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Parasitus fimetorum and Macrocheles muscaedomesticae (Acarina:Parasitidae, Macrochelidae) as Natural Predators of the Root Knot Nematode, *Meloidogyne javanica* Treub

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Abstract

The potential use of two predacious mites, *Parasitus fimetorum* (Berlese 1904) and *Macrocheles muscaedomesticae* (Scopoli 1972), for controlling the root knot nematode, *Meloidogyne javanica* Treub 1885 was evaluated under laboratory and semi-field conditions. Obtained results revealed that the 2 predators significantly reduced the root knot nematode numbers. In addition, the highest reduction percentage (57.24%) in nematode juveniles was recorded at the treatment of (1000 nematode + 10 mites). For *M. muscaedomesticae,* the highest mortality percentage (50.83%) in nematode juveniles was recorded at the treatment of (1000 nematode + 50 mites), followed by (1000 nematodes + 20 mites) 48.88%, while the treatment of (1000 nematode + 10 mites) gave (47.13%). The combination of the 2 mite species (1000 nematodes + 50 mites/species) caused the highest mortality percentages in nematode juveniles (69.29%), followed by (1000 nematodes + 20 mite/species) 50.51% and the treatment of (1000 nematode + 10 mite/species) (37.66%). At the pot experiments, the highest overall mortality percentage in *M. javanica* juveniles was recorded at the treatment of *P. fimetorum* + *M. muscaedomesticae* giving (57.07%), followed by the treatment of *P. fimetorum* (39.17%), and then, by *M. muscaedomesticae* alone that recorded only (17.47%). In conclusion, predacious mites can be partially considered a control tool of the parasitic nematodes.

Keywords: Predaceous mites, *Parasitus fimetorum*, *Macrocheles muscaedomesticae*, Biological control, Plant parasitic nematodes

Background

The root knot nematode, *Meloidogyne javanica* (Treub 1885), is one of the most serious pests, attacking large numbers of field, vegetable, and fruit plants in Egypt. It can be found in all types of soils and cultivated regions of Egypt. The use of chemical compounds for the control of nematodes is costly and negatively affecting the environment as well as human and animal health. Meanwhile, nematodes have a diverse range of natural enemies. Therefore, scientists are constantly exploring other biological control methods, rather than the use of chemical compounds.

Biological control of plant-parasitic nematode using predatory mites has been explored in several countries, especially in protected crops (Carrillo et al. 2015). Cosmopolitan mites of the families Laelapidae, Parasitidae, and Macrochelidae are free-living predators feeding on eggs and immature stages of other soil-inhabiting micro-arthropods and nematodes (Kazemi et al. 2013).

In Egypt, Taha et al. (1988) studied the effect of feeding *Neocunaxoides andrei* (Baker and Hoffmann) on the

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nematode, *Panagrolimaus rigidus* (Schneider 1866) Thorne 1937, on its developmental time and fecundity under laboratory conditions of 30 °C and 70% RH, and found that cunaxids are generalist predators because they feed on diverse prey, such as plant mites and other small arthropods and nematodes. In addition, Walter and Kaplan (1991) found that *Coloscerius simplex* Ewing colonized in greenhouse pot cultures fed on *Meloidogyne* spp. Mostafa et al. (1997) reported that *Lasioseius dentatus* Fox 1946 could develop on *Meloidogyne javanica* egg masses under laboratory conditions. El-Khateeb (1998) reared *Coloscerius aegyptiacus* Gomaa and El-Khateeb on the free living nematode, *Rhabditis* (*Rhabditella*) *muscicola* (Andrássy 1986), while Sholla Salwa (2000) reared *Coloscerius buratus* Den Heyer on the same previous nematode species. El-Hady Mona and El-Naggar (2001) studied the possibility of using the predacious laelapid mites, *Hypoaspis bregetovae* (Shereef and Afifi) and *H. sardous* (Canestrini 1884), as biological control agents of root knot nematode infesting sunflower plants. Maareg et al. (2005) evaluated the potentiality of 7 predacious mite species in feeding on the juveniles of *Meloidogyne incognita* and found that all the tested mites fed successfully on nematode stages except *Cunaxa* sp.

Although the acarina communities in Egyptian soils have not been widely studied, limited information is available on the mesostigmatid fauna. Owing to their numerical importance, the gamasid mites have received more attention than other soil Acari. The majority of these species are predators and found associated with small and immature stages of insects and nematodes inhabiting soil surface (El-Hady Mona and El-Naggar 2001; Mostafa et al. 2013; Carrillo et al. 2015). The natural enemies of plant parasitic nematodes include fungi, bacteria, and predacious invertebrates. These natural enemies of nematodes are often used in agricultural practices to suppress the populations of plant parasites (Kerry and Hominick 2002).

Mostafa et al. (2013) indicated that the type of tested nematode food and temperatures had a slight significant difference on the incubation period of uropodid mite, *Uroobovilla krantzi* Zaher and Afifi (both sexes), when fed on free living and plant parasitic nematodes. However, predacious mites and predacious nematodes can be essential control agents for certain nematodes (Yeates and Wardle 1996). Nevertheless, the practice of using predacious mites as control agents in agriculture is still limited.

The aim of the present work was to study the efficacy of the predatory mites, *P. fimetorum* (Berlese 1904) and *M. muscaedomesticae* (Scopoli 1972), against the root knot nematode, *M. javanica*, under laboratory and greenhouse conditions.

Materials and methods

Root knot nematode culture

Root knot nematode, *M. javanica,* juveniles were obtained from a pure culture reared at the Biological laboratory of Economic Entomology and Agricultural Zoology Department at the Faculty of Agriculture, Menoufia University, Egypt, by incubating egg masses in modified Baermann units. Newly hatched nematode juveniles were used for conducting experiments.

Culture of *Parasitus fimetorum*

The predatory mite, *P. fimetorum*, was collected from soil samples including leaf litter and farmyard manure and extracted by using modified Tullgren funnels for 72 h (Lindquist et al. 1979). The extracted predators were collected in distilled water and then transferred into plastic rearing units (Fouly 1996; Al-Rehiayni and Fouly 2005). Samples were taken from the experimental farm at the Faculty of Agriculture, Menoufia University, Egypt.

Macrocheles muscaedomesticae culture

Predatory mite specimens of *M. muscaedomesticae* were extracted, using Tullgren funnels from a house fly culture reared on artificial diet of 9 g powder milk and 5 g yeast dissolved in 100 ml water, then added to 100 g fine bran (Wilkins and Khalequzzaman 1993). Glass cages (60 × 35 × 40 cm) were used for rearing the house fly under laboratory conditions (25 ± 5 °C, 60 ± 5% RH), and for 12:12 (L:D) (Palacios et al. 2009).

Laboratory experiments

To study the efficacy of both mite species and their potential in feeding on the root knot nematode juveniles, plastic Petri dishes (5 cm) were filled with 50 g pure fine sand to conduct different treatments:

1. First and second experiments were as follows:

- 1000 J2 *M. javanica* + 10, 20, and 50 ind. *P. fimetorum* or *M. muscaedomesticae* (15 dishes)
- 1000 J2 of *M. javanica* only (15 dishes) (control)

Treated dishes were randomized arranged and moistened with 30 ml water every 5 days. Ten days later, 5 dishes from each treatment were examined for mites and nematodes by extraction, using the modified Baermann units and Tullgren funnels. Numbers of juveniles of root knot nematode and mite individuals were counted under dissecting stereomicroscope. The previous step was repeated 20 and 30 days after beginning.

2. Third experiment

It consisted of 60 dishes as follows:

- 1000 J2 *M. javanica* + 10, 20, and 50 ind. *P. fimetorum* + 10 ind. *M. muscaedomesticae* (15 dishes)
- 1000 J2 *M. javanica* only (15 dishes) (control)

Greenhouse experiments

Seventy plastic pots, each contained 2 kg of pure sand soil, were prepared for the following treatments:

- 5000 J2 *M. javanica* + 100 ind. *P. fimetorum, M. muscaedomesticae,* 100 ind. from each species together (10 pots each).
- 100 individuals of *P. fimetorum* and *M. muscaedomesticae* (10 pots)
- 5000 J2 of *M. javanica* only (control) (10 pots)
- Check treatment without any additives (10 pots)

Each pot was transplanted with two tomato seedlings (25 days old) and received the required populations of nematodes and mites as previously mentioned. Pots were randomized and arranged in the greenhouse at 23 ± 2 °C and 65 ± 5% RH. Pots were watered as required and received a standard nutritional solution. Thirty days later, the soils of 5 pots/ treatment were examined for nematode and mites, using the modified Baermann units and Tullgren funnels.

Statistical analysis

Data were analyzed using CoStat Soft Program 6.400 (CoStat version 6.400 Copyright © 2008) and ANOVA test with LSD (5%) and mean ± SD. Mortality percentages were computed according to Abbott's formula (Abbott 1925).

Results and discussion

Laboratory experiments

Efficacy of Parasitus fimetorum against Meloidogyne javanica juveniles

Statistical analysis of the obtained data indicated that there were significant differences in the numbers of nematode juveniles between the treatment with the nematode only (control) and each of the other treatments at the 3 periods of examination. Moreover, there were significant differences in nematodes' population among the 3 rates of the released predatory mite, *P. fimetorum* (Table 1). As shown in the table, there were significant differences between numbers of predatory mites, along experimental sampling, among the 3 ratios of release. Numbers of *P. fimetorum* were relatively low after 30 days at the treatment of (1000 nematodes + 10 mites), while it increased at other treatments.

Mortality percentages in nematode juveniles indicated also that the highest reduction (57.24%) was recorded at the treatment of (1000 nematodes + 10 mites), followed by (53.77%) at (1000 nematode + 50 mites) and then (50.87%) at the treatment of (1000 nematodes + 20 mites).

The previous data revealed that there were significant differences in the activity of the predatory mite species towards the root knot nematode. The results are similar to those reported by Van de Bund (1972) with the predatory mite, *Hypoaspis aculeifer* (Canestrini 1884), which decreased the population of nematode *M. javanica* by 42%.

Table 1 Mean numbers ± SE of *Meloidogyne javanica* juveniles (*M.*) and *P. fimetorum* mite (*P.*) extracted from different treatments and mortality percentages under laboratory conditions

Treatments	Mean numbers ± SE of *M. javanica* juveniles (days post-treatments)		
	10	20	30
M. + *P.* (1000:10)	825.33 ± 36.74b	212.33 ± 1.45c	120.67 ± 1.20c
M. + *P.* (1000:20)	712.00 ± 30.02c	369.33 ± 18.70b	207.00 ± 25.11b
M. + *P.* (1000:50)	656.00 ± 6.11d	377.67 ± 34.72b	151.67 ± 12.02c
Nematode only (1000 J2)	960.67 ± 6.36a	841.00 ± 29.67a	704.33 ± 27.51a
LSD (P = 5%)	110.6	65.6	32.7
	Mean numbers ± SE of *P. fimetorum* mite		
M. + *P.* (1000:10)	7.00 ± 0.58c	6.00 ± 1.16c	6.33 ± 0.67c
M. + *P.* (1000:20)	15.67 ± 1.45b	14.67 ± 0.67b	13.67 ± 0.88b
M. + *P.* (1000:50)	32.33 ± 1.45a	27.00 ± 4.04a	34.00 ± 1.53a
LSD (P = 5%)	2.1	1.8	2.5
	Reduction percentages of *M. javanica* juveniles		
M. + *P.* (1000:10)	14.09	74.75	82.87* (57.24)
M. + *P.* (1000:20)	25.88	56.08	70.61* (50.87)
M. + *P.* (1000:50)	31.71	55.09	74.47* (53.77)

*Numbers between brackets presented overall reduction
Means in each column followed by the same letter(s) are not significantly different at 5% level

Also, Imbriani and Mankau (1983) reported that the predatory mite, *Lasioseius scapulatus* Kennett 1958, drastically reduced the population of *Aphelenchus avenae* Bastian 1865. Chen et al. (2013) stated that the number of *Radopholus similis* (Cobb 1893) Thorne 1949 decreased by (66%) with the predatory mite, *Blattisocius dolichus* (Ma 2006). While the data presented by Dmowska et al. (1997) proved that it was still premature to evaluate the effectiveness of *Parasitus bituberosus* Karg 1972 against rhabditid nematodes because the life table parameters did not seem to be totally convincing.

Efficacy of Macrocheles muscaedomesticae feeding on Meloidogyne javanica juveniles

Data in Table 2 indicated that there were significant differences in numbers of nematode juveniles between the treatments in which the predatory mite, *M. muscaedomesticae*, was released and control at the 3 intervals of examination. Moreover, there were significant differences in nematode population among the 3 rates of the released mite. The obtained data also indicated that there were significant differences in the numbers of *M. muscaedomesticae* mite among the 3 rates of the predator. Mortality percentages of *M. javanica* juveniles presented in Table 2 showed that the highest mortality rate (50.83%) was recorded at the treatment of (1000 nematodes + 50 mites), followed by (48.88%) at (1000 nematodes + 20 mites) and then by (47.13%) at (1000 nematodes + 10 mites).

Obtained results are in agreements with Beaulieu and Weeks (2007) who demonstrated that macrochelid mites have a potential role as biological control agents on vermiform nematodes and organisms. Machrochelidae possess greater predatory potentials, mainly because of their ability to prey a variety of nematodes in large numbers in culture and in experimental dishes (McSorley and Wang 2009).

Moreover, Sholla Salwa and El Kady (2009) reported the feeding capacity of the cunaxid mite *Neocunaxoides andrei* and its feeding capability on *Meloidogyne javanica* under laboratory or semi-field conditions. The female of *Neocunaxoides andrei* consumed 177.2 juveniles (J2s) of *M. javanica* within 5 days under the laboratory conditions, and in addition, the presence of 20, 40, and 60 newly emerged *Neocunaxoides andrei* females together with 500 J2s, *M. javanica*, in pots cultivated with tomato seedlings 15 days old caused a reduction of 59, 74, and 86% of *M. javanica,* respectively.

Recently, Azevedo et al. (2019) recorded *Rhabditella axei Rhabditis* (*Rhabditella*) *axei* (Feng and Li, 1950) as a complementary prey of *Macrocheles embersoni* Azevedo, Berto, and Castilho.

Efficacy of P. fimetorum and M. muscaedomesticae mites in feeding on Meloidogyne javanica juveniles

Statistical analysis of the obtained data indicated that there were significant differences in the numbers of nematode juveniles at the 3 periods of examination between the treatment of nematode only (control) and other treatments of mites releasing (Table 3).

Statistical analysis of the obtained data indicated that there were significant differences in the numbers

Table 2 Mean numbers ± SE of *Meloidogyne javanica* juveniles (*M.*) and *M. muscaedomesticae* mite (*Mac.*) extracted from different treatments and mortality percentages under laboratory conditions

Treatments	Mean numbers ± SE of *M. javanica* juveniles (days post-treatments)		
	10	20	30
M. + *Mac.* (1000:10)	531.33 ± 1.76c	451.67 ± 20.88c	378.33 ± 1.45b
M. + *Mac.* (1000:20)	732.33 ± 33.27b	378.00 ± 10.07d	245.67 ± 10.27c
M. + *Mac.* (1000:50)	632.33 ± 10.75bc	562.00 ± 7.02b	121.67 ± 3.53d
Nematode only (1000 J2)	954.67 ± 6.12a	865.33 ± 2.85a	745.33 ± 5.49a
LSD (P = 5%)	117.8	70.1	38.4
	Mean numbers ± SE of *M. muscaedomesticae*		
M. + *Mac.* (1000:10)	8.00 ± 0.58c	7.00 ± 0.58c	6.33 ± 0.33c
M. + *Mac.* (1000:20)	16.00 ± 1.16b	14.33 ± 1.20b	16.33 ± 0.88b
M. + *Mac.* (1000:50)	44.00 ± 1.53a	40.33 ± 2.91a	39.67 ± 2.03a
Nematode only (1000 J2)	4.1	3.2	2.5
	Reduction percentages of *M. javanica* juveniles		
M. + *Mac.* (1000:10)	44.34	47.80	49.24* (47.13)
M. + *Mac.* (1000:20)	23.29	56.32	67.04* (48.88)
M. + *Mac.* (1000:50)	33.76	35.05	83.68* (50.83)

*Numbers between brackets presented overall reduction
Means in each column followed by the same letter(s) are not significantly different at 5% level

Table 3 Mean numbers ± SE of *M. javanica* juveniles and *P. fimetorum* and *M. muscaedomesticae* mites at different ratios and mortality percentages under laboratory conditions

Treatments	Mean numbers ± SE of *M. javanica* juveniles (days post-treatments)		
	10	20	30
M. + *P.* + *Mac.* (1000:10:10)	708.67 ± 28.69b	583.33 ± 9.82b	304.67 ± 18.82b
M. + *P.* + *Mac.* (1000:20:20)	569.33 ± 5.46c	428.67 ± 9.40c	263.67 ± 9.39c
M. + *P.* + *Mac.* (1000:50:50)	319.33 ± 62.36d	351.0 ± 19.69d	121.67 ± 2.03d
Nematode only	956.00 ± 5.29a	866.33 ± 4.67a	668.67 ± 1.86a
LSD 5%	122.3	75.4	62.3
	Mean numbers ± SE of *P. fimetorum* and *M. muscaedomesticae*		
M. + *P.* + *Mac.* (1000:10:10)	8.67 ± 0.33c 7.67 ± 0.33c	6.67 ± 0.33d 7.00 ± 0.58d	5.67 ± 0.33c 6.00 ± 0.58c
M. + *P.* + *Mac.* (1000:20:20)	15.67 ± 0.88b 14.33 ± 1.20b	14.00 ± 0.58c 9.00 ± 0.58d	11.67 ± 0.88b 7.67 ± 0.88c
M. + *P.* + *Mac.* (1000:50:50)	40 ± 3.06a 43 ± 1.73a	38.67 ± 2.19b 42.67 ± 1.20a	35.67 ± 3.48a 36.33 ± 1.20a
LSD 5%	3.1	2.9	2.7
	Reduction percentages of *M. javanica* juveniles		
M. + *P.* + *Mac.* (1000:10:10)	25.87	32.67	54.44* (37.66)
M. + *P.* + *Mac.* (1000:20:20)	40.45	50.52	60.57* (50.51)
M. + *P.* + *Mac.* (1000:50:50)	66.60	59.48	81.80* (69.29)

*Numbers between brackets presented overall reduction
Means in each column followed by the same letters are not significantly different at 5% level

of the 2 mite species among the 3 rates of the predator (Table 3). The highest mortality percentages in nematode juveniles (69.29%) was recorded at the treatment of (1000 nematodes + 50 mite/species), followed by (50.51%) at (1000 nematodes + 20 mite/species) and (37.66%) at (1000 nematodes + 10 mite/species).

Greenhouse experiments

At the pot experiments in the greenhouse, there were several interactions between the population of predacious mites and nematodes under such semi-field conditions. Tomato seedlings were used during the course of the study. Statistical analysis of the obtained data revealed that there were significant differences in the numbers of nematode juveniles extracted from different treatments, as well as between the 2 periods of examination (Table 4). The highest nematode juvenile numbers were recorded at the treatment of *M. muscaedomesticae* mite, giving 3236 and 4308.67 J2 at 30 and 60 days of nematode inoculation (LSD 5% = 354.2 and 502.4, respectively, followed by the treatment with *P. fimetorum* mite, giving 2264 and 3316 J2 at 30 and 60 days of nematode inoculation (LSD 5% = 354.2 and 502.4), respectively, while the lowest nematode juvenile numbers were found at *M. muscaedomesticae* + *P. fimetorum* mite treatments, giving 1752 and 2162 J2 at 30 and 60 days of nematode inoculation (LSD 5% = 354.2 and 502.4), respectively.

As for the mean numbers of mite species summarized in (Table 5), extracted from tomato soil, 30 and 60 days after planting, results show that there were significant differences in the numbers of mites, as well as between the 2 periods of examination (Table 5).

Data in Table 6 show that the highest overall mortality percentage in *M. javanica* juveniles (57.07%) was recorded at the treatment of *P. fimetorum* and *M. muscaedomesticae,* followed by (39.17%) at the treatment with

Table 4 Mean numbers ± SE of *M. javanica* juveniles extracted from tomato soil at the treatments of 2 mite species, *P. fimetorum* and *M. muscaedomesticae,* under greenhouse conditions

Treatments	Mean numbers ± SE of consumed nematode (juveniles per 2 kg soil)	
	30 days	60 days
M. + *P.* (5000:100)	2264 ± 65.13c	3316 ± 161.39c
M. + *Mac.* (5000:100)	3236 ± 100.06b	4308.67 ± 183.68b
M. + *P.* + *Mac.* (5000:100 + 100)	1752 ± 102.01d	2162 ± 35.04d
M. javanica (control)	4206 ± 61.19a	4889 ± 316.84a
P. fimetorum	0	0
M. muscaedomesticae	0	0
Check	0	0
LSD 5%	354.2	502.4

Means in each column followed by the same letter are not significantly different at 5% level

Table 5 Mean numbers ± SE of the mite species, *P. fimetorum* and *M. muscaedomesticae*, when fed on root knot nematode, *M. javanica* juveniles, extracted from tomato soil under greenhouse conditions

Treatments	Mean no. of mites ± SE/2 kg soil after two intervals	
	30 days	60 days
M. + *P.* (5000:100)	86.67 ± 0.88a	89.00 ± 4.00a
M. + *Mac.* (5000:100)	59.00 ± 1.16c	62. 67 ± 6.49b
M. + *P.* + *Mac.* (5000:100:100)	73.67 ± 4.98b 51.33 ± 4.63d	93.00 ± 2.52a 62.00 ± 4.36b
M. javanica	0	0
P. fimetorum 100	57.33 ± 1.76cd	39.33 ± 0.88c
M. muscaedomesticae 100	41.00 ± 3.22e	32.00 ± 1.16d
Check	0	0
LSD 5%	6.5	6.2

Means in each column followed by the same letter(s) are not significantly different at 5% level

P. fimetorum, while the treatment of *M. muscaedomesticae* recorded only (17.47%).

Results in Table 7 show the average numbers of root knot nematode galls in tomato roots (60 days) at different treatments of predatory mites in comparison with control. The statistical analysis of the data indicated that there were significant differences in gall numbers among treatments.

Results in Table 7 indicated that the highest decrease percentage in root knot nematode galls (56.3%) was recorded at the treatment of *P. fimetorum* and *M. muscaedomesticae* mites, followed by *P. fimetorum (*44.3%), while the least (30%) was obtained at the treatment of *M. muscaedomesticae*. The obtained results are in agreements with (McSorley and Wang 2009) who reported that bioagent treatments reduced numbers of *M. javanica* was greater in tomato soil, especially mites, collembola. Also, Manwaring et al. (2015) stated that *Macrocheles matrius* and *Onychiurus armatus* (collembolan) are known to feed on nematodes and other plant parasites and decrease the root knot nematode galls and egg masses.

Table 6 Reduction percentages of *M javanica* juveniles in tomato soil, consumed by the predatory mites, *P. fimetorum* and *M. muscaedomesticae*, at different rates and periods under greenhouse conditions

Treatments	Reduction (%)		Overall reduction (%)
	30 days	60 days	
M. j. + *P. f.* (5000:100)	46.17	32.17	39.17
M. j. + *M. m.* (5000:100)	23.06	11.87	17.47
M. j. + *P. f.* + *M. m.* (5000:100:100)	58.35	55.78	57.07

Table 7 Average numbers of root knot galls in tomato roots (60 days) at different treatments of predatory mites in comparison with control treatment

Treatments	Average numbers of root knot galls per root	Reduction percentages (%)
M. + *P.* (5000:100)	9.3c	44.3
M. + *M.* (5000:100)	11.7b	30.0
M. + *P.* + *M. m.* (5000:100:100)	7.3c	56.3
M. javanica (control)	16.7a	–
LSD 5%	2.2	

Means in the column followed by the same letter are not significantly different at 5% level

Conclusion

Using combined treatment of two predatory mites, *P. fimetorum* and *M. muscaedomesticae*, showed a high potential in reducing the number of *M. javanica* than using each predatory mite alone. Moreover, the results confirmed that parasitic nematodes can be safely controlled by predacious mites in an attempt to reduce depending upon chemical pesticides.

Abbreviations

P.: Parasitus fimetorum; *Mac.: Macrocheles muscaedomesticae*; *M.: Meloidogyne javanica*

Authors' contributions

The author collected and identified predacious mites and nematode and wrote the manuscript. The author read and approved the final manuscript.

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Availability of data and materials

All data generated and/or analyzed during the present study are available in the manuscript, and the corresponding author has no objection to the availability of data and materials.

Ethics approval and consent to participate

Not applicable. The study was conducted on mites and nematode species that are abundant in the environment and does not require ethical approval.

Consent for publication

The author agrees to publish this paper. The data has not been published in completely or in part in other journal.

Competing interests

The author declares that he has no competing interests.

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