ISSN 1996-403X

Asian Journal of Nematology

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OPEN ACCESS
Asian Journal of Nematology

ISSN 1996-403x
DOI: 10.3923/ajn.2016.1.7

Research Article
Impact of Potassium Silicate Application on *Meloidogyne incognita* Infecting Cucumber Plant under Greenhouse Conditions

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Abstract
Greenhouse experiment was conducted to study the impact of potassium silicate applications by three methods i.e., pre-planting, post planting and foliar spraying accompanied with six times of applying this materials in comparison with oxamyl against *Meloidogyne incognita* on cucumber plant cv. Hybrid Alpha at 23±5°C. Results indicate that all tested methods and times of adding potassium silicate obviously improved plant growth parameters and reduced nematode criteria as well. Among tested applications, foliar spraying of potassium silicate once on cucumber plant infected with *M. incognita* after 7 days of its inoculation overwhelmed other methods and times of application in the increment values of plant length (39.8%), total plant fresh weight (141.0%), shoot dry weight (88.6%) and number of leaves/plant (50.0%) respectively and in suppressing nematode parameters since its values were amounted to 0.2 for rate of reproduction, final population density (93.6%), number of galls (81.0%) and egg masses (95.0%) even that of oxamyl values comparing to the check.

Key words: Cucumber plant, *Meloidogyne incognita*, control, oxamyl, potassium silicate

Received: January 14, 2015 Accepted: April 24, 2015 Published: June 15, 2016

Citation: A.G. El-Sherif, S.B. Gad and S.M. Saadoon, 2016. Impact of Potassium Silicate Application on Meloidogyne Incognita Infecting Cucumber Plant under Greenhouse Conditions. Asian J. Nematol., 5: 1-7.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Root-knot nematodes (*Meloidogyne* spp.) are one of the most wide spread and damaging agricultural pests in the world causing an estimated US $100 billion loss/year worldwide (Oka *et al*., 2000). They were widely distributed in the cultivated areas of Egypt causing remarkable crop losses, particularly with cucumber yields. During the two last decades, nematode control was based mostly on the use of nematicides. However, because of environmental toxicity and cost of these chemicals, other control techniques are of a great goal. Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment and has the added benefit of supplying small amounts of potassium. Potassium silicate reduces levels of *Tylenchulus semipenetrans* in soil (Walker and Morey, 1999). On the other hand, no carcinogenicity, mutagenicity or developmental toxicity data is available for potassium silicate which can be used as an alternative tool to avoid environment pollution from pesticides against nematode.

The objective of the present investigation was to study the impact of method and time of potassium silicate application in comparison with oxamyl on *M. incognita* infecting cucumber under green house conditions (23±5°C).

MATERIALS AND METHODS

Source of nematodes: Second stage juveniles (J2) of *Meloidogyne incognita* (Kofoid and White) Chitwood, were obtained from a pure culture of *M. incognita* that was initiated by a single egg mass propagated on coleus plants, *Coleus blumei* in the greenhouse of Nematology Research Unit, (NERU) Agricultural Zoology Department, Faculty of Agriculture, Mansoura University, Egypt, where this work was carried-out.

Nematicide: Oxamyl (Vydate) 24% L. Methyl-N'N'-dimethyl-N [(methyl) carbamyloxy]-1- thioxamidate, which is used at the rate of 0.3 mL/plant.

Impact of method and time of potassium silicate application in comparison with oxamyl on *M. incognita* infecting cucumber under green house conditions (23±5°C): In order to study the effect of method and time of Potassium silicate application (K_2O_3Si)in comparison with oxamyl on protecting cucumber plant *Cucumis sativus* cv. Hybrid Alpha from *M. incognita* infection under greenhouse conditions at 23±5°C. Forty five plastic pots were filled with 900 g of steam-sterilized sandy: Loam soil (1:1) (v:v) (pot 10 cm-d). Four pots received a dose of 5 g/pot of potassium silicate was separately mixed with soil particles, then watered to keep dose moist and to facilitate proper decomposition of potassium silicate (pre-planting application). One week later, cucumber seeds were sowing in all pots, three for each pot, one week after seedlings were thinned to one plant/pot and potassium silicate (5 g/pot) was added to another five pots and mixed with soil particles (before nematode inoculation). After another week, forty plastic pots were then separately inoculated with 1000 juveniles of *M. incognita* (N), five of the untreated pots received a 0.3 mL/pot of oxamyl (vydate 24% E.C) at the recommended dose. One week after nematode inoculation, another five pots received (5 g/pot) of potassium silicate mixed with soil particles (one week after inoculation application). Seven days after nematode inoculation as post-planting application, untreated fifteen seedlings inoculated with *M. incognita* treating with potassium silicate as foliar spraying (1 g L^{-1} of distilled water) (one time application) and a week later, ten seedlings from them received the same application (two times application). Finally a week later, five seedlings also received the same application (three times application). In addition, five seedlings (pots) with nematode only and other seedlings of cucumber plant were left free of nematode and any application to serve as check (ck). Each treatment was replicated five times. Treatments were as follows:

- Pre-planting application potassium silicate application (5 g/pot as soil amendments) (5 pots)
- Post-planting application
- Week before nematode inoculation (5 g/pot as soil amendments) (5 pots)
- Week after nematode inoculation (5 g/pot as soil amendments) (5 pots)
- Foliar spraying application
- One time foliar spraying, 7 days after nematode inoculation (1 g L^{-1}) (15 pots)
- Two times, two weeks after nematode inoculation (1 g L^{-1}) (10 pots)
- Three times, three weeks after nematode inoculation (1 g L^{-1}) (5 pots)
- Oxamyl (ox) (0.3 mL/pot) (5 pots)
- N alone (5 pots)

Plant free of any treatments and N (5 pots): Pots were irrigated with water as needed, treated horticulturally the same and were arranged in a randomized complete block design in a greenhouse bench at 23±5ºC. During the period of the experiment, plants were protected against mites and insects pests by conventional pesticides. Cucumber plants were harvested after 45 days of nematode inoculation. Plant growth criteria viz., plant length, plant fresh (shoot and root) weights and shoot dry weight as well were measured and recorded. Nematode parameters i.e., number of galls, egg masses, developmental stages and females/root system were also determined by stained infected root system/replicate in lactic acid fuchsin (Bybd Jr *et al*., 1983) and recorded. *Meloidogyne incognita* (J_2s)/pot was also separately extracted from soil of each treatment by sieving and modified Baermann technique (Goodey, 1957). Number of nematode juveniles were determined by Hawksely counting slide under 100X magnification and recorded for each replicate/treatment/plant.

Statistical analysis: Statistically, the obtained data was subjected to analysis of variance (ANOVA) (Gomez and Gomez, 1984) followed by Duncan's multiple ranges to compare means (Duncan, 1955).

RESULTS AND DISCUSSION

Data presented in Table 1 and 2 illustrate the impact of method and time of potassium silicate application in comparison with oxamyl on plant growth response of cucumber plant cv. Hybrid Alpha infected with *M. incognita* and its reproduction, development and population density under greenhouse conditions (23±5°C). In general, results indicated that all tested applications obviously improved plant growth parameters of cucumber plants and significantly diminished nematode criteria as well (Table 1 and 2). Among the tested broadcasting applications, pre-planting application of mixing potassium silicate with soil as soil amendment one week before nematode inoculation surpassed that of post planting application in both cases either before or after nematode inoculation in the increment percentage increase values of plant growth and in suppressing nematode criteria as well since its values recorded to be 32.8, 88.9, 53.2 and 30.0% for plant length, total plant fresh weight, shoot dry weight and number of leaves/plant of cucumber, followed by that of post planting broadcasting application of potassium silicate that added after nematode inoculation by one week comparing to nematode alone. However, plant receiving potassium silicate as post planting broadcasting treatment before nematode inoculation by 7 days, gave the lowest percentage increase values of plant growth parameters comparing to nematode alone. With respect to foliar spraying applications, spraying potassium silicate 7 days after nematode inoculation overwhelmed other foliar spraying of 15 and 21 days tested in percentage increase values of plant length (39.5%), total plant fresh weight (141.0%), shoot dry weight (88.6%) and number of leaves per cucumber plant (50.0%, followed by that of 15 days (twice), whereas, plant receiving three time of foliar spraying potassium silicate gave the least percentage increase values that were amounted to 35.8, 112.3, 84.8 and 50.0% for the same criteria in this respect, however it surpassed values of potassium silicate treatment when used as pre-planting application that were amounted to 32.8, 88.9, 53.2 and 20.0% for the same plant growth parameters comparing to nematode alone, respectively (Table 1). Meanwhile, oxamyl as a systemic nematicide ameliorated plant growth values that averaged 55.0, 91.6, 68.4 and 50.0% for plant length, total plant fresh weight, shoot dry weight and number of leaves/plant, respectively, comparing to nematode alone.

Data presented in Table 2 reveal that all tested treatments showed protection performance in cucumber plant cv. Hybrid Alpha plant against nematode infection in terms of reduction percentage of final nematode population on such host plant, It was clear that nematode population density and rate of nematode reproduction as well were significantly affected by all tested potassium silicate applications. The application of potassium silicate as foliar spraying one time at 7 days after nematode inoculation overwhelmed other tested applications in this work in suppressing nematode population density (93.6%), root galling numbers (81.0%) and egg-masses (95.0%), followed by that of two times foliar spraying treatment with values of 85.6, 81.0 and 95.0% for the same nematode criteria, respectively comparing to nematode alone. Moreover, plant receiving potassium silicate as foliar spraying once after one week of nematode inoculation achieved reduction of nematode parameters values that were on par with that of oxamyl treatment since these values were 0.2 and 0.2, 93.6% and 91.7, 81.0 and 81.0%; 95.0 and 95.0% for reproduction factor, population density, number of galls and egg masses/root, respectively, comparing to nematode alone (Table 2).

It is worthy to note that the addition of potassium silicate (5 g/pot) as pre-planting application gave a considerable percentage reduction values of nematode build up (0.4), final nematode population (83.6%), number of galls (81.0%) and egg masses/root system (95.0%), respectively comparing to nematode alone (Table 2). Moreover, plant receiving none of potassium silicate treatment and free of nematode showed low values of percentage increase of plant growth characters that were amounted to 12.0, 10.0, 9.1 and 8.9% for plant

Table 1: Impact of Potassium silicate application on the growth of cucumber plant (*Cucumis sativus*) infected with *Meloidogyne incognita* under greenhouse conditions at 23±5°C

Treatment		Plant growth response											
		Length (cm)				No. of leaves/		Fresh wt. (g)					
Time of application	Type of application	Shoot	Root	Total plant length (cm)	Inc (%)	plant	Inc (%)	Shoot	Root	Total plant FW (g)	Inc (%)	Shoot DW (g)	Inc (%)
Pre-planting	Broadcasting	42.0^{ab}	15.0^{a}	57.0^{c}	32.1	13.0^{c}	30.0	22.5^{c}	6.6^{b}	29.1^{b}	88.9	12.1^{c}	53.2
Post planting	Broadcasting												
(i) One week before nematode inoculation		40.0^{b}	13.0^{c}	53.0^{d}	27.2	12.0^{d}	20.0	19.9^{g}	4.5^{dc}	24.4^{bc}	58.4	10.6^{g}	34.2
(ii) One week after nematode inoculation		42.0^{ab}	13.0^{c}	55.0^{bc}	29.6	12.0^{d}	20.0	20.4^{f}	4.6^{d}	25.0^{d}	62.3	11.9^{f}	50.6
Foliar spraying	Spraying												
(i) One time at 7 days after nematode inoculation		49.0^{a}	14.0^{b}	63.0^{a}	39.5	15.0^{a}	50.0	30.1^{a}	7.1^{a}	37.10^{a}	141.0	14.9^{a}	88.6
(ii) Two times 7 and 14 days after nematode inoculation		45.0^{ab}	15.0^{a}	60.0^{ab}	35.8	15.0^{a}	50.0	28.0^{b}	4.7^{df}	32.70^{df}	112.3	14.6^{b}	84.8
(iii) Three times 7, 14 and 21 days after nematode inoculation	42.0^{ab}	14.0^{b}	56.0^{b}	30.9	14.0^{b}	40.0	26.0^{c}	5.6^{f}	31.60^{c}	105.2	13.4^{c}	69.6	
Oxamyl (ox)		40.0^{b}	15.0^{a}	55.0^{bc}	29.6	15.0^{a}	50.0	24.5^{d}	5.0^{d}	29.50^{d}	91.6	13.3^{d}	68.4
N alone		20.0^{d}	11.0^{d}	31.0^{f}	-	10.0^{f}	-	11.5^{i}	3.9^{f}	15.40^{f}	-	7.90^{i}	-
Plant free of any treatments and N		31.0^{c}	11.0^{d}	42.0^{e}	13.6	11.0^{e}	10.0	13.8^{n}	3.0^{g}	16.80^{g}	9.1	8.6^{n}	8.90
LSD		1.491	0.872	1.255		0.760		0.651	0.387	0.718		0.424	

N: 1000J2 of *M. incognita*, Each value is the mean of five replicates, Means in each column followed by the same letter (s) are not significantly different ($p<0.05$) by Duncan's multiple range test, FW: Fresh weight, DW: Dry weight

Table 2: Development and reproduction of *M. incognita* infecting cucumber plant (*Cucumis sativus*) controlled by potassium silicate under greenhouse conditions at 23±5°C

Treatment		Nematode population											
			Root										
Time of application	Type of application	Soil/pot	stages	Develop Females	Total (Pf)	RF	Red (%)	No. of galls	Red (%)	RGI	No. of egg masses	Red (%)	EI
Pre-planting	Broadcasting	408.1^{b}	5.2^{d}	5^{b}	418.3	0.4	83.6	12^{c}	81.0	3	2^{c}	95.0	1
Post planting	Broadcasting												
(i) One week before nematode inoculation		650.3^{c}	6.6^{c}	4^{c}	660.9	0.7	74.1	12^{c}	81.0	3	2^{c}	95.0	1
(ii) One week after nematode inoculation		515.5^{e}	4.4^{d}	4^{c}	523.9	0.5	79.5	13^{bc}	79.4	3	3^{b}	92.5	2
Foliar spraying	Spraying												
(i) One time at 7 days after nematode inoculation		142.8^{b}	14.6^{b}	5^{b}	162.4	0.2	93.6	12^{c}	81.0	3	2^{c}	95.0	1
(ii) Two times 7 and 14 days after nematode inoculation		357.1^{i}	5.9^{cd}	5^{b}	368.0	0.4	85.6	12^{c}	81.0	3	2^{b}	95.0	1
(iii) Three times 7, 14 and 21 days after nematode inoculation		765.2^{d}	13.6^{b}	5^{b}	783.8	0.8	69.3	15^{b}	76.2	3	3^{b}	92.5	2
Oxamyl (ox)		208.6^{h}	2.3^{e}	1^{d}	211.9	0.2	91.7	12^{c}	81.0	3	1^{d}	97.5	1
N alone		2442.6^{g}	54.4^{d}	55^{a}	2552.0	2.6	-	63^{a}	-	4	40^{a}	-	4
LSD		0.519	0.612	3.059	2.963			4.412			2.596		

N: 1000J2 of *M. incognita*, Each value is the mean of five replicates, RF: final population (Pf)/initial population (Pi): Reproduction factor, Means in each column followed by the same letter (s) are not significantly different ($p<0.05$) by Duncan's multiple range test, Root gall index (RGI) and egg mass index (EI) was determined and recorded as follows: 0: No galls or egg masses, 1: 1-2 galls or egg masses, 2: 3-10 galls or egg masses, 3: 11-30 galls or egg masses, 4: 31-100 galls or egg masses and 5: more than 100 galls or egg masses, according to the scale given by Taylor and Sasser (1978) length, number of leaves/ plant, total plant fresh weight and shoot dry weight comparing to nematode alone, respectively (Table 1).

Apparently, in the present study, three methods i.e., preplanting, post planting and foliar spraying of potassium silicate applications in comparison with oxamyl showed nematicidal properties against the target pest, *M. incognita* infecting cucumber plant cv. Hybrid Alpha, since all tested applications obviously caused ameliorating plant growth and suppressed nematode criteria as well, respectively. These findings emphasized that the potential potassium silicate that seemed to have higher toxic action. A few reports in literature illustrated the role of potassium silicate in managing plant parasitic nematodes. Foliar applications of potassium silicate showed the reduction of powdery mildew severity and increase chlorophyll content and plant growth in strawberries (Wang and Galletta, 1998). Potassium silicate did not reduce isolation frequency of *Phytophthora nicotiana* and *Pythium ultimum* or root rot, however it did diminish levels of citrus nematode *T. semipenetrans* in soil (Walker and Morey, 1999). Potassium silicate has been used in nutrient solutions to control *Pythium* diseases on tomatoes and cucumbers (Adatia and Besford, 1986). An industry-sponsored study showed a foliar potassium silicate spray provided "good to excellent control" of powdery mildew on wine grapes throughout pre-harvest at 630 ppm SiO_2 and 1260 ppm SiO_2 solutions, applied at 500 L ha^{-1} (McFadden-Smith, 2001). On cucumber plants, silicate fertilizer added at a rate of 700 or 1400 kg SiO_2 ha^{-1} $year^{-1}$ for three years improved plant growth and diminish damage caused by wilt disease (Miyake and Takahashi, 1983). A study showing the uptake of silicate by hydroponic cucumbers gave pronounced resistance to powdery mildew (*Sphaerotheca fuliginea*) when added at 110 mg L^{-1} SiO_2 (Adatia and Besford, 1986). In a greenhouse study, dissolved silicate amendments via drip line diminished damage to cucumbers caused by *Didymelia byronise* (O'Neil, 1991).

According to Guimaraes *et al.* (2008), potassium silicate was effective in inducing sugarcane resistance to *M. incognita*, since it reduced the number of pathogen eggs in the RB867515 and RB92579 varieties. However, it did not affect the aerial part biomass of the RB867515 and RB863129 varieties, nor the population density of *Pratylenchus zeae* Graham in the soil, 100 days after transplanting. Dutra *et al.* (2004) reported a greatest decrease in the number of galls and eggs of a number of *Meloidogyne* species in common bean, tomato and coffee treated with calcium silicate.

CONCLUSION

Finally, the use of potassium silicate as foliar spray application at 1 g L^{-1} either once or twice for one week interval on cucumber plant infected with *M. incognita* resulted in improving plant growth characters and in suppressing nematode criteria much better than other tested applications comparing to nematode alone in this investigation, however more research in this direction is needed before final recommendations can be done.

ACKNOWLEDGMENT

This work is apart of M.sc. Thesis of Saadoom M. Saadoon (Post graduate student) and was supported by a grant from the Government of Iraq. The authors thank the staff members of the Nematology Research Unit (NERU), Agricultural Zoology Department, Faculty of Agriculture, Mansoura University, Egypt for their encouragement to carried-out this work.

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