The Pharma Innovation Journal 2022; 11(3): 1347-1351

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 1347-1351

www.thepharmajournal.com
Received: 10-01-2022
Accepted: 18-02-2022

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Evaluation of selected Nematicides for *Meloidogyne incognita* on cucumber

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Abstract
The root-knot nematode is particularly difficult to manage because of high susceptibility of all commercial cucumber cultivars. Synthetic pesticides still constitute an integral part of conventional agricultural systems, compared to pesticides of biological origin or bio-pesticides. But, their use is not yet that extensive and a conclusion cannot be drawn as far as their efficacy is concerned on a large scale. So, growers have conventionally relied on nematicides applications to control root knot nematode. The experiment was conducted, in which three nematicides; Basamid, Formalin, Triazophos with three different concentrations for each were examined for their efficacy in reducing gall severity and soil nematode population and improving growth of cucumber along with control and Carbofuran was used as treated check. This experiment was conducted in pots as well as in infested seed beds. Basamid @ 40 g/sqm was found to be most effective in management of root knot nematode followed by application of Formalin @ 3%. The roots of cucumber were healthy and growth parameters were increased in this treatment. Results of this study will provide guidance for improving nematicides efficiencies in soil against root-knot nematode.

Keywords: Root knot nematode, cucumber, Nematicide, Basamid

1. Introduction
Plant parasitic nematodes are one of the most dangerous pests of cultivated crops and are responsible for an average annual loss of 12.3% in the world's major crops (Kshetrimayum *et al*., 2018) [9]. Internationally, root knot nematodes have been causes severe yield losses in abundant crops due to their ability to invade several of crop species (Kayani *et al*., 2017) [8]. They cause damage by direct feeding and by inducing large galls throughout the root system of infected plants. Their infestation can alter the uptake of water and nutrients interfere with translocation of photosynthates (Davis *et al*. 2003) and increase the incidence and severity of other soil borne pathogens, i.e. *Fusarium oxysporum* f. sp. *Radicis-Cucumerinum* diseases (Vakalounakis 1999) [17].
Cucumber (*Cucumis sativus*) is an important vegetable crop cultivated in India. Most cucurbits are extremely susceptible to root nematodes. Root- knot nematodes are one of the limiting factors in cultivated crops like fig, pomegranate, carrot, pigeon pea, cucumber and cotton in Maharashtra causing considerable yield losses (Lavhe *et al*., 2019) [10]. Individually, cucumber being susceptible is attacked by root-knot nematode (*Meloidogyne incognita*). The incidence of *M. incognita* in Punjab (Pakistan) was recently quantified at 58 per cent with a gall severity rating of 8.5 out of 9, causing 25 per cent annual yield loss for cucumber plants in open fields (Anwar and McKenry 2010) [1]. Losses up to 33 per cent due to root-knot nematodes have been estimated in cucumber by Sasser (1979) [15]. About 88 per cent yield losses due to root-knot nematode have been observed under protected cultivation (Giné *et al*. 2014) [17].
Management of root-knot nematode, therefore, becomes vital for sustaining the production of cucumber. Numerous agricultural practices have been tested against root-knot nematodes (Collange *et al*., 2011) [4]. But they are not much effective against pathogen. An actual approach toward control of root-knot nematode (RKN) is given by the use of nematicides (Giacometti *et al*., 2010, Nicolopoulou-Stamati *et al*., 2016) [4, 13]. The use of pesticides to specifically control nematode infestations in crops dates back at least as far as the 1850s, when carbon disulfide was used to fumigate vineyard soils in France (SC Gad, 2014). During the last 50 years, many new nematicidal compounds have been introduced, and are a ubiquitous part of agriculture the world over. Following developments in synthetic chemistry and demonstrable crop yield improvements from the use of certain pesticides, new compounds became available.

Therefore the studies were conducted to evaluate some nematicides for the management of root-knot nematode in cucumber.

2. Material and Methods

Nematode Inoculation

Infested plants from a pure culture maintained in pot house and research field, Department of Plant Pathology, Punjab Agricultural University Ludhiana were uprooted, their roots were gently washed water. After washing the roots, egg masses were removed and placed in Petri plate having water for hatching second stage juvenile. After 24 hours, the hatched larvae were used for further inoculations. Before inoculations, the juvenile's number per ml of suspension was counted by taking an average of at least three counts. The juvenile levels were adjusted with water to add an equal volume of nematode suspension in each experiment for further experimentation whenever necessary.

2.1 Evaluation of chemicals against root-knot nematodes

The studies on effect of chemicals root knot nematode population in cucumber was studied in pot house and research field, Department of Plant Pathology, PAU, Ludhiana. This experiment was conducted in pots as well as in infested seed beds. For the pot experiment, earthen pots of 15 cm diameter were filled with known initial population and for the field experiment; seed beds of 2 sqm with known initial population were made. The treatments with different chemicals were done in pots as well as in seed beds, 15 days before transplanting as per dosages given below. The detail of treatments for experiments was as T-I: Soil application with Basamid @ 20 g/sqm, T-2: Soil application with Basamid @ 30 g/sqm, T-3: Soil application with Basamid @ 40 g/sqm, T-4: Soil drenching with Formalin @ 1%, T-5: Soil drenching with Formalin @ 2%, T-6: Soil drenching with Formalin @ 3%, T-7: Soil drenching with Triazophos 0.1%, T-8: Soil drenching with Triazophos 0.5%, T-9: Soil drenching with Triazophos 1.0%, T-10: Soil application with Carbofuran @ 2.0 kg a.i./ha (Treated check), and T-11: Control.

Observations were recorded after 60 days on soil nematode population/250 cc soil as per modified Cobb's sieving and decanting method (Cobb 1918 and Schnidler 1961) [3]. After uprooting and washing, the roots of each plant was spread on paper and was graded for root gall index (RGI) based on the per cent root system galled by using a 0-10 scale (Bridge and Page, 1980) [2]. The reproduction factor (Rf) was calculated by dividing the final population (Pf) by the initial one (Pi). Observations on growth parameters were recorded immediately after uprooting the plants. To remove the soil and adhering inert material, the roots were washed. Excess water from the root surface was removed by placing the root between the blotting papers, and then fresh root weight and shoot weight were taken with the help of an electronic balance. Root portion from the shoot portion was separated by cut with a blade, then the length of the main root was measured up to the growing point, and shoot length was measured from the soil surface to the growing bud with the help of scale observations were recorded. The per cent increases and reductions in these variables were calculated over control as described below

% Reduction/Increase = (Treatment/Control-1) x 100

Statistical analysis: The data (values obtained for soil nematode population, and root gall index), were confirmed to meet the statistical assumptions of normality and homogeneity of variances (one way ANOVA), and were submitted to analysis of variance and the means compared by Duncan's Multiple Range Test using software R-studio software.

3. Results and Discussion

3.1 Effect of different chemicals on root knot nematode infestation and growth parameter of cucumber (Pot Experiment 2016)

The results from Table 1 showed effect of different chemicals was significantly different on *Meloidogyne incognita* population and root gall index in cucumber. In the pot experiment, amongst all the treatments, Basamid @ 40 g/sqm was found to be most effective where 80 percent reduction in soil nematode population and 65.18 percent reduction in root gall index were observed over control. Soil nematode population (136 nem/250 cc soil) and root gall index (2.67) was observed very low in this treatment. Application of Basamid @ 30 g/sqm was observed to be significantly at par with application of Formalin @ 3% while both these treatments were significantly different from application of Basamid @ 40 g/sqm. Reduction in root gall index was observed to be more than 40 percent in both the treatments i.e. Basamid @ 30 g/sqm and Formalin @ 3%. Root knot nematode population was also observed to decrease in lower doses of Basamid and Formalin i.e. Basamid @ 20 g/sqm and Formalin @ 1% and 2%. However, in these treatments, comparatively less reduction in nematode population was observed as compared to treatments T_3 and T_6,

Table 1: Effect of different chemicals on soil nematode population and root gall index of *Meloidogyne incognita* in cucumber crop

Treatments	Pot Experiment 2016					Field Experiment 2017				
	Soil nematode population/ 250cc	Per cent Reduction	Reproduction Factor ($Rf=P_f/P_i$)	RGI	Per cent Reduction	Soil nematode population/ 250cc	Per cent Reduction	Reproduction Factor ($Rf=P_f/P_i$)	RGI	Per cent Reduction
T-I: Basamid @ 20 g/sqm	316^{h}	53.65	1.25	5.00^{de}	34.81	533^{f}	34.69	2.16	6.00^{f}	30.79
T-2: Basamid@ 30 g/sqm	250^{i}	63.41	0.98	4.33^{e}	43.54	450^{i}	44.89	1.82	5.00^{g}	42.32
T-3: Basamid@ 40 g/sqm	136^{j}	80.00	0.65	2.67^{f}	65.18	233^{k}	71.44	1.35	3.33^{i}	61.59
T-4: Formalin @ 1%	416^{e}	39.02	1.64	6.33^{bc}	17.47	583^{d}	28.57	2.36	7.33^{c}	15.45
T-5: Formalin @ 2%	383^{f}	43.90	1.51	5.67^{cd}	26.07	466^{h}	42.85	1.89	6.00^{f}	30.79
T-6: Formalin @ 3%	233^{i}	65.85	0.92	4.33^{e}	43.54	400^{j}	51.02	1.62	4.67^{h}	46.13
T-7: Triazophos 0.1%	566^{b}	17.07	2.23	7.00^{ab}	8.73	633^{b}	22.44	2.56	7.67^{b}	11.53
T-8: Triazophos 0.5%	533^{c}	21.95	2.10	6.67^{b}	13.03	616^{c}	24.48	2.50	7.00^{d}	19.26
T-9: Triazophos 1.0%	466^{d}	31.70	1.84	5.33^{d}	30.50	550^{e}	32.65	2.22	6.33^{e}	26.98
T-10: Carbofuran @ 2.0 kg	350^{g}	48.78	1.38	7.00^{ab}	8.73	483^{g}	40.81	1.95	7.33^{c}	15.45

A.I./ha										
T-11: Control	683[a]			7.67[a]		816[a]			8.67[a]	

* The values following the same letter are not significantly different according to Duncan's Multiple Range Test
Initial population- 253.33nem/250 cc soil (Pot Experiment 2016)
Initial population- 246.66nem/250 cc soil (Field Experiment 2017)

Minimum reduction in soil nematode population and root gall index was observed to be 17.07 percent and 8.73 percent respectively when soil was treated with Triazophos @ 0.1%. Soil nematode population was observed to be 566 nem/ 250 cc soil and root gall index was 7.0 in this treatment. Multiplication of nematode was observed to be higher (2.23) in this treatment. Maximum soil nematode population was observed to be 683 nem/250 cc soil in untreated soil (control) and severe galling on the roots of cucumber plants was found in control showing root gall index 7.67.

Growth parameters root length, shoot length and shoot weight of cucumber were significantly higher in treated pots as compared to control. Maximum increase in growth parameter shoot length, root length and shoot weight was observed in application of Basamid @ 40 g/sqm. Growths parameters shoot length, root length and shoot weight were observed to be 200 cm (Fig. 1a), 13 cm (Fig. 1b) and 48.10 g (Fig. 2a), respectively in T_3 treatment. Among these treatments, minimum shoot length and weight and root length was observed in Triazophos @ 0.1%. Shoot length was observed to be effected by Triazophos @ 1.0%. Roots of the cucumber plants were observed to be healthier in Basamid treated pots than roots of untreated pots (control). Though the weight of the roots higher in untreated soil, this was probably due to the heavy galls on cucumber roots which led to increase in root weight.

3.2 Effect of different chemicals on root knot nematode infestation and growth parameter of cucumber (Field Experiment 2017): Effect of different chemicals was also studied in field conditions. Trails were conducted in infested field. Data in Table 1 revealed that different chemicals had significant effect on soil nematode population of root knot nematode and root gall index. Maximum decrease in nematode population in soil was observed in Basamid @ 40 g/sqm. Nematode infestation was observed to reduce by more than 60 percent in soil and roots of cucumber in plots of this treatment followed by application of Formalin @ 3%. Use of Formalin @ 2% was found to be less effective (42.85 percent) then Basamid @ 30 g/sqm.

Soil nematode population was observed to be 816 nem/ 250 cc soil in control and root gall index was observed to be 8.67 in control. 59.18 percent reduction in soil nematode population and 61.59 percent reduction in root gall index were observed when soil was treated with Basamid @ 40 g/sqm followed by 51.02 percent reduction in soil nematode population and 46.13 percent reduction in root gall index was observed when soil was treated with Formalin @ 3%. Application of Triazophos 0.1% was found to be least effective against root knot nematode population showing 22.44 percent reduction in soil nematode population and 11.53 percent reduction root gall index.

Shoot length and weight and root length was observed to be maximum in Basamid @ 40 g/sqm treated plots. Growth parameters also increase significantly with application of Formalin @ 3% was also found to be effective against root knot nematode showing shoot length 189.33 cm, root length 19.33 cm and shoot weight 50.74 g.

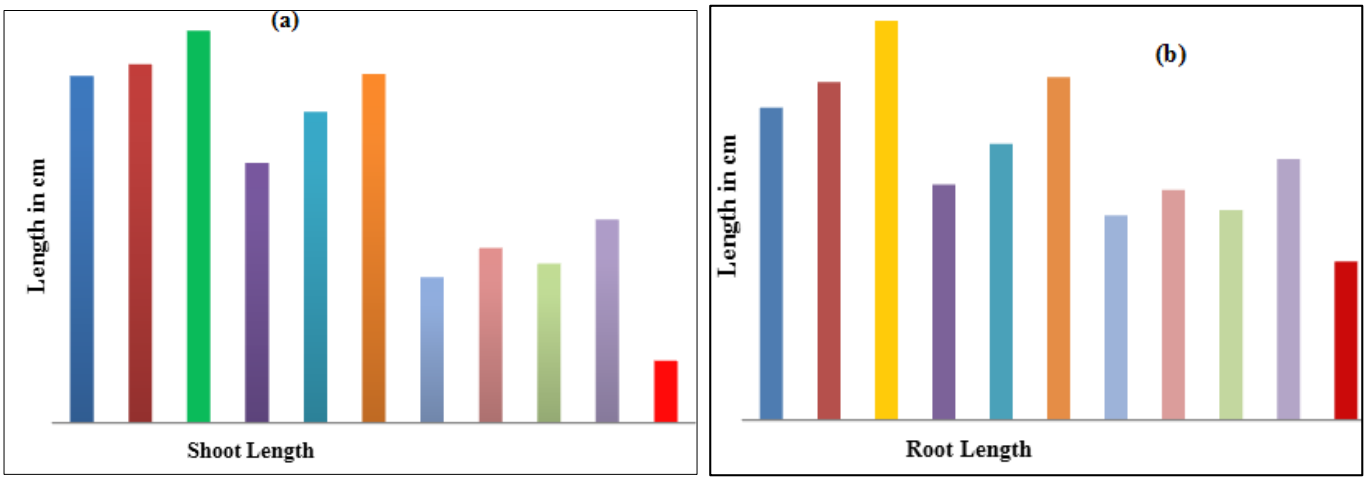

Fig 1: Effect of different chemicals on (a) shoot length and (b) root length of cucumber plants (Pot experiment 2016)

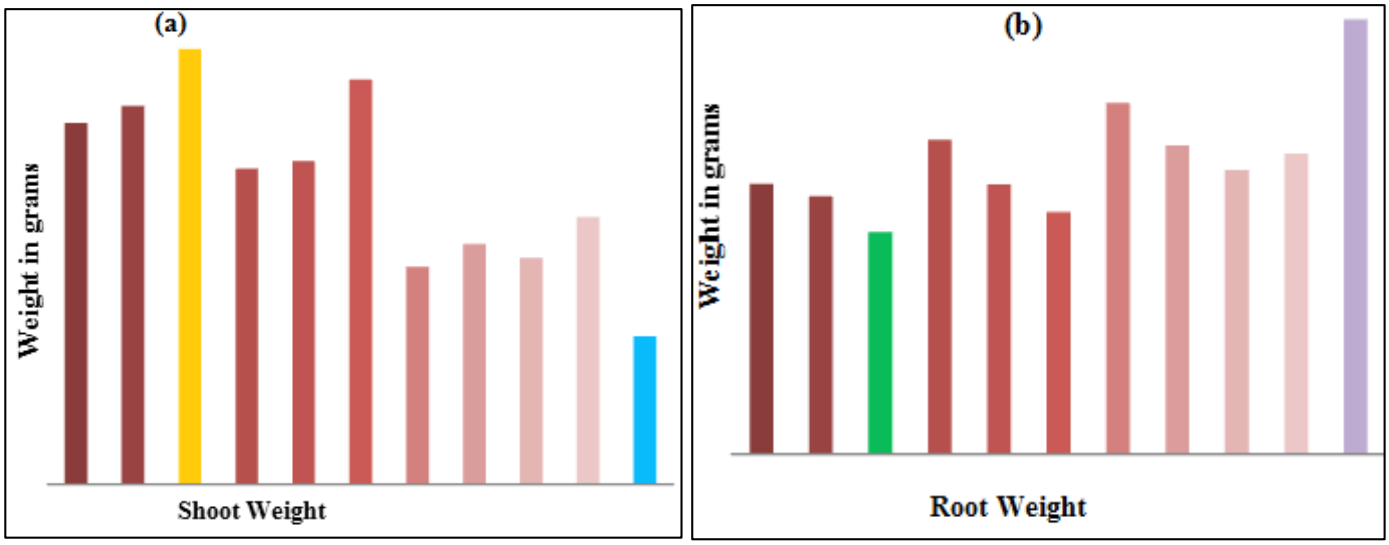

Fig 2: Effect of different chemicals on (a) shoot weight and (b) root weight of cucumber plants (Pot experiment 2016)

4. Discussion

The present studies revealed that soil application of chemicals significantly affected nematode population and growth parameters. Of the three chemical evaluated of different concentration, Basamid @ 40 g/sqm was observed to be most effective in reducing nematode populations in soil as well as in roots of cucumber. Manzoor Hussain *et al*. (2017) [8] studied the effect the chemical nematicides Vydate, Basamid (G) and fertilizer calcium cyanamide for the control of root knot nematode, *Meloidogyne hapla*, through greenhouse conditions. He observed that Basamid was found to be effective in significantly reducing nematode infestation levels in soil compared to an untreated control. Dazomet has been reported to be a successful multi-fumigant which decomposes into methyl isothiocyanate, formaldehyde, hydrogen sulfide and methylamine and these byproducts reduce nematode density and gall and egg mass indices (Roberts and Hutson 1999) [14]. Basamid (active ingredient: Dazomet) sterilizes the soil and kill the nematodes through gaseous degradation. Mehar *et al*. (2010) reported that spray application of Triazophos (Hostathion 40 EC) was found to be effective against *M. incognita* and *R. reniformis* infesting chickpea and tomato. Reduction in soil nematode population observed was 31-61 percent in chickpea and 31-66 percent in tomato. However in the present studies Triazophos was not found to be effective in reduction of root knot nematode population.

5. Conclusion

The present studies revealed that application of Basamid @ 40 g/sqm can be explored further for management of root knot nematode in cucumber and other crops.

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