Optimizing *Peganum harmala* L. and *Ricinus communis* L. for Sustainable Nematode Control and Growth Stimulation in Melon Cultivation

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Abstract

Root-knot nematode (*Meloidogyne javanica*) is a major pest responsible for significant crop losses globally, particularly affecting melon (*Cucumis melo*). Organic amendments offer an eco-friendly alternative to chemical nematicides for managing plant-parasitic nematodes while enhancing soil health and crop growth. This study evaluated the efficacy of dried powder from *Ricinus communis* (castor) aerial parts and *Peganum harmala* (Syrian rue) seeds as bionematicides and biostimulants. Pot experiments were conducted to establish dose-response relationships and determine the effective inhibitory dose (DI90) of these botanicals against *M. javanica* in melon cultivation. Results showed that *P. harmala* and *R. communis* significantly reduced nematode populations at DI90 levels of 0.72% and 1.52%, respectively. In addition to nematode suppression, both treatments enhanced plant growth, with *P. harmala* showing a superior biostimulant effect. Substrate analysis further indicated improvements in organic matter content and nitrogen availability, especially in *P. harmala*-treated soils. These findings highlight the potential of *P. harmala* and *R. communis* as sustainable alternatives for nematode management, with promising applications in organic and conventional farming systems. Future research should focus on identifying active compounds responsible for the observed effects and further evaluating their field-scale efficacy.

Keywords: Bionematicide, *Meloidogyne javanica*, organic amendments, sustainable agriculture, melon cultivation

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1. Introduction

Plant parasitic nematodes (PPNs) represent a significant threat to global agriculture, with *Meloidogyne* spp. (root-knot nematodes) among the most destructive, affecting a wide range of crops worldwide. Recent estimates indicate that global crop losses due to nematode infestations exceed $100 billion annually, contributing substantially to food insecurity and economic instability, particularly in developing nations (Ntalli & Caboni 2012; Jones et al. 2013). The severity of damage caused by *Meloidogyne* spp. is underscored by their ability to infect over 200 plant species, including major cash and subsistence crops (Sikora & Fernandez 2005; van den

Hoogen et al. 2019). These nematodes are obligate parasites, disrupting root systems by inducing the formation of galls, which impairs water and nutrient uptake, stunting plant growth, and significantly reducing crop yields (Hussey 1985; Sasse 1979). In melon (*Cucumis melo*, Cucurbitaceae), for instance, the tolerance threshold for nematode infestation can be as low as 0.48–3.53 J2/100g of soil (Ploeg & Phillips 2001), and yield losses may reach as high as 65%, depending on the infestation severity (Lamberti 1979; Netscher & Sikora 1990).

Nematode Management Practices: Limitations and Emerging Alternatives

Traditionally, nematode management strategies have relied on cultural practices such as crop rotation, the use of resistant cultivars, and chemical nematicides (Ntalli & Caboni 2012). While chemical nematicides have proven effective, they are often expensive and present numerous environmental and health challenges (Obidari et al. 2024 Azlay 2022). The extensive use of synthetic nematicides has led to soil and water contamination, disruption of beneficial soil organisms, and risks to human health (Rich et al. 2004). Furthermore, resistance development in nematode populations poses a growing concern (Greco et al. 2021). In light of these challenges, there is an urgent need for environmentally friendly, cost-effective, and sustainable alternatives that can be integrated into nematode management programs without compromising crop productivity or ecological balance (Nico et al. 2021). The increasing awareness of the environmental impact of chemical nematicides has driven research into organic and biological alternatives. Organic farming systems, in particular, restrict the use of synthetic inputs and emphasize practices that enhance soil health and biodiversity. In organic production systems, the management of soil-borne pests is typically achieved through cultural practices such as crop rotation, tillage, and the application of organic amendments that improve the physical, chemical, and biological properties of soils (Sharma et al. 2022; van den Hoogen et al. 2019).

Plant-Based Organic Amendments for Nematode Management

Organic amendments, such as plant-based materials, manure, and compost, have been shown to reduce nematode populations while promoting soil fertility and enhancing crop performance (Ferji et al. 2006; Mayad 2013 Basaid et al. 2020). These materials offer a promising alternative to chemical nematicides because they are biodegradable, easy to apply, and support the growth of beneficial soil organisms that contribute to pest suppression (Ntalli & Caboni 2012).

Organic amendments from plants including plant extracts, powders, oil cakes, and chopped plant parts proved to be nematicidal against root knot nematodes Meloidogyne spp., specifically *Meloidogyne javanica in vitro* and in pot experiments (Nandal & Bhatti 1990; Lopes et al. 2009; Ashraf et al. 2010; Oka 2012; Ojo Umar 2013; Senhaji et al. 2018). *Peganum harmala* L. (Nitrariaceae), and *Ricinus communis* L. (Euphorbiaceae) are among plants, which have an anti-nematode effect against *M. javanica*. Aqueous extract of *P. harmala* seeds was effective at killing second stage juveniles of *M. javanica in vitro* and in pot experiments on tomato (El Allagui et al. 2006; Abood 2017), while aqueous extract and powdered seeds of *P. harmala* were effective at reducing density of *M. javanica* in soil of melon crop (Mayad et al. 2013). Previous work indicated that extract from *P. harmala*, has nematostatic reversible effect against root knot nematode (Mayad et al. 2019). Methanolic extracts of aerial parts of *R. communis* showed inhibition of *M. javanica in vitro* (Mayad et al. 2006). Aqueous extract of grounded aerial parts and castor oil cake reduced density of *M. javanica* in pot experiments on tomato culture (Ferji et al. 2006; Gardiano et al. 2009; Lopes et al. 2009; Bahmanziari et al. 2017), and powder and chopped leaves of *R. communis* reduced *M. javanica* population in banana and eggplant crops respectively (Nandal et Bhatti 1990; Ferji et al. 2013).

The Role of Organic Amendments in Soil Health and Crop Productivity

In addition to their nematicidal properties, organic amendments derived from plant materials contribute to improving soil health, which is vital for sustainable agricultural systems. Organic amendments have been shown to enhance soil structure, increase organic matter content, and promote the activity of beneficial soil microorganisms (Brenzinger et al. 2018). These microorganisms play a crucial role in nutrient cycling, organic matter decomposition, and disease suppression, contributing to the overall resilience of cropping systems (Olimi et al. 2023). For example, blending compost with nutrient-dense organic materials such as sewage sludge or digestate has been shown to improve crop production while reducing greenhouse gas emissions (Brenzinger et al. 2018). This dual benefit underscores the potential of organic amendments not only to suppress nematodes but also to enhance the sustainability of agricultural systems by improving soil fertility and crop productivity (Azim et al. 2017). Moreover, studies suggest that the efficacy of organic amendments in nematode management may be influenced by their chemical composition, particularly the carbon-to-nitrogen (C/N) ratio (Agbenin et al. 2004). Organic amendments with a high nitrogen content tend to release ammonia during decomposition, which has been shown to have nematicidal properties (Tenuta & Lazarovits 2002). The biocidal effect of ammonia on nematodes is believed to be due to its ability to alter cell membrane integrity, leading to nematode mortality (Rush & Lyda 1982). This suggests that amendments with higher nitrogen content, such as those derived from *P. harmala* and *R. communis*, could offer enhanced nematode control while also providing essential nutrients for plant growth.

Research Gap and Study Objective

Despite the growing body of research supporting the use of plant-based nematicides, there is still limited knowledge regarding the dose-response relationship required for effective nematode suppression in specific crops such as melons. Understanding the optimal dosages of these organic amendments is crucial for maximizing their efficacy while minimizing potential phytotoxicity or negative impacts on soil health. Furthermore, while many studies have focused on the nematicidal properties of these plants, their potential biostimulant effects on plant growth and crop yield remain underexplored. The objective of this study is to determine the dose-response relationship and the effective inhibitory dose (DI90) of dried powder from *R. communis* aerial parts and *P. harmala* seeds in pot experiments on melon crops infested with *M. javanica*. Additionally, this study aims to evaluate whether these amendments have biostimulant effects on plant growth and soil composition, contributing to the development of sustainable agricultural practices.

2. Materials and methods

The experiment was conducted at the experimental greenhouse of the Horticultural Complex of Agadir (C.H.A), equipped with cooling and ventilation systems, which allows forced air renewal. The maximum temperatures varied between 21 and 44°C, and the lows fluctuated between 5 and 14°C.

2.1 Preparation of organic amendment

Organic amendments used in treatments in this experiment consisted of dried powder from *P. harmala* seeds and *R. communis* aerial parts (Shoot, leaves and fruits). Both products were prepared from plant materials collected in the Souss Massa region between June and July, and were powdered in an electric grinder after drying at 40°C. The powder was kept in a dried atmosphere in the dark until application.

2.2 Experimental protocol

The botanical products were applied as soil amendments to the substrate (mixture v/v of 1/3 peat and 2/3 of soil with sandy-loam texture) in 5 liters black plastic pots by manual incorporation, mixing with the superficial third volume of pot. The used soil was naturally infested by *Meloidogyne spp.*, and the level of infestation (the initial population) was estimated at 173 ± 16 J2 / 100cm^3 of soil and the final concentration of J2 in the final substrate was 115±16 J2 / 100cm^3 of soil. The substrate was kept under high humidity by watering daily before planting to avoid phytotoxicity. Two-weeks-old seedlings of melon (*Cucumis melo* var. Leonardo) were planted one week after organic amendments application. Both products under evaluation were incorporated to the prepared substrates in five distinct doses (w/w). The doses for P. harmala were set at 2.5g, 6.25g, 12.5g, 25g, and 50g, while those for R. communis were 6.25g, 12.5g, 25g, 50g, and 100g. Each application aimed to achieve a 5kg substrate weight per pot. Positive and negative controls were considered respectively as substrate mixed with naturally infested soil with *Meloidogyne* spp. and autoclaved substrate. All treatments were performed in four repetitions and arranged in a completely randomized block design. The experimental unit consisted of three plants. The effectiveness of treatments was estimated by determination of the root knot nematodes population density in the substrate before application of treatments and three months after planting. Galling index and plant growth parameters were also determined.

The percentage of nematode reduction (PR) was estimated as follow:

$$PR = ((FPc – FPt)/ FPc)*100$$

Where FP_c: Final population of control and FP_t: Final population of treatment.

The gall index was assessed per plant according to Taylor and Sasser (1978) scale: 0= no gall; 1= 1 to 2 galls; 2= 3 to 10 galls; 3= 11 to 30 galls; 4= 31 to 100 galls; 5= more than 100 galls. The length, fresh and dry weight of aerial parts, root volume and the number of flowers per plant were measured as agronomic parameters. The volume of the plant roots was determined using the water displacement method. This involved submerging the washed roots in a known volume of water and measuring the increase in water level, which corresponds to the volume of the submerged roots.

Substrate parameters such as organic matter, total nitrogen (NTK), C/N ratio, pH and electrical conductivity (EC) were measured according to AOAC (1984).

2.3 Statistical analysis

All collected data were subjected to a statistical analysis of variance and means ware classified following the Newman and Keuls test ($P \leq 5\%$), to highlight the eventual dose-effect on both root knot nematode and melon plant parameters. All these analyses were carried out using the statistical software SPSS (Version 11.5). The inhibitory dose of 90% (DI90) of *Meloidogyne* spp. population was determined on the basis of the reduction rates of J2 populations counted in each soil sample, by the Probit method using PC-software POLO (LeOra Software 1987).

3. Results

3.1. Health status of infested plants

During the experiment, no phytopathological symptoms were observed on the plants, until the last two weeks when *Bemisia tabaci* individuals were detected; without a significant impact on the growth of the melon plants.

3.2. Impacts of treatments on Meloidogyne spp. densities and multiplication rate in the substrate

The final density of juveniles of the 2nd instar and the reproduction rate *Meloidogyne* spp. population increased in the case of the positive control (absence of the treatments by botanicals). However, the density of nematodes was significantly reduced by treatments, and it decreased with increasing dose of botanicals prepared from both *P. harmala* and *R. communis* (Table 1). Highly significant and negative correlations were observed (R = -0.86 for *R. communis*, R = -0.88 for *P. harmala*). All tested treatments differed significantly from the positive control. The lowest nematode density of *Meloidogyne* spp. was observed by applying *R. communis* at 2% and *P. harmala* at two doses: 1% and 0.5%. The highest densities of root knot nematodes were recorded with doses lower and equal to 0.25% for of *R. communis* and lower and equal to 0.125% for *P. harmala* bioproducts respectively (Table 1).

Table 1. Effect of dried *R. communis aerial part* and *P. harmala* seeds powder at different concentrations on root knot nematode population density (J2/100cm^3 of substrate) and inhibitory doses of 90% of the population (DI90) after 90 days of melon cultivation.

Treatments	Concentration (%)	Nematode density	% of population reduction	DI90 (%)	Slope
R. communis	0.125	223.00 d*	14.97 d	1.52	1.40
	0.25	207.75 d	20.78 d		
	0.50	95.50 c	63.58 c		
	1.00	53.00 b	79.79 b		
	2.00	**16.75 ab**	**93.61 ab**		
P. harmala	0.05	214.00 d	18.40 d	0.72	2.27
	0.125	192.00 d	26.79 d		
	0.25	117.75 c	55.10 c		
	0.50	**39.50ab**	**84.94ab**		
	1.00	**13.50ab**	**94.85ab**		
Positive control	-	262.25e	-	-	-

* Numbers followed by the same letter in the same column are not significantly different according to the

Newman and Keuls test (P ≤ 5%)

3.3 Impacts of treatments on galling of root symptoms

The degree of infestation of melon was determined by the gall number and galling index. Roots of the plants representing the negative control showed no sign of infestation (0 galls). Except for the plants treated with 1% *P. harmala* and 1% and 2% *R. communis*, all other plants exhibited gall numbers comparable to the positive control, indicating a pronounced infestation level. Only plants treated with 1% *P. harmala* botanicals showed significant differences compared to the positive control (Table 2).

3.4 Impacts on plant growth and physic-chemical parameters of substrates

3.4.1 Impact of treatments on dry weight and root volume

There was no phytotoxicity recorded at the end of the test, although the negative control showed a lower value in dry weight and root volume compared to the positive control. With reference to the negative control, all treatments generally showed a significant improvement in root growth except for the doses lower and equal to 0.25% of *R. communis* and the doses lower and equal to 0.125% of *P. harmala*. Root growth was significantly improved by doses of 2% (+32.50%) and 1% (+34.58%) of *R. communis*, and 1% (+63,75%) and 0.5% (+41,67%) of *P. harmala* compared to the positive control. The highest root volume (+63,75%) and weight (+73,02%) are obtained with *P. harmala* at 1% (Table 3).

Table 2. Effect of dried *R. communis aerial part* and *P. harmala* seeds powder at different concentrations on the galling index and the number of galls induced by *Meloidogyne javanica* after 90 days of melon cultivation

Treatments	Concentration (%)	Gall index	Gall Number
R. communis	0.125	4.50 d	98.00 d
	0.25	4.50 d	97.25 d
	0.5	5.00 d	101.25 d
	1.00	3.50 bcd	51.75 cd
	2.00	3.25 bcd	32.25 bc
P. harmala	0.05	5.00 d	102.25 d
	0.125	5.00 d	104.25 d
	0.25	4.25 cd	90.25 d
	0.50	3.50 bcd	63.25 d
	1.00	**2.75 b**	**21.25 b**
Positive control	-	5.00 d	113.75 d
Negative control	-	0.00 a	0.00 a

* Numbers followed by the same letter in the same column are not significantly different according to the Newman and Keuls test (P ≤ 5%).

3.4.2 Impact of treatments on aerial part and yield

With the exception of the application of 0.25% and 0.5% of *R. communis* as well as 0.125% and 0.05% of *P. harmala*, all treatments have generally resulted in a significant improvement in growth of the aerial part of the crop compared to both controls. The fresh and dry weight of the stem and its length were increased particularly by the high doses (1% and 0.5% of *P. harmala* as well as 2% and 1% of *R. communis*) regardless of the organic amendment origin. The 1% *P. harmala* treatment emerged as the most promising for crop development. However, when considering the dry weight of the stem, this treatment was statistically comparable to the 0.5% *P. harmala*. Additionally, for stem length, the 1% *P. harmala* treatment showed no significant differences when compared to the 0.5% and 0.25% *P. harmala* treatments and the 2% *R. communis* treatment, as detailed in Table 4.

Improved text: The number of flowers per melon plant varied significantly across the treatments. For plants treated with *R. communis*, the highest number of flowers was observed at the 1.00% concentration (14.75 flowers/plant) while the lowest was at the 0.125% concentration with 6.70 flowers/plant. In the *P. harmala* treatments, the 0.50% concentration led to the highest number of flowers with 18.50 flowers/plant, whereas the 0.125% concentration resulted in 12.50 flowers/plant. It is noteworthy that the P. harmala treatment at 0.50% outperformed all other treatments, including both controls. The negative and positive controls exhibited 10.00 and 9.25 flowers/plant, respectively. Overall, as the concentration of the botanical treatments increased, there was a general trend of increasing flower numbers, with *P. harmala* showing more pronounced positive effects than *R. communis* (Table 4).

Table 3. Impact of dried *R. communis aerial part* and *P. harmala* seeds powder at different concentrations on dry weight and root volume of plants after 90 days of melon cultivation

Treatments	Concentration (%)	Root volume (ml)	dry weight (g)
R. communis	0.125	1.01 e	0.40 e
	0.25	1.08 e	0.44 e
	0.50	1.85 d	1.46 c
	1.00	**3.23 b**	**2.35 ab**
	2.00	**3.18 b**	**2.04 ab**
P. harmala	0.05	1.20 e	1.00 d
	0.125	1.50 e	1.08 d
	0.25	1.93 d	1.20 cd
	0.50	3.40 b	1.95 b
	1.00	**3.93 a**	**2.18 ab**
Negative control	-	1.18 e	0.97 d
Positive control	-	2.40 c	1.26 cd

* Numbers followed by the same letter in the same column are not significantly different according to the Newman and Keuls test (P ≤ 5%).

Table 4. Impact of dried *R. communis aerial part* and *P. harmala* seeds powder at different concentrations on growth and yield of melon plants in pot experiment after 90 days of melon cultivation

Treatments	Concentration (%)	Fresh weight (g)	Dry weight (g)	Length (cm)	Number of flowers/plant
R. communis	0.125	30.99 e	08.38 e	105 c	6.70 e
	0.25	31.99 e	08.58 e	110 c	7.75 e
	0.50	45.51 de	16.95 bcde	135 b	11.75 cde
	1.00	93.37 d	20.20 bcd	172 ab	14.75 abc
	2.00	177.06 c	25.21 b	**200 a**	13.00 bcd
P. harmala	0.05	74.00 de	14.00 cde	172 ab	13.00 bcde
	0.125	77.27 de	15.10 cde	176 ab	12.50 bcde
	0.25	150.77 c	23.37 bc	**205 a**	14.75 abc
	0.50	219.91 b	**33.94 a**	**230 a**	**18.50 a**
	1.00	**271.25 a**	**38.75 a**	**225 a**	17.25 ab
Negative control	-	**59.34 de**	**12.96 de**	**140 bc**	**10.00 de**
Positive control	-	56.67 de	13.98 de	127 bc	09.25 de

* Numbers followed by the same letter in the same column are not significantly different according to the Newman and Keuls test (P ≤ 5%).

3.4.3 Impact of treatments on substrates composition

Chemical analysis of substrates in function of bioproduct treatments shows that both botanicals exhibited higher values for organic matter and C/N in soil, compared to positive control. *P. harmala* powder also showed a slight increase in NTK value, whereas *R. communis* had the same nitrogen content, as the positive control. Both botanicals resulted in a decrease in substrate pH and electrical conductivity (Table 5).

Table 5. Effect of *P. harmala* and *R. communis* organic amendments on the chemical composition of the soil after 90 days of melon cultivation

Treatment	Organic matter % (w/w)	Total Nitrogen (NTK) %	C/N	pH	Electrical Conductivity at 25°C ($dS.cm^{-1}$)
R. communis (2%)	3,29	0,43	4,40	7,5	0,25
P. harmala (0,5%)	7,77	0,50	8,94	7,82	0,20
Positive control	1,88	0,43	2,52	8,13	0,29

4. Discussion and conclusion

Applied as an organic amendment, the seed mill of *P. harmala* significantly reduced the population development of *M. javanica*, and allowed a growth improvement of melon plants, in comparison with ground aerial parts of *R. communis*. Generally with respect to several parameters, the response intensity of the dose increase was in favor of ground meal of *P. harmala,* compared to *R. communis* seed meal above a certain dose threshold (0.25% for *P. harmala* and 0.5% for *R. communis*). The increased degree of infestation of melon roots by *M. javanica* during this trial was favored by the high level of the substrate initial population (115 ± 16 J2/100cm^3 substrate) and the high temperatures of July and August. The resulting effect of both botanicals on melon growth is in accordance with previous studies, which reported the beneficial effect of *P. harmala* and *R. communis* on plant growth when applied as soil amendment. Aqueous extract and seeds powder of *P. harmala* improved growth parameters of melon infested with *M. javanica* (Mayad et al. 2013), whereas *R. communis* aqueous extract showed increase in plant growth of tomato plants, infested with *M. javanica* (Bahmanziari et al. 2017), and *R. communis* oil cake enhanced plant growth of Black gram, tuberose and okra plants confronted to root knot nematode *M. incognita* (Rehman et al. 2014; Jothi & Poornima 2017; Archana & Goswami 2017). Thoden et al. (2011) suggested a possible mechanism, which might be responsible for the observed enhancement of crop yields by organic amendments. This mechanism is related to the proliferation of non-pathogenic, free-living nematodes and their overall positive effects on organic matter decomposition, nutrient availability, plant morphology, soil microbial populations, and ecosystem stability. Plants can exhibit biochemical mechanisms to counteract the activity of nematodes (Akhtar & Malik 2000). The differences observed in terms of effectiveness between the organic amendments based on *P. harmala* and *R. communis* can be explained, by the nature of the toxic compounds released directly or indirectly in each ground material towards nematodes, the potential antagonistic stimulant and predatory microorganisms at rhizosphere level, the fertilizer effect and change of soil parameters such as pH and EC. The antinematode effect of *R. communis* has been attributed to lectins, particularly ricin (Rich et al. 1989; Akhtar & Mahmood 1996). A recent study by Pedroso et al. (2018) showed that *R. communis* bean cake amended to soil emitted volatile organic compounds such as phenol, 4-methylphenol, γ-Decalactone, and Skatole, which reduced density of *M. incognita* on tomato culture. The action of *P. harmala* seed meal on the *Meloidogyne* spp. populations and its impact on crop infestation is due, on one hand, to their richness in β-Carboline alkaloids and on the other hand to its nitrogen content. Organic amendments may provide inconsistent control efficiency, depending on amendment and soil type. Thus, understanding the mechanisms involved in their suppression of nematodes is vital for obtaining maximum control efficacy. Organic soil amendments act on nematodes by several mechanisms: the release of preexisting plant tissues used as an amendment, the production of nematicidal compounds during the biodegradation of amendments, stimulation of antagonistic organisms, stimulation of tolerance/resistance in the host plant (phytoalexins) and occurrence of physical changes in the soil (EC, pH, structure ...) (Oka 2010; Sobkowiak et al. 2018). According to Agbenin (2004), the effectiveness of an organic amendment for the management of nematodes depends on the type of nematode, its C/N ratio, its degree of hydration and the decomposition time. Based on the C/N ratio, Miller et al., (1968; 1973) concluded that nitrogen bioavailability increases the ability of the organic amendments to control nematodes, which is in accordance with the findings of this actual study. The *P. harmala* treatment exhibited slightly higher nitrogen availability in the soil compared to *R. communis* and contained a greater percentage of organic matter. Mian & Rodriguez-Kabana (1982) attributed the potential of an organic amendment to manage nematode, directly to its nitrogen content, or inversely with the C/N ratio. Ammonium from the microbial decomposition of the amendments plays an important role in the control of nematodes and fungi for a short time (a few days to a few weeks) after application (Oka et al. 1993; Tenuta & Lazarovits 2002). The biocide mode of ammonia action is yet to be explained. Possible mechanisms involved include alteration of the cell membrane (Rush & Lyda 1982) and depletion of the chemical energy of cells carrying cytosolic ammonia against the concentration gradient (Brito et al. 2001). The use of nitrogen-releasing organic amendments is limited by the amount needed for effective control, since it is frequently phytotoxic or not economically viable (Stirling 2014). Oka (2010) reported that the nematicidal activity of this type of amendment could be improved by manipulating the soil environment to reduce the amount needed for practical control.

Organic amendment has also a positive role in soil fertility as an effective means of organic matter rebuilding through carbon sequestration and an important nutrient reservoir for to the depleted agricultural soils (Azim et al. 2017a). *R. communis* and *P. harmala* treatments have improved organic matter content of treated substrates and also resulted in a pH acidification and increase in EC. Those results could be explained by the mineralization of organic matter that release organic acids and total salts which are responsible for pH acidification and salinity augmentation as suggested by Rynk (1992) and Azim et al (2018b) respectively.

Significant progress has been made in the characterization of organic amendments, application of strategies for their use, and elucidation of mechanisms by which they suppress soil borne pests (Rosskopf et al. 2020). Nonetheless, their utility is still limited. Economic considerations are important in commercial agriculture. The grower's acceptance of using organic amendments for controlling plant-parasitic nematodes will involve practical considerations such as availability of plant materials, the logistics of introducing them into crop production systems and efficacy of treatment compared to commercial nematicides (Akhtar 2000). Based on the price of dried powder of *P. harmala* seeds and *R. communis* aerial part (stems, leaves, flowers and seeds) in local and regional market (0,8 to 1.5 USD per kg) the economic feasibility remains encouraging especially in high-value crops. The average cost of application of these products at the effectives doses to treat one hectare (20000 plants) using one application may range between 1900 and 2500 USD including the labor cost for their application (unpublished data).

5. Conclusion

In conclusion, Plant-based amendments from *P. harmala* and *R. communis* may be considered as promising components of a biological control program of the root knot nematode *M. javanica*, at effective doses (DI90) of the order of 0.72% for the seed meal of *P. harmala* and 1.52% for *R. communis*. These doses have the merit of being evaluated for their nematicidal potential with impact on high value crop production. Identification of active nematicidal compounds released from *P. harmala* and *R. communis* based products in amended soils, and determination of their concentrations may prove a direct effect of nematicidal compounds on the root knot nematode. These active compounds can be applied to soil as organic amendments, or undergo further refinements to be developed as biopesticides, that constitute an efficient organic bio-nematicide for managing *M. javanica* in both organic and conventional production systems. Further studies are then suggested to explore the reactive potential of *Peganum sp*., *Ricinus sp*. and other potential botanicals as bio-pesticides for biological management of soil-born pests.

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