker (HUSSEY; BAKER, 1973), modified by Bonetti and Ferraz (BONETTI; FERRAZ, 1981) and quantified under light microscope with the aid of a Peter's chamber.

In the experiments, seedlings of lettuce variety "Regina" and cucumber variety "Caipira" were obtained by sowing seeds on commercial substrate (Plantmax® HT – Vegetables), conditioned in Styrofoam trays with 128 cells. Seedlings were transplanted 30 days after its germination. Coffee, variety "Catuaí Vermelho IAC 144" seedlings with four pair of leaves, and banana variety 'Grand Naine', with 20 cm height, were purchased in the local market.

Components of the UFV-TM100 were purchased in the local market (Viçosa-MG, Brazil) and mixed with the aid of a building mixer to homogenize the product. UFV-TM100 contained: 24.9 g of nitrogen; 130 g of phosphorus; 40 g of potassium; 14.4 g of calcium; 4.7 g of magnesium; 40 g of sulfur; 289 mg of zinc; 1.148 mg of iron; 47 mg of manganese; 920 mg of copper and 840 mg of boron, for each kilogram of product. The C/N ratio was of 10.2 and pH = 5.8.

The substrate intended for growing plants was constituted by a mixture of hillside soil and sand, at a 1:1 (volume/volume) proportion. This mixture was previously treated with methyl bromide at a dosage of 80 cm^3 m^{-3} of substrate.

Independent experiments were configured for each pathosystem under greenhouse conditions. Plastic pots with 3 L capacity were filled with substrate for plant support and UFV-TM100 was incorporated at dosages of 0, 6, 12, 18, 24 and 30 g L^{-1} of substrate. Additionally, each pot was infested with 5.000 eggs of *Meloidogyne* sp. Seedlings were transplanted 14 days after the product was incorporated to the substrate. The experiments with lettuce and cucumber were harvested 60 days after transplantation. Coffee and banana plants were harvested 120 days after transplantation.

During the experimental period with lettuce and cucumber, the mean values for maximum and minimum temperatures were of 33.7 and 15.0 ^oC, respectively. In the experiments with banana and coffee, mean values for maximum temperatures were of 32.1 and 34.7 ^oC and 19.4 and 19.9 ^oC for minimum temperatures, respectively.

A completely randomized design was set up for the experiments. Each treatment was replicated six times and the experimental unit considered in one pot with one plant for each crop.

In all experiments, plant height, fresh weight of shoots, fresh weight of roots, the number of galls and number of *Meloidogyne* sp. eggs per radicular system, were evaluated. In addition, the diameter of lettuce heads and coffee canopy were evaluated, as well as the number of leaves and the fresh weight of rhizomes in banana plants.

The statistical analysis of data was performed with the aid of the software Statistica 7.0 (Statsoft, Inc.) and submitted to regression analysis in order to define the optimal dosage (maximum point) of UFV-TM100 for each crop and for each nematode species studied. The selected linear models exhibited the parameter, lack of fit of the regression, higher than 5% and the parameters of the equations were considered significant by the t-test at 5% probability.

Results

Diameter of the lettuce heads, fresh weight of shoots and fresh weight of roots, were influenced by dosages of UFV-TM100 incorporated to the substrate (Figure 1). Lettuce plants had a greater head diameter at higher dosages (Figure 1a). However, in the case of fresh weight of shoots and fresh weight of roots of lettuce, the best dosages were 18.1 and 10.5 g L^{-1} of UFV-TM100 incorporated to the substrate (Figure 1b, c), respectively.

Moreover, the application of increasing dosages of UFV-TM100 to the substrate reduced the number of galls and eggs of *M. javanica* within the roots system of lettuce (Figure 2).

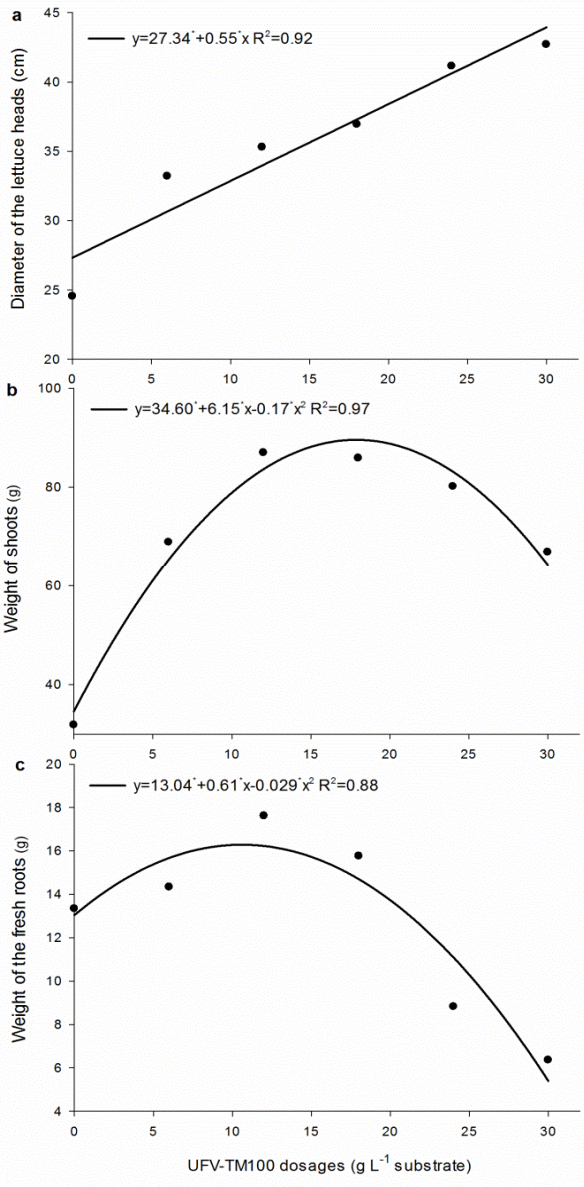

Figure 1. Effect of organo-mineral fertilizer UFV-TM100 dosages on head diameter (a), shoot weight (b) and root fresh weight (c), of lettuce plants cultivated on substrate infested with *Meloidogyne javanica*. *Significant by t test at 5% probability.

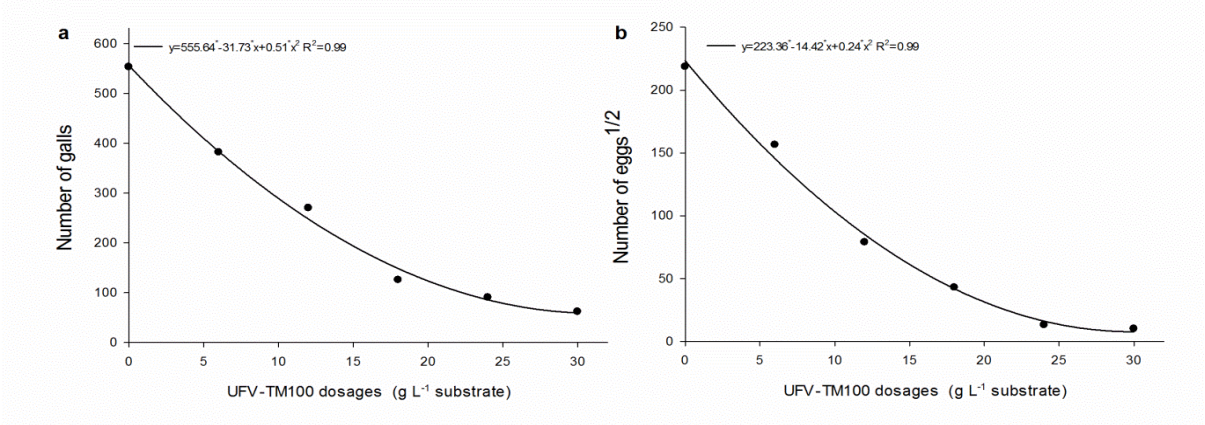

Figure 2. Effect of dosages of the organo-mineral fertilizer UFV-TM100 on the number of galls (a) and eggs (b) of *Meloidogyne javanica,* in roots of lettuce plants. *Significant by the t test at 5% probability. [1]Data transformed to $\sqrt{x}$.

The height of cucumber plants and the fresh weight of shoots and roots increased when UFV-TM100 was incorporated at dosages of 13.2, 15.2 and 11.0 g L^{-1} of substrate, respectively (Figure 3).

The increase of product dosages influenced directly the number of galls and eggs of *M. javanica*, reducing its numbers in cucumber's roots system ($p<0,05$) (Figure 4).

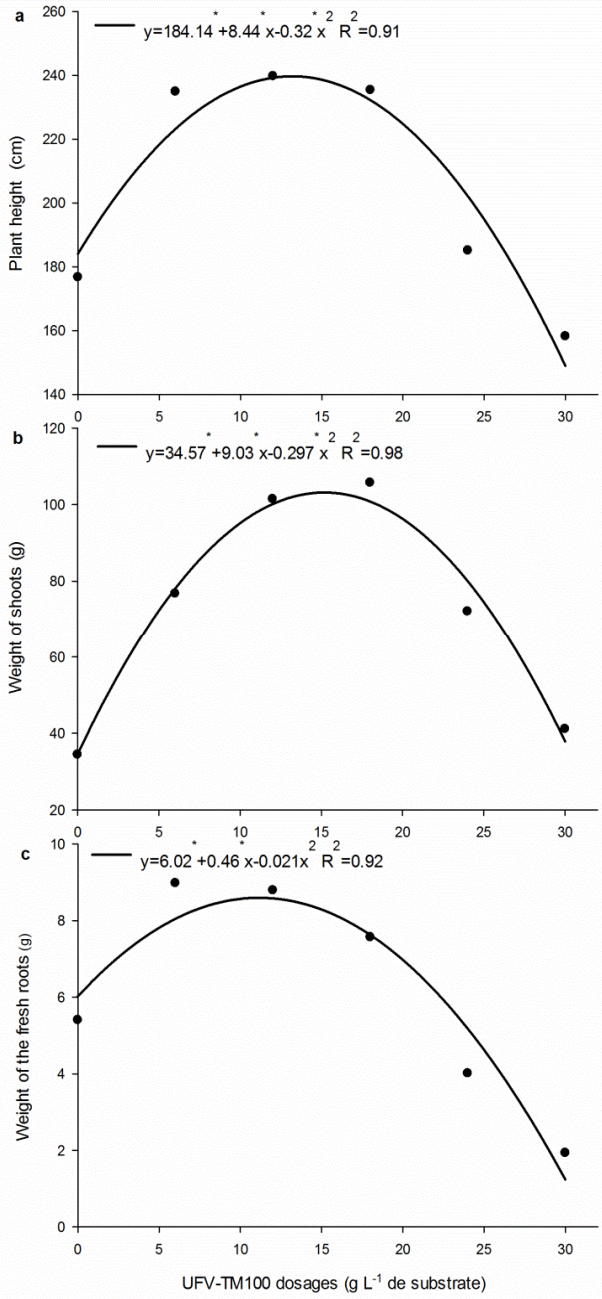

Figure 3. Effect of the organo-mineral fertilizer UFV-TM100 dosages in plant height (a), shoot weight (b) and root fresh weight (c), in cucumber plants cultivated on substrate infested with *Meloidogyne javanica.* *Significant by the t test at 5% probability.

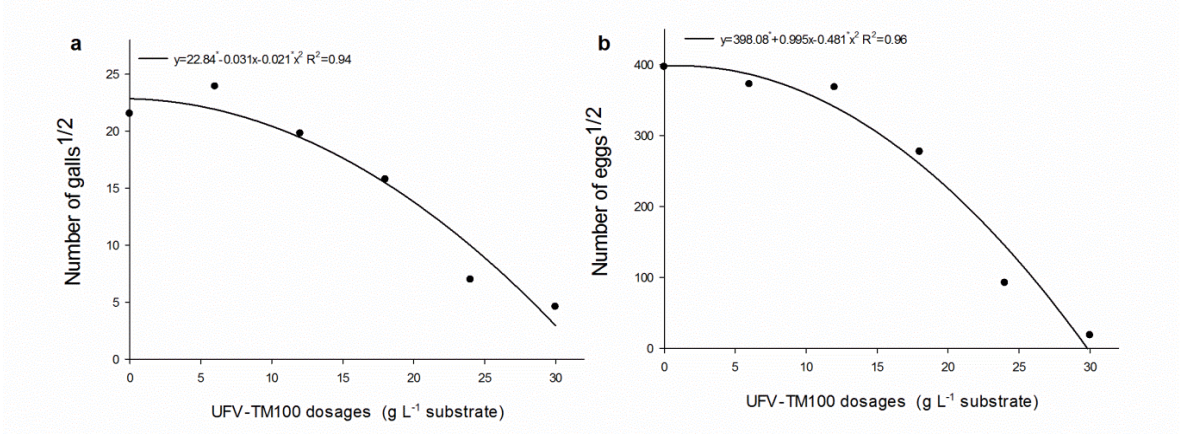

Figure 4. Effect of dosages of the organo-mineral fertilizer UFV-TM100, in the number of galls (a) and eggs (b) of *Meloidogyne javanica,* in roots of cucumber plants. *Significant at 5% probability by the t test. ½Data transformed to $\sqrt{x}$.

Plant height, the number of leaves per each banana plant and fresh weight of shoots and rhizome were influenced ($p<0.05$) by the incorporation of UFV-TM100 to the substrate (Figure 5). For plant height, number of leaves per plant and fresh weight of shoots, the same tendency was observed, with an increment of such variables at dosages of 22.5, 21.3 and 21.1 g L^{-1} of substrate, respectively. However, weight of banana rhizomes was higher when UFV-TM100 was incorporated to the substrate at the higher dosages (Figure 5d).

The number of galls were reduced ($p<0.05$) with increasing dosages of the product (Figure 5e). On the other hand, the reduction in the number of eggs of *M. javanica* was observed starting at dosages of 8.8 g L^{-1} of substrate, with a maximum reduction of 85% in the number of propagules at the dosage of 30.0 g L^{-1} of substrate, when compared with the treatment without application of UFV-TM100 (Figure 5f).

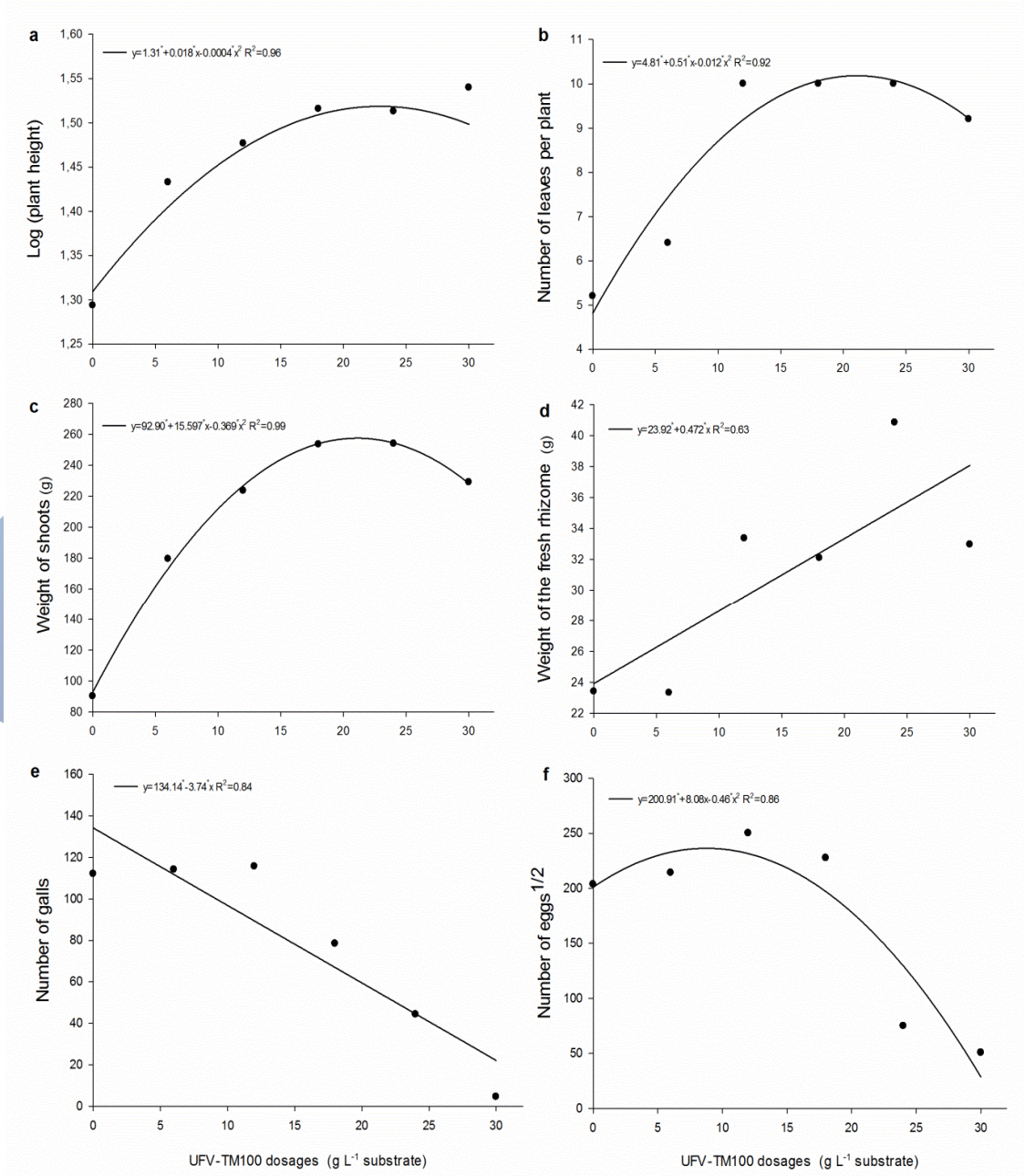

Figure 5. Effect of dosages of the organo-mineral fertilizer UFV-TM100, in plant height (a), number of leaves per plant (b), shoot fresh weight (c), rhizome weight (d), number of galls (e) and the eggs (f) in plants of banana cultivated on substrate infested with *Meloidogyne javanica.* *Significant at 5% probability by the t test. ^{log}Data transformed to $Log_{10}(x)$. ^{½}Data transformed to $\sqrt{x}$.

In coffee plants, plant height, canopy diameter and dry weight of shoots were higher when UFV-TM100 was incorporated at dosages of 7.1, 12.0 and 10.0 g L^{-1} of substrate, respectively (Figure 6). However, the fresh weight of roots was reduced ($p<0.05$) when product dosages were increased (Figure 6d).

The number of galls and eggs of *M. exigua* per root of coffee plant were reduced with the increase of UFV-TM100 dosages incorporated to the substrate, with a maximum suppression of 100 (Figure 6e) and 88% (Figure 6f), respectively, at the dosage of 30.0 g L^{-1} of substrate.

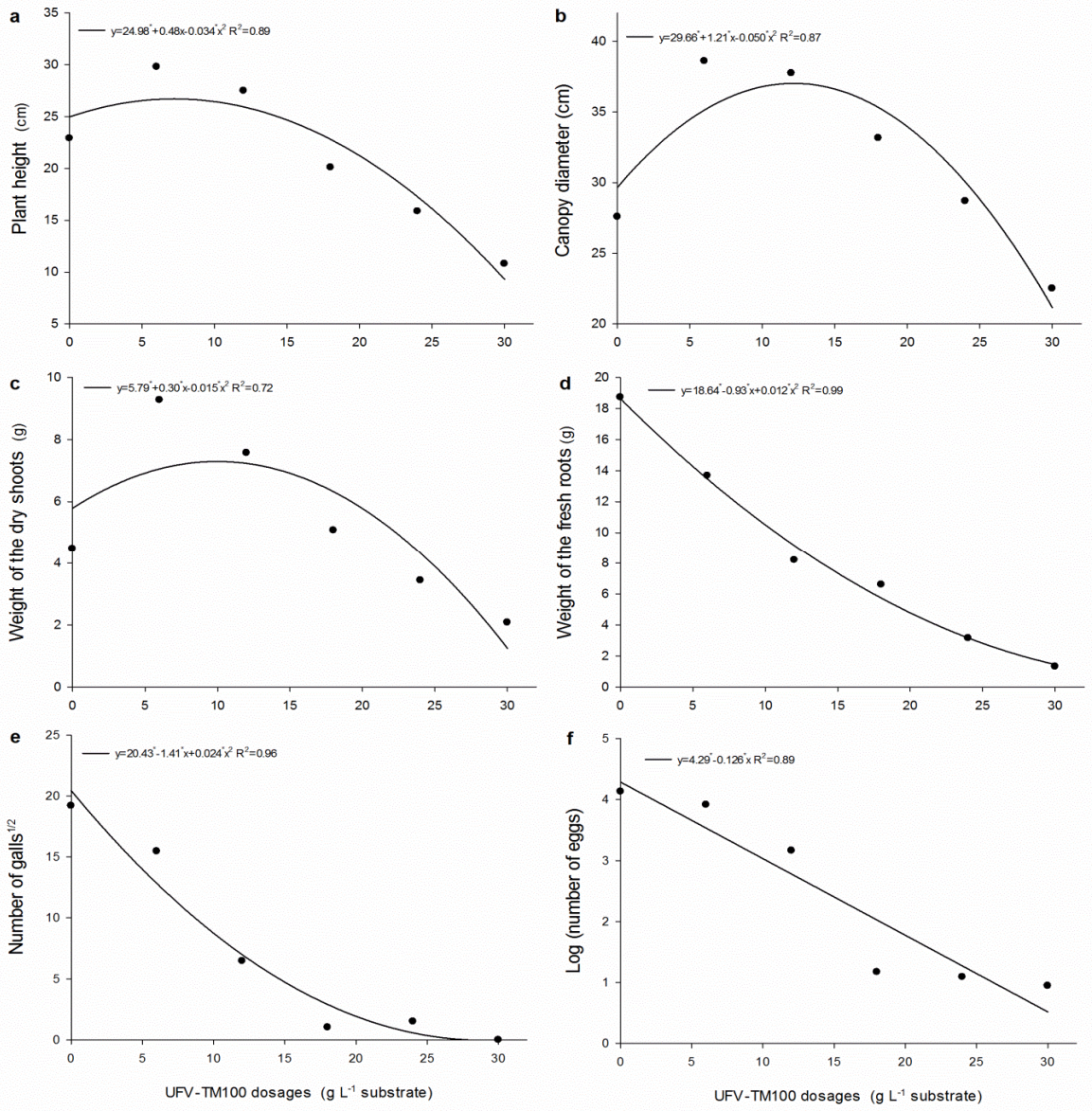

Figure 6. Effect of dosages of the organo-mineral fertilizer UFV-TM100 in plant height (a), canopy diameter (b), shoot dry weight (c), root fresh weight (d), number of galls (e) and eggs (f) in coffee plants cultivated in substrate infested with *Meloidogyne exigua*. *Significant by the t test at 5% probability. $^{1/2}$Data transformed to $\sqrt{x}$. ^{log}Data transformed to $Log_{10}(x)$.

Discussion

The organo-mineral fertilizer, UFV-TM100, enhanced the vegetative growth of the tested plants. However, plant species had different responses to the product when incorporated to the substrate. Coffee plants were those among the tested species, with the higher development observed under minor dosages of the fertilizer, ranging from 7.1 to 12.0 g L^{-1} of substrate, corresponding to dosages of 2.000 to 4.000 kg ha^{-1} in an area with a density of 5.000 coffee plants. In cucumber plants, the product dosages that promoted the best results in plant development ranged from 11.0 to 15.2 g L^{-1} of substrate, corresponding to dosages of 12.000 to 16.000 kg ha^{-1}, with an 1.0 x 6.0 m spacing plantation. Plants of lettuce had the highest development, depending on the variable evaluated, at dosages starting from 10.5 g L^{-1} of substrate and continued until the highest dosages of the product. Still, the optimal dosage (point of maximum) of UFV-TM100 must be set at approximately 18.0 g L^{-1} of substrate, corresponding to 24.000 kg ha^{-1}, with this being the dosage that resulted in the greatest weight of the shoot. Finally, banana was the plant that required the highest dosages of the UFV-TM100 for its development, with doses ranging from 21.1 to 30.0 g L^{-1} of substrate. Nevertheless, when converting these dosages per hectare, banana was the plant that required the lowest product quantities, corresponding to 1.500 and 2.000 kg ha^{-1}, due to the few number of plants per area (1.111 banana plants ha^{-1}).

Although the use of 2.00 to 50.000 kg per hectare of organic materials is recommended for agricultural areas (KIEHL, 1985; RIBEIRO et al, 1999; ALCARDE, 2007), this may be economically unfeasible. In this respect, the use of organo-mineral fertilizer in low density crops may be profitable, as in the case of coffee and banana or even when directional applying the fertilizer to the soil.

The population reduction of the root-knot nematodes in all tested crops was directly related with the increment of UFV-TM100 dosages. Though, the maximum dosage capable to control the pathogen without causing plant toxicity must be observed, due to the high concentration of toxic compounds produced during the breakdown of organic material constituting the organo-mineral fertilizer (MIAN; RODRÍGUEZ-KÁBANA, 1982; AKHTAR; ALAM, 1993; COLLANGE et al., 2011; MEYER et al., 2011; SEVERINO et al., 2012; ASMUS; NUNES, 2014). Even though, application of UFV-TM100 at maximum dosages that positively influenced plant productivity, also reduced the number of galls and eggs of *Meloidogyne* spp. in 65.9 and 35.3% in coffee plants, 23.3 and 24.1% in cucumber,

73.1 and 81.4% in lettuce and 83.6 and 85.4% in banana plants, respectively, when compared with plants that did not received the product.

Among the evaluated crops, coffee plant showed the highest variation level between average reduction of galls (65.9%) and eggs (35.3%) of *M. exigua*, when UFV-TM100 was incorporated at dosages of 12.0 g L^{-1} of substrate. It is most like this effect occurred due to the fact that nematodes produce the vast majority of its egg masses within the host roots (SILVA et al., 2006). Consequently, the direct contact between the nematode and toxic compounds originating from the decomposition of organic materials is reduced, as well as colonization of these egg masses by antagonist organisms, which are stimulated by organo-mineral mineral fertilizers (RICH et al., 1989; AKHTAR; ALAM, 1993; OKA, 2010; COLLANGE et al., 2011; MCSORLEY, 2011).

Analogous to the present work, soil incorporation of a granular organo-mineral fertilizer, Suneem G + Urea, increased plant height and shoot weight in 78.5% and 76.9%, respectively, while reduced the population of plant pathogenic nematodes in 88.6% and increased population of free living nematodes in 42.8%, in tomato plants (AKHTAR; MAHMOOD, 1997).

This shows that despite scarce studied, organo-mineral fertilizers hold potential for the management of plant pathogenic nematodes, development of plants of economic concern and conservation of the agricultural system sustainability.

Conclusions

Thus, UFV-TM100 represents a feasible alternative to control parasitic nematodes in different plants. Product dosages selected to control *M. javanica* in lettuce, cucumber and banana plants were 18.0, 15.0 and 30.0 g L^{-1} of substrate, respectively. In coffee plants the dosage of UFV-TM100 selected to control *M. exigua* was of 12.0 g L^{-1} of substrate. Nevertheless, additional research should be performed in order to select product dosages to be incorporated in different pathosystems with economic viability.

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