Research Article

Effect of Certain Insect Growth Regulators for the control of Root Knot Nematode, *Meloidogyne incognita* Infecting Eggplant

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Abstract | Under screenhouse conditions, the experiment was carried out to evaluate the efficacy of four insect growth regulators viz. ,lufenuron at 25,12.5, and 6.25ppm, pyriproxyfen at 25,12.5 and 6.25ppm, spirotetramat at 50,25 and 12.5 ppm and methoxyfenozide at 120,60, and 30 ppm in biocontrolling root- knot nematode, *Meloidogyne incognita* infecting eggplant (*Solanum melongena* L.) cv. Baladi i.e. at the recommended and other two lower concentrations. The tested materials at the highest concentrations were more effective in reducing nematode criteria than the other concentrations compared to untreated control. The moderate and highest concentrations of methoxyfenozide caused the highest percentages of reduction in nematode final population (81.36 and 81.06% respectively) followed by lufeuron, pyriproxyfen and spirotetramat. Plant growth was improved, spirotetramat achieved the highest percentages of increases of root and shoot dry weights.

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Introduction

Root- knot nematodes (*Meloidogyne* spp.) are obligate parasites and very damaging plant pests limiting the vegetable productivity causing from 15 to 60% loss of yield (Krishnappa *et al.*, 1992). Chitin, a polymer of β_1.4-linked N-acetyl-d-glucosamine (GlcNAc) is a constituent of nematodes (Spindler *et al.*, 1990). It is abundant in nature and found in many living organisms and microorganisms including nematodes (Zhang *et al.*, 2005). Chitin is mostly located in eggshells including those of plant and animal parasitic nematodes (Mansfield *et al.*, 1992). The insect growth regulators (IGRs) are considered to be safe for non-target organisms and microorganisms because they mainly harm and disrupt the insect development and physiology or affect the chitinous structure (Mulla *et al.*, 1986; Gurr *et al.*, 1999). Lashein *et al.* (2014) evaluated the effect of flufenoxuron (a chitin synthesis inhibitor compound) against root- knot nematode, *Meloidogyne incognita* which reduced the number of galls, egg masses, females and developmental stages. Also, lufenuron is an effective and selective compound which considered as an inhibitor to chitin formation disrupting the molting process and stop egg hatching. Sabry and Abdou

(2016) reported that lufenuron was tested against the first instar larvae of pink bollworm. Methoxyfenozide acts as an ecdyson (molting hormone) agonist and can be incorporatrd in integrated pest management (IPM) programs (Ahmed *et al*., 2022). Hence, Shah *et al*. (2015) considered it to be eco-friendly compound. Pyriproxyfen is a juvenile hormone (JH) mimic. This compound artificially maintained molting regulation after lowering of natural JH levels; this affected the development of ova and immature stages and finally caused death (Ishaaya and Horowitz, 1995). Suman *et al*. (2013) reported that pyriproxyfen, a juvenile hormone analogue, diflubenzuron, a chitin synthesis inhibitor and azadiractin, an ecdysone agonist are three insect growth regulators which are considered selective and effective insecticides against mosquitoes, which have significant negative impacts on different stages of mosquito mermithid that can imbalance host parasite population interaction. Lashein *et al*. (2014) reported that pyriproxyfen was effective in reducing *M. incognita* criteria. Spirotetramat is systemic and lipid synthesis inhibitor. This compound affected against the immature stages (Nauen *et al*., 2008), and reduced the reproduction and total lipid biosynthesis (Nauen, 2005). It was currently considered as an insecticide but has suppressed nematode populations (McKenry *et al*., 2009, 2010). Vang *et al*. (2016) reported that, spirotetramat consistently reduced *Heterodera glycines* and *M. incognita* development and reproduction with a single application to foliage at 1-2 weeks after nematode inoculation.

The objective of this study aimed to evaluate the possible efficacy of certain insect growth regulators for biocontrolling *Meloidogyne incognita* (Kofoid and white) Chitwood infecting eggplant under screenhouse conditions.

Materials and Methods

Tested chemicals

1. Lufenuron (Match 5% EC) produced by Syngenta, Swaziland. This insecticide acts as a chitin synthesis inhibitor. It acts by preventing and inhibiting of chitin synthesis. Field rate is 200 ml per feddan (4200 m^2).
2. Pyriproxyfen (Admiral 10% EC) produced by Sumitomo Chemical Company. This insecticide acts as juvenile hormone mimic and a potent inhibitor of embryogenesis, metamorphosis and adult formation. Field rate is 100 ml per feddan.
3. Spirotetramat (Movento 10% SC) a lipid synthesis inhibitor produced by Bayer Crop science Pty Lt. Field rate is 200 ml per feddan.
4. Methoxyfenozide (Runner 24% SC) produced by Dow Agro Sciences. This compound acts as ecdysone agonist (antimolting). This disruption of the normal molt cycle prevents the larvae from completely shedding its old cuticle resulting in starvation, dehydration and death within a few days. Field rate is 200 ml per feddan.

Screenhouse trial

Three concentrations were used at all tested compounds, the highest (field rate) and other two lower concentrations as illustrated in Table 1. Fifty day - old seedlings of eggplant (*Solanum melongena* L.) cv. Baladi were transplanted to 10 cm diameter earthen pots filled with 1 kg sandy loam soil (1:1w/w). After seedling establishment in soil, 20 days later, they were treated with the above chemicals. A 50 ml from each concentration was added in each pot separately and a total of 1000 freshly hatched juveniles as inoculum was added at the same time. Pots were arranged in a completely randomized design with four replicates for each treatment, and equal numbers of non-treated replicates served as control. Two months later, plants were uprooted and and plant growth criteria as indicated by shoot and root lengths, fresh and dry weights were recorded. Second stage juveniles (J2s) in soil were extracted by sieving and decanting method (Barker, 1985). Numbers of galls, egg masses, and females were recorded on root system.

Table 1: *The concentrations of the tested compounds.*

Concentrations (ppm)	C1	C2	C3
Lufenuron	25	12.5	6.25
Pyriproxyfen	25	12.5	6.25
Spirotetramat	50	25	12.5
Methoxyfenozide	120	60	30

Statistical analysis

The statistical analysis system was performed by using analysis of variance (ANOVA) test. Differences among groups were determined by Duncan's Multiple Range test. This was carried out by Computer Statistical Package (COSTAT) User Manual Version 3.03, Barkley Co.

Results and Discussion

Impact on nematode population

Data in Table 2 illustrated the influence of the

insect growth regulators, lufenuron, pyriproxyfen, spirotetramat and methoxyfenozide in biocontrolling root-knot nematode, *Meloidogyne incognita* in eggplant cv.Baladi. Generally, the statically analysis revealed that all tested materials significantly (P≤0.05) reduced the numbers of galls, egg masses, females and final nematode population in roots and soil compared to inoculated non treated control. The percentages of reduction in nematode final population were used to compare among the efficacy of treatments. It was obviously noticed that the highest concentration from each material proved to be highly effective in reducing nematode criteria as indicated by numbers of egg masses, females and second stage juveniles in soil and vice versa. The moderate and highest concentrations of methoxyfenozide caused the highest percentages of reductions in nematode final population (81.36 and 81.06%, respectively) followed by other materials. Spirotetramat at the three concentrations caused the least percentages of reduction 62.74, 52.25 and 50.70%, respectively. Number of galls behaved the same trend. The different nematode criteria differed in their response according to the testes materials and their concentrations.

Table 2: *Reduction of root- knot nematode, Meloidogyne incognita on eggplant as influenced by four insect growth regulators.*

Treatments	Dilution (ppm)	No. of nematode parameters/pot									
		No. of Galls	% Red.	Egg masses	% Red.	Females	% Red.	Second stage juveniles (J2s) in soil	% Red.	Final nematode population	% Red.
Lufeuron	25	382 g	58.30	366 f	59.96	474 h	60.66	126 g	89.87	966 h	71.28
	12.5	407 f	55.57	414 d	54.70	562 cd	53.36	160 f	87.14	1136 g	66.22
	6.25	475 cd	48.14	453 c	50.44	571 c	52.61	420 b	66.24	1444 c	57.06
Pyriproxyfen	25	438 e	52.18	390 e	57.33	490 g	59.34	69 i	94.45	949 i	71.78
	12.5	444 e	51.53	447 c	51.09	524 e	56.51	87 i	93.01	1058 h	68.54
	6.25	458 de	50.00	451 c	50.66	555 d	53.94	156 f	87.46	1162 g	65.45
Spirotetramat	50	486 c	46.94	408 d	55.36	531 e	55.93	314 d	74.76	1253 e	62.74
	25	633 b	30.90	580 b	36.54	705 b	41.49	321 d	74.20	1606 d	52.25
	12.5	620 b	32.31	572 b	37.42	710 b	41.08	376 c	69.77	1658 b	50.70
Methoxyfenozid	120	285 h	68.89	252 g	72.43	316 i	73.78	69 i	94.45	637 k	81.06
	60	287 h	68.67	244 g	73.30	293 j	75.68	90 hi	92.77	627 j	81.36
	30	401 fg	56.22	417 d	54.38	503 f	58.26	258 e	79.26	1178 f	64.97
Untreated control		916 a	-	914 a	-	1205a	-	1244 a	-	3363 a	-

-Values in each column are averages of four replicate. -In each column, averages with the same letter(s) are not significantly different according to Duncan's Multiple Range Test at the probability p≤0.05.-Red. = Reduction.

Table 3: *Growth parameters of eggplant as affected by using four insect growth regulators for biocontrolling root- knot nematode, Meloidogyne incognita.*

Treatments	Dilutions (ppm)	Length (cm)				Fresh weight (g)				Dry weight (g)				% Total percentages of increase	% average total percentages of plant growth Inc.
		Root	% Inc.	Shoot	% Inc.	Root	% Inc.	Shoot	% Inc.	Root	% Inc.	Shoot	% Inc.		
Lufeuron	25	36 a	9.09	35 ab	6.06	11.9 bc	26.60	11.4 de	8.57	1.3 ab	8.33	3.4 ab	61.90	120.55	20.09
	12.5	37 a	12.12	36 ab	9.09	12.3 bc	30.85	16.5 ab	57.14	1.4 ab	16.67	3.3 ab	57.14	183.01	30.50
	6.25	36 a	9.09	41 a	24.24	13.0 bc	38.30	14.4 bc	37.14	1.3 ab	8.33	3.5 ab	66.67	183.77	30.63
Pyriproxyfen	25	34 a	3.03	37 ab	12.12	8.6 de	-	10.1 e	-	1.0 b	-	2.8 ab	33.33	48.48	8.08
	12.5	39 a	18.18	37 ab	12.12	13.0 bc	38.30	14.6 bc	39.05	1.4 ab	16.67	3.1 ab	47.62	171.94	28.66
	6.25	38 a	15.15	38 ab	15.15	12.2 bc	29.79	11.6 de	10.48	1.7 ab	41.67	3.0 ab	42.86	155.10	25.85
Spirotetramat	50	35 a	6.06	35 ab	6.06	12.1 bc	28.72	13.2 cd	25.71	1.6 ab	33.33	3.7 ab	76.19	176.07	29.35
	25	36 a	9.09	40 ab	21.21	18.6 a	97.87	19.1 a	81.90	2.1 a	75.00	4.1 a	95.24	380.31	63.39
	12,5	37 a	12.12	38 ab	15.15	15.1 b	60.64	15.0 bc	42.86	1.6 ab	33.33	3.9 ab	85.71	249.81	41.64
Methoxyfenozid	120	35 a	6.06	34 bc	3.03	7.7 e	-	10.1 e	-	1.1 ab	-	2.1 d	-	9.09	1.52
	60	36 a	9.09	36 ab	9.09	11.9 bc	26.90	10.9 e	3.81	1.3 ab	8.33	2.7 bc	28.57	85.79	14.30
	30	39 a	18.18	34 bc	3.03	11.5 bc	22.34	11.7 de	7.62	1.3 ab	8.33	2.3 cd	9.52	69.02	11.50
Untreated control	-	33 a	-	33 c	-	9.4 cd	-	10.5 e	-	1.2 ab	-	2.1 d	-	-	-

-Values in each column are averages of four replicates. In each column, averages with the same letter(s) are not significantly different according to Duncan's Multiple Range Test at the probability p≤0.05.- Inc.= Increase.

Impact on plant growth

As for the studied plant growth criteria (Table 3), it was noticed the tested substances significantly ($p \leq 0.05$) increased shoot and root lengths, fresh and dry weights as determined by average total percentages of plant growth increases. These increases were positively proportional to the moderate concentration followed by the least one from each material. However, the highest concentrations caused the least increases in such criteria. Methoxyfenozid and pyriproxyfen caused the least increases by their highest concentrations compared to lufeuron and pyriproxyfen. On the other hand, spirotetramat at the three concentrations achieved the highest percentages of increases of root and shoot dry weights and average percentages of total increases (Table 3).

In this study, the growth regulators inhibited nematode parameters as evidenced by numbers of egg masses, females and juveniles in soil and number of galls on roots which were compared on the basis of the percentages of reduction in nematode final population per pot at harvest stage. The reduction in nematode population by lufeuron may be referred to that this substance performed as developmental insecticide and had larvicidal effects (Sabry and Abdou, 2016).The effect of pyriproxyfen in reducing nematode population may be due to that it acts as juvenile hormone mimic and a potent inhibitor of development and adult formation which agreed with the previous study by Lashein *et al.* (2014). Spirotetramat performed against the immature stages (Nauen *et al.* 2008), and reduced the reproduction and total lipid biosynthesis (Nauen, 2005). It was currently considered as an insecticide, but has also been proved to inhibit nematode populations (McKenry *et al.*, 2009, 2010). Vang *et al.* (2016) reported that, Spirotetramat consistently reduced *Heterodera glycines* and *Meloidogyne incognita* development and reproduction by using single application to foliage at 1-2 weeks after nematode inoculation. Also, reduction occurred in nematode population by methoxyfenozid may be interpreted on the basis that this substance performs as antimolting agent causing disruption of the normal molt cycle and stops the larvae from completely removing its old cuticle resulting in starvation, dehydration and death within a few days (Ahmed *et al.*, 2022). The present research proved also that the tested insect growth regulators may inhibit egg formation through inhibiting cuticle structure in egg shell which agreed with Veech (1977).

Conclusions and Recommendations

The tested insect growth regulators proved to be inhibitors against nematode parameters as evidenced by the reduction in numbers of egg masses, females and juveniles in soil and number of galls on roots, as they had larvicidal effects and reduced embryology, reproduction and fecundity of root-knot nematode, *M. incognita* and enhanced plant growth criteria.

Novelty Statement

This method is considered a new approach for controlling root-knot nematode. The mode of action of the tested substances may depend mainly upon interfering and disrupting the development and physiology of the tested nematode or affecting its chitinous structure. Therefore, this method could be incorporated in Integrated Pest Management Program (IPM).

Author's Contribution

AMSL and A-KHS were equal in designing and carrying out the experiment. MMAY collected the necessary literature and wrote the manuscript. All authors reviewed and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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