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Host-Parasite Relationship between *Meloidogyne javanica* and Plantain (*Musa paradisiaca*), and Nematicidal activity of Lantana (*Lantana camara* L.) and Mistletoe (*Viscum album* L.)

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Abstract
The nematode *Meloidogyne javanica* is a constraint to the production of *Musa* spp. in Cameroon. Management is mainly with expensive synthetic nematicides which are environmentally unsafe. Two experiments were conducted in Buea, Cameroon, in 2017 and 2018 to determine (i) the effects of five nematode populations (0, 1300, 2600, 3900 and 5200 nematodes) on plantain, and (ii) the management potential of lantana (*Lantana camara* L.) and mistletoe (*Viscum album* L.). In the latter, treatments were ground leaves of lantana and mistletoe (4 and 16 g/plant) and the synthetic nematicide (Ethoprofos), incorporated into the soils with the plantlets 4 weeks after planting; which was 1 week after nematode inoculation (WAI). The control was without botanical or nematicide. The results showed that treatments with 0 and 1300 nematodes had taller plants with larger stem diameter than those with 2600–5200 nematodes at 5 WAI. Treatments with lantana, mistletoe and Ethoprofos had significant ($P \leq 0.05$) increase in growth parameters and decrease in nematodes and galls. Application of 16 g/plant of both botanicals or of Ethoprofos reduced nematode populations and prevented gall formation on plant roots. The findings indicate that lantana and mistletoe have the potential to manage *M. javanica* and could serve as alternatives to synthetic nematicide.

Keywords: Lantana camara, management, Meloidogyne javanica, Musa spp., Viscum album

Introduction

Plantain (*Musa paradisiaca*) is a major staple crop in West and Central Africa (WCA), where it contributes significantly to food security. It is also an important source of revenue for those involved in its production and marketing (Osei *et al*., 2013; Dépigny *et al*., 2018). Cameroon is the fourth largest producer in WCA (Tripathi *et al*., 2015; Folefack *et al*., 2017). The crop ranks second, after cassava, in terms of high calorie ratio to cost price among staple foodstuff in the tropics and subtropics (Osei *et al*., 2013). It is a good source of carbohydrate and energy (Tripathi *et al.*, 2015; Folefack *et al*., 2017); as well as potassium, calcium, phosphorus, nitrogen, iron and vitamins, especially C and E (Imam and Akter, 2011).

The production of *Musa* spp is constrained by several factors, which include; disease (black sigatoka and banana bunchy top) infestation, nematode (burrowing: *Radopholus similis*, lesion: *Pratylenchus coffeae,* spiral: *Helicotylenchus multicinctus,* root-knot: *Meloidogyne* spp. and reniform: *Rotylenchulus reniformis*) infection, weevil (*Cosmopolites sordidus*) infestation, inadequate capital, high cost of inputs and climate change (Adegbola *et al*., 2013; Kainga, 2013; Osei *et al*., 2013; Tripathi *et al*., 2015; Lum and Acha, 2018). Nematode infections account for 31 to 50% annual yield losses in plantain (Norgrove and Hauser, 2014; Tripathi *et al.*, 2015). The above ground symptoms induced by nematodes are often similar to those caused by nutrient deficiency and may be attributed to other agents. Nematodes destroy the primary roots of the plant; disrupt its ability to anchor and this results in toppling especially when it bears fruits (Osei *et al*., 2013).

The root knot nematode is one of the top 10 most important plant-parasitic nematodes in molecular plant pathology (Jones *et al.*, 2013). *Meloidogyne* spp. damage plants by modifying the cells and forming feeding sites (Roderick *et al*., 2012). They incite galling of roots thereby distorting the root system (Osei *et al*., 2013). *Meloidogyne javanica* is a constraint to the production of *Musa* spp. in Cameroon. Several studies carried out on the effect of *Meloidogyne* spp on crop growth indicated that the damage caused by the nematodes was directly proportional to their initial population densities (Maleita *et al*., 2012; Jagdale *et al*., 2013; Azhagumurugan and Rajan, 2015; Ndifon, 2019).

Management of nematodes has been mainly with synthetic nematicides which are expensive and environmentally unfriendly. Some botanicals have been reported to manage pests of *Musa* spp and other crops. For example, the use of *Argemone mexicana*, *Calotropis procera*, *Solanum xanthocarpum* and *Eichhornia echinulata* together with normal or deep ploughing controlled plant parasitic nematodes and soil-inhabiting fungi infesting chickpea, and also improved crop growth (Rizvi *et al*., 2012). In another study carried out in Buea, Cameroon, the authors reported that the aqueous extract of neem had insecticidal effects against the banana borer weevil (Lum and Acha, 2018). The use of these botanicals for pest management is environmentally safe. Information is scarce on the host-parasite relationship between *Meloidogyne javanica* and plantain in Cameroon; and the use of botanicals for management of the nematode on *Musa* spp. Thus, the objectives of this study were to determine the effect of different populations of the root knot nematode *M. javanica* on the growth of plantain and the potential of lantana (*Lantana camara*) and mistletoe (*Viscum album* L.) for its management.

Methodology

The experimental site

Two experiments were carried out in a screenhouse at the Teaching and Research Farm of the University of Buea (4.09 N, 9.014 E; 870 m a.s.l.) in 2017 and 2018. Buea is located in the humid forest agro-ecological zone of Cameroon. It has an equatorial climate with rainy and dry seasons.

Raising the nematode inoculum and extraction

For both experiments, egg masses of *M. javanica* were extracted from fresh samples of infected carrot plants growing on the farm using the modified Baerman's method reported by Okafor *et al*. (2015). After identification, the nematode eggs were inoculated into sterilized soil with *Celosia argentea* L. as host plants for three months. The nematodes in the soils collected from the experimental units were also extracted and counted using the method outlined by Okafor *et al*. (2015).

Plantlet production and transplanting

The seedlings were produced in a propagator using the PIF micro-propagation method ('Plantes Issus de Fragments de tige') (Faturoti *et al*., 2002; Ngo-Samnick, 2011). The roots and corms of the suckers were cleaned; the roots were cut with a knife, the bark was peeled and the white underlying layers of the corms were exposed. Each of the conical pseudo-stems was removed by cutting 2 mm above the knot. After four intersecting cross cuts were made on the corms to divide the meristem, they were disinfected and submerged in sawdust in the propagator (Faturoti *et al.*, 2002; Ngo-Samnick, 2011). The soil was steam sterilized for one hour, spread on large polythene paper and left in the open air for 14 days before it was put into polythene bags. Twenty-one days old plantlets from the propagator were planted in the bags, and kept to acclimatize for 21 days. They were placed in a shaded area on the floor to develop roots before they were taken into the screenhouse.

Preparation and application of lantana and mistletoe

Leaves of lantana were obtained from whole plants growing in the University of Buea campus, while those of mistletoe were collected from pear trees in the same location. The leaves of both species were air-dried separately for 72 hours. The dried leaves were ground into powder using an electric blender and stored in airtight bottles. The different concentrations (4 and 16 g/plant of powdered leaves of each plant) were applied to the soil in the polythene bags containing the plantlets one week after nematode inoculation (WAI). Agronomic practices were carried out as recommended.

Experimental design

Each experiment was arranged as a completely randomized design with three replicates. The plants were placed 30 cm apart in the screenhouse and each unit had a single plantlet in a polythene bag. The experiment on population dynamics consisted of five populations: 0, 1300, 2600, 3900 and 5200 nematodes. The experiment on nematode management comprised leaves of lantana and mistletoe (each 4 and 16 g/plant), Ethoprofos (a synthetic nematicide) and a control (without the plants and synthetic nematicide). Each plantlet was inoculated with 1300 nematodes in a polythene bag.

Data collection and analysis

Data were obtained on plant height and stem diameter at 3 and 5 WAI for the experiment on population dynamics, and at 5 WAI for that on nematode management. Plant height was measured using a meter rule and stem diameter was obtained with a caliper. In both experiments, galls on plant roots were assessed on a scale of 1 to 10 (Bridge and Page, 1980) at 5 WAI. The number of *Meloidogyne* larvae in 250 ml of soil was counted using a stereo-microscope and the mean of three different samples was used to determine the number of nematodes in the soil when egg masses had all hatched in moistened soil. The data were subjected to analysis of variance and the means were separated using Tukey HSD at $P \leq 0.05$.

Results and Discussion

Results

Population dynamics: Plant height

The population densities of *M. javanica* had significant effect ($P \leq 0.05$) on plant height at 3 and 5 WAI (Table 1).

In general, there was an increase in plant height from 3 to 5 WAI. At 3 and 5 WAI, the control treatment without nematodes and plots with 1300 nematodes had taller plants than the others. Treatments with 3900 and 5200 nematodes had similar plant heights.

Population dynamics: Stem diameter

The effect of *M. javanica* population densities on the stem diameter of plants in the screen house is presented in Table 1. There were significant differences ($P \leq 0.05$) in the stem diameter of the plants at the different population densities. In general, there was an increase in stem diameter for all the treatments from 3 to 5 WAI. The control plots and treatments with 1300 nematodes had larger stem diameter than all the others at 3 and 5 WAI. The higher populations of nematodes (2600–5200) resulted in smaller stem diameters than the lower ones.

Population dynamics: Formation of galls

At 5 WAI, plants on soils inoculated with the different nematode populations had tiny galls which were difficult to count because the roots were tender (data not shown). Plants in the control treatment without nematodes did not have galls.

Management of M. javanica: Plant height

Results of the effects of lantana and mistletoe on the plants are presented in Table 2 and Figures 1 and 2. At 5 WAI, there were significant differences ($P \leq 0.05$) in plant height among the treatments (Table 2). In general, treatments with Ethoprofos had the tallest plants. Treatments with 16 g/plant of mistletoe resulted in taller plants than all the others with botanicals. The shortest plants were recorded in the control treatment.

Management of M. javanica: Stem diameter

The stem diameter varied significantly ($P \leq 0.05$) among the treatments at 5 WAI (Table 2). The largest stem diameter was obtained in treatments with Ethoprofos. For each botanical, the stem diameter was larger at 16 g/plant than at 4 g/plant. Overall, the least stem diameter was obtained in the control treatment.

Management of M. javanica: Population

At 5 WAI, the population of *M. javanica* in soils treated with Ethoprofos was significantly ($P \leq 0.05$) lower than that in all other treatments (Figure 1). Among the botanicals, there were fewer nematodes in soils treated with 16 g/plant than in those with 4 g/plant. The population of nematodes in the control plots was higher than that at the onset, and in all other treatments.

Management of M. javanica: Formation of galls

At 5 WAI, there were significant differences ($P \leq 0.05$) in the number of root galls (Figure 2). Treatments with 4 g/plant of lantana and mistletoe had tiny galls on the plant roots, which were difficult to count. Those with 16 g/plant of both botanicals had no galls, similar to those with Ethoprofos. The control treatment had the highest number of galls which were visible enough.

Discussion

The results of this study revealed that *M. javanica* reduced the height and stem diameter of plantain, and increased the number of root galls. The reduction in growth parameters increased as the population of *M. javanica* also increased. Therefore, high population densities of the nematode resulted in shorter plants with smaller diameters than the low ones. This indicates that the nematode significantly affected the growth of the plants. These results agree with those of earlier studies that reported a decrease in growth parameters with increasing levels of nematode inoculum (Maleita *et al*., 2012; Kshetrimayum, 2014; Prabhu *et al*., 2018). The reduction in growth parameters could lead to a decrease in yield and to plants toppling over especially under conditions of low moisture. When the nematode attacks crops early, heavy and widespread distribution in the field could result, hence a higher cost of control measures. Thus, control when the plantlets are in the nursery could be cheaper and is recommended as a necessary pre-transplanting procedure once symptoms such as galls are noticed. Application of lantana and mistletoe at 16 g/plant reduced the population of the nematode and prevented the formation of galls on the plant roots. Treatments with 4 g/plant of both botanicals did not reduce the nematode population to a level that could prevent the formation of root galls. Treatments with Ethoprofos had no nematodes and therefore, no galls were formed. Lantana and mistletoe had the potential to manage *M. javanica*; therefore, both plants could be harnessed as botanical nematicides. These findings are in line with those of Feyisa *et al.* (2016) who reported that leaf extracts of lantana and three other botanicals controlled the root-knot nematode *M. incognita*; and Maher *et al*. (2021) who indicated that mistletoe had nematicidal activity against *Meloidogyne incognita*.

Conclusion

The host-parasite interaction between plantain and *M. javanica* was detrimental to the growth of the crop especially at higher population densities of the nematode. Management of *M. javanica* with lantana and mistletoe produced better results than the control, although both botanicals were not as effective as Ethoprofos. Lantana and mistletoe therefore have the potential to manage the nematode and should be exploited further.

Table 1: Effects of *M. javanica* population densities on the height and stem diameter of *Musa* plants at 3 and 5 weeks after inoculation

Nematode Population	Plant height (cm)		Stem diameter (cm)	
	3 WAI	5 WAI	3 WAI	5 WAI
0	14.8a	22.0a	1.2a	1.8a
1300	14.5a	22.5a	1.1ab	1.8a
2600	13.7b	18.0b	0.7d	1.3c
3900	11.5c	16.0c	1.0bc	1.4bc
5200	11.7c	17.0bc	0.9cd	1.5b

Means in each column with different letters are significantly different using Tukey HSD at P≤0.05. WAI: Weeks after inoculation

Table 2: Effects of lantana and mistletoe on the height and stem diameter of *Musa* plants at 5 weeks after inoculation

Treatments	Plant height (cm)	Stem diameter (cm)
Control	14.6d	5.1f
Ethoprofos	18.0a	6.4a
Lantana 4g/plant	15.2c	5.3e
Lantana 16g/plant	15.4c	6.2b
Mistletoe 4g/plant	15.2c	5.6d
Mistletoe 16g/plant	16.6b	5.8c

Means in each column with different letters are significantly different using Tukey HSD at P≤0.05

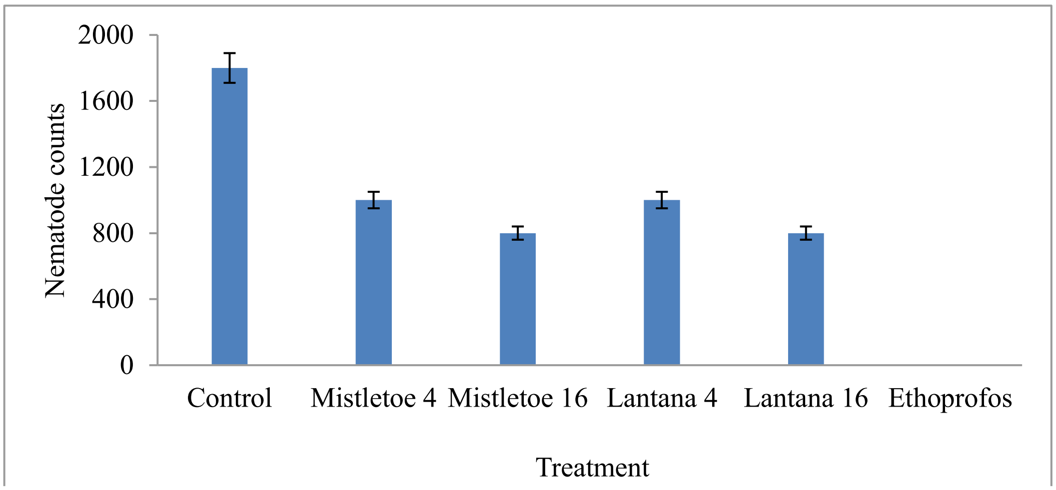

Figure 1: Effects of lantana and mistletoe on the population of M. javanica

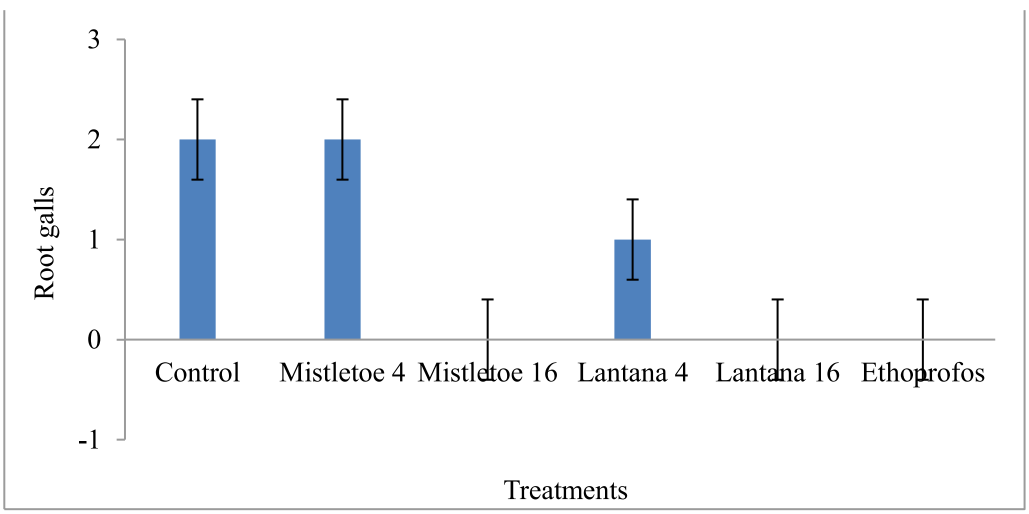

Figure 2: Effects of lantana and mistletoe on root galls

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