Evaluation of some chemical nematicides against Reniform nematode (*Rotylenchulus reniformis*) on tomato (*Solanum lycopersicum* L.)

Abstract: Investigations were carried out to evaluate the efficacy of two chemical viz., Nimitz®(Fluensulfone) and Velum Prime (Fluopyrum) for the management of Reniform nematode (*R. reniformis*) on tomato (var. Pusa Ruby) under net house condition. All the treatments with chemicals showed efficacy against reniform nematodes as compared to control. The plant growth parameters in tomato were found to be maximum in the treatment with Nimitz® @2.5kg/ha followed by, Carbofuran CG @3.0 kg a.i./ha, Velum Prime @1000 ml/ha, Nimitz® @2.00 kg/ha , and Velum Prime @750 ml/ha. The chemicals suppressed nematode reproduction as indicated by the lower nematode population and lower numbers of eggs on the roots as compared to control. The minimum populations of *R. reniformis* were recorded with the treatment Nimitz® @2.5kg/ha followed by Carbofuran CG @3.0 kg a.i./ha, Velum Prime @1000 ml/ha, Nimitz® @2.00 kg/ha , and Velum Prime @750 ml/ha.

Key words: Plant-parasitic nematode, Reniform nematode, Horticultural crops, Tomato, Reniform nematode (*Rotylenchulus reniformis*), Management, Chemical nematicides, Nimitz® (Fluensulfone), Velum Prime (Fluopyrum)

INTRODUCTION

Horticultural crops play a major role in nutritional and food security. Tomato is an important horticultural crop having high nutritive value as minerals, vitamin A, vitamin C and anti-oxidant. Tomato is grown all over the world in temperate, subtropical and tropical areas. But the production is vulnerable by several biotic and abiotic factors. Among biotic factors plant-parasitic nematodes are considered as one of the most important plant pathogens. Plant parasitic nematodes often interact with fungal, bacterial and viral pathogens to cause disease complexes. The Reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira, 1940), is one of the most important plant-parasitic nematodes in the world (Robinson *et al*.,1997; Jones *et al*.,2013). In low population densities between 0.1 to 5 nematodes / cm^3 of soil can cause yield suppression (Gaur and Perry, 1991). Nematicides and crop rotation are some of the management measures of *R.reniformis.* The objective of the study was to evaluate some of the new nematicides to determine their potential to reduce the *R.reniformis* population and enhance tomato growth under net house condition.

MATERIALS AND METHODS

The pot experiment was carried on for evaluation of chemical nematicides against reniform nematode (*R. reniformis*) on tomato (Var. Pusa Ruby) during the Kharif season (June 2023-August 2023) in the net house of Department of Nematology, Assam Agricultural University, Jorhat in 26°47 North latitude to 94º12 East longitude and 86.8 meter above sea level. The laboratory investigation was conducted in the Post Graduate Laboratory of Department of Nematology, Assam Agricultural University, Jorhat. Seeds of tomato (Var. Pusa Ruby) were surface sterilized before sowing. In each pot, 3 seeds were sown at the depth of 5-6 cm which contains sterilized soil. Seedlings were thinned out after one week of germination keeping only one healthy seedling in each pot. The nematode inoculums was quantified using the Magnüs microscope and standardized to apply at pathogenic level (1000 vermiform life stages) per 3ml of water. After inoculation the plants were treated with the nematicides. Treatment Carbofuran CG @ 3.0 kg a.i./ha as soil application was included for comparison. Three inoculated plants were left without adding treatments to serve as control.The treatments were as follows:

Treatments	**Method of application**
T1: Velum Prime (Fluopyrum 34.48% Sc) @ 250 ml/ha	Soil drench
T2: Velum Prime (Fluopyrum 34.48% Sc) @ 500 ml/ha	Soil drench
T3: Velum Prime (Fluopyrum 34.48% Sc) @ 750 ml/ha	Soil drench
T4: Velum Prime (Fluopyrum 34.48% Sc) @ 1000 ml/ha	Soil drench
T5: Nimitz® (Fluensulfone 2% Gr) @ 0.5 kg/ha	Soil application
T6: Nimitz® (Fluensulfone 2% Gr) @1.0 kg/ha	Soil application
T7: Nimitz® (Fluensulfone 2% Gr) @ 2.0 kg/ha	Soil application
T8: Nimitz® (Fluensulfone 2% Gr) @ 2.5 kg/ha	Soil application
T9: Carbofuran 3% CG@ 3.0 kg a.i./ha	Soil application
T10: Control	

The experiment was laid out in Completely Randomize Design (CRD) with 3 replications. Observations were taken at 60 days after planting. Potted plants were uprooted with tap water very carefully and slowly remove the adhering soil particles from the root system. Shoot length, root length, fresh and dry weight of shoot and root, number of females and eggmasses per root system, larval population (250 cc of soil), total nematode population, and reproductive rate were recorded. For recording the dry weight of shoot and root materials were packed in a paper bags labeled and dried at 30-35°C and were weighed .The experimental data obtained were analysed by following the Fisher's method of Analysis of Variance (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

The data (Table 1.) revealed that all the chemical treatments increased plant growth parameters significantly over untreated control. Maximum shoot as well as root length was recorded in the treatment with Nimitz® (Fluensulfone) @ 2.5 kg/ha and in the treatment with Carbofuran CG @3.0 kg a.i./ha followed by Velum Prime (Fluopyrum) @ 1000 ml/ha, Nimitz® (Fluensulfone) @ 2.0 kg/ha , Velum prime (Fluopyrum) @ 750 ml/ha, whereas minimum shoot length and root length was recorded in untreated control. However, no significant difference in shoot length were recorded in treatments with Nimitz® (Fluensulfone) @ 2.5 kg/ha, Carbofuran CG @3.0 kg a.i./ha ,Velum Prime (Fluopyrum) @ 1000 ml/ha, Nimitz® (Fluensulfone)@ 2.0 kg/ha ,and Velum prime (Fluopyrum)@ 750 ml/ha. The mean data on the fresh and dry weight of shoot and root recorded with different treatments revealed the fresh weight of shoot and root showed significant increase in all chemical treatments as compared to untreated control. The maximum fresh weight of shoot and root was recorded in the treatment with Nimitz® (Fulensulfone) @ 2.5 kg/ha , followed Carbofuran CG @ 3.0 kg a.i./ha, Velum Prime (Fluopyrum) @1000 ml/ha, Nimitz® (Fluensulfone) @2.00 kg/ha , Velum Prime (Fluopyrum) @750 ml/ha, whereas minimum fresh weight of shoot and root was recorded in untreated control. The dry weight of shoot and root recorded in all the treatments differed significantly from untreated control. The mean data (Table 2) on the number of females per root system recorded in different treatments revealed the females per root system produced by *Rotylenchulus reniformis* on tomato (Fig.1) decreased significantly in all treatments as compared to untreated control. The minimum number of females (12.00) was recorded in the treatment with Nimitz® (Fluensulfone) @2.5kg/ha, followed by 2.33 with the treatment Carbofuran CG @3.0 kg a.i./ha, 12.66 in the treatment with Velum Prime (Fluopyrum) @1000 ml/ha, 13.33 in the treatment with Nimitz® Fluensulfone @2.00 kg/ha, 13.00 in the treatment with Velum Prime (Fluopyrum) @750 ml/ha, while the maximum number of females was recorded in untreated control. The mean data on the number of egg masses per root system recorded in different treatments revealed the number of egg masses per root system produced by *Rotylenchulus reniformis* on tomato decreased significantly in all treatments when compared to untreated control. The minimum number of egg masses was recorded in the treatment with Nimitz® (Fluensulfone) @2.5kg/ha followed by Carbofuran CG @3.0 kg a.i./ha, Velum Prime (Fluopyrum) @1000 ml/ha, Nimitz® (Fluensulfone) @2.00 kg/ha, Velum Prime (Fluopyrum) @750 ml/ha, while maximum number of egg masses was recorded in untreated control The data on the mean of larval population recorded in different treatments revealed the number of egg masses per root system produced by *Rotylenchulus reniformis* on tomato decreased significantly in all treatments when compared to untreated control. The minimum number of larval population was recorded in the treatment with Nimitz® (Fluensulfone) @2.5kg/ha and in the treatment with Carbofuran CG @3.0 kg a.i./ha followed by Velum Prime (Fluopyrum) @1000 ml/ha, Nimitz® (Fluensulfone) @2.00 kg/ha, Velum Prime (Fluopyrum) @750 ml/ha, wherein maximum number of larval population was recorded in untreated control The data on mean of final nematode population recorded in different treatments revealed the total number of *Rotylenchulus reniformis* nematode population recorded in all the treatments differed significantly when compared to untreated control. The minimum number of females was recorded in the treatment with Nimitz® (Fluensulfone) @2.5kg/ha followed by Carbofuran CG @3.0 kg a.i./ha, Velum Prime (Fluopyrum) @1000 ml/ha, Nimitz® (Fluensulfone) @2.00 kg/ha, Velum Prime (Fluopyrum) @750 ml/ha, while low nematode population was recorded in untreated control. The data on the mean of the reproductive rate recorded in different treatments showed that all the treatments reduced the reproduction rate of *R. reniformis* on tomato significantly. All the treatments with chemicals differed significantly from the untreated control. The minimum reproductive rate (1.03) was recorded in treatment with Nimitz® (Fluensulfone) @2.5kg/ha followed by, 1.09 in the treatment with Carbofuran CG

@3.0 kg a.i./ha, (1.10) in treatment with Velum Prime (Fluopyrum) @1000 ml/ha, and (1.10) in treatment with Nimitz® (Fluensulfone) @2.00 kg/ha, (1.11) in treatment with Velum Prime (Fluopyrum) @750 ml/ha. The untreated control had the maximum reproductive rate(7.89).This study revealed that both the chemical has detrimental effects on *R. reniformis* population development. The chemicals suppressed nematode reproduction as indicated by the lower nematode population and lower numbers of eggs found on the roots of tomato as compared to control. As there is no significant difference among the treatment Nimitz® (Fluensulfone) @2.5kg/ha, Velum Prime (Fluopyrum) @1000 ml/ha, Nimitz® (Fluensulfone) @2.00 kg/ha, Velum Prime (Fluopyrum) @750 ml/ha, Carbofuran CG @3.0 kg a.i./ha, therefore it can be inferred that Nimitz® @ 2.0 kg/ha or the Velum prime @ 750 ml/ha are the best treatment against *R.reniformis* and cost effective ,can be recommended as an alternative to Carbofuran CG in tomato. Fluopyram has been tested against *R.reniformis* under *in vitro* condition, where it had nematistatic effects and reduced *R.reniformis* viability on tomato in greenhouse assay (Faske and Hurd, 2015). Fluopyram efficacy can be observed by managing *R.reniformis* egg populations in roots at 25-44 days after planting and increasing yield (Lawrence *et al*., 2016). The concentration of fluopyram needed to cause paralysis and inhibit infection of *M. incognita* and *R. reniformis* on tomato was low (Faske and Hurd, 2015). Heald, (1978) observed 15% increase in tomato yield with application of nematicides in nematode infested field. Fensulfothion, aldicarb, carbofuran, turbufos, phorate etc., have been reported to be effective as soil treatments against reniform nematodes on tomato (Reddy and Seshadri, 1972; Krishna *et al*., 1977; Heald and Thames, 1982). Fluopyram applied at 249g a.i./ha two weeks after tomatoes were inoculated with *M. incognita* eggs, reduced the number of eggs per gram of root by 91% compared with the untreated control, demonstrating the importance of application timing. Similarly, Jones *et al*., (2017) observed the efficacy of both Fluopyram and Fluensulfone against *M. incognita* in lima bean with reduced galling 55 and 64% in greenhouse as well as microplot. Fluensulfone at 2.34 L a.i./ha was the most effective against *M. incognita* with 81% reduction in galling on lima beans (Hajihassani *et al*., 2019). Thoden and Wiles, (2019) and Wram and Zasada, (2019) in a greenhouse study on *M. incognita* on tomato cultivars observed that Fluensulfone suppressed *M. incognita* reproduction more than fluopyram at concentrations ranging from labeled rates to 24-hr sublethal pre-exposure doses. The nematicidal effect of Fluopyram has also been observed for multiple nematodes (Beeman and Tylka, 2018; Faske and Hurd, 2015; Kim et al., 2016; Roper, 2017;Feist et al., 2020;Storelli et al.,2020). Exposure to fluopyram for 1 hr at the rate 1.3 and 3.3 ug/ml for *M. incognita* and *R. reniformis* reduced reproduction of nematodes on tomato (Wram and Zasada, 2019). Fluopyram was found to reduce the number of free-living nematodes for a long period (up to 238 days after application), especially bacterivores, fungivores, and omnivores (Moreira and Desaeger, 2019; Waldo et al., 2019). Fluensulfone (Nimitz®, Adama) is a systemic fluoroalkenyl compound for use in vegetable crops (EPA, 2014). The mode-of-action of Fluensulfone is that it is a fatty acid beta oxidation inhibitor. Kearn *et al*., (2014) observed immobility and eventual death *Caenorhabditis elegans* and *M. incognita*. *Globodera pallida* second-stage juveniles (J2) exposed o Fluensulfone led to increased lipid content, loss of cell viability, and tissue degeneration and reduced stylet thrusting , reduced mobility along with coiling posture but not seen in adult and dauer *C. elegans* (Kearn *et al*., 2017). Fluensulfone at 25 ppm impacted *M. incognita* J2 activity after 24 hr exposure, and egg hatch was reduced at 95 ppm (Moreira and Desaeger, 2019; Wram and Zasada, 2019). Exposing *M. javanica* J2 to Fluensulfone at sublethal concentrations for 17 hr was able to reduce the number of J2 attracted to lettuce root tips in pluronic agar and those that invaded produced smaller galls (Oka and Saroya, 2019). *Aphelenchoides besseyi* and *A. fragariae* which had 50% immobility after 48 hr of exposure. More than 60% of *Pratylenchus penetrans* and *P. thornei* were immobilized after exposure to Fluensulfone at 4 mg/L and found to be immobilized even after removal of the compound (Oka, 2014). *Xiphinema* index was also affected irreversibly by exposure to Fluensulfone at 1 mg/L with 60% immobility after 48 hr of exposure and a 24 hr rinse (Oka, 2014).

Fig.1. Mature female of Reniform nematode on tomato root

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Table 1. Effect of different treatments on the plant growth parameters of tomato infected by *Rotylenchulus reniformis*

(Mean of 3 replications)

Treatments	Shoot length (cm)	Fresh wt. of shoot(g)	Dry wt. of shoot (g)	Root length (cm)	Fresh wt. of root (g)	Dry wt. of root (g)
T1: Velum Prime @ 250 ml/ha	38.63^{c}	19.33^{c}	5.76^{c}	9.33^{c}	6.23^{c}	1.30^{c}
T2: Velum Prime @ 500	43.50^{b}	20.26^{bc}	5.90^{b}	10.60^{b}	7.50^{b}	2.60^{b}

ml /ha						
T3: Velum prime @ 750 ml/ha	54.00^{a}	23.63^{a}	7.60^{a}	11.60^{a}	8.50^{a}	3.60^{a}
T4: Velum Prime @ 1000 ml/ha	54.53^{a}	24.03^{a}	7.70^{a}	11.70^{a}	8.60 ^{a}	3.70^{a}
T5:Nimitz® @ 0.5 kg/ha	39.00^{c}	19.46^{bc}	5.90^{c}	9.56^{c}	6.46^{c}	1.56^{c}
T6: Nimitz® @ 1.0 kg/ha	44.83^{b}	21.13^{b}	6.66^{b}	10.66^{b}	7.56^{b}	2.66^{b}
T7:Nimitz® @ 2.0 kg/ha	54.50^{a}	23.81^{a}	7.66^{a}	11.63^{a}	8.53^{a}	3.66^{a}
T8:Nimitz® @ 2.5 kg/ha	55.33^{a}	25.36^{a}	7.80^{a}	11.80^{a}	8.70^{a}	3.80^{a}
T9: Carbofuran 3%CG @3.0kg a.i./ha	55.33^{a}	25.23^{a}	7.76^{a}	11.76^{a}	8.66^{a}	3.76^{a}
T10: Control	33.63^{d}	17.06^{d}	4.63^{d}	7.53^{d}	5.53^{d}	1.00^{d}
S.Ed. (±)	1.53	0.83	0.13	0.13	0.12	0.12
C.D (P=0.05)	3.23	1.73	0.27	0.29	0.26	0.27

*Mean followed by the same letter in the superscript(s) statistically *at par.*

Table 2. Effect of different treatments on number of females, egg masses and nematode population of *Rotylenchulus. reniformis* on tomato (Mean of 3 replications)

Treatments	No. of females/root system	No. of egg masses/root system	Larval population/200 cc of soil	Total population/ 1 kg soil	RR%

22.66		18.66 (4.32)^{b}	253.00 (15.90)^{b}	1314.33	1.30^{bc}
T1: Velum Prime @ 250 ml/ha		16.33 (4.03)^{cd}	237.33 (15.39)^{c}		1.21^{bcd}
	(4.75)b	8.00 (2.82)^{e} 7.66	220.33 (14.84)^{e}	1208.00	1.11^{bc}
19.33		(2.76)^{e} 18.33	219.66 (14.82)^{e}		1.10^{cde}
T2: Velum Prime @ 500 ml /ha		(4.28)^{bc} 16.00	249.66 (15.80)^{b}	1122.33	1.29^{bc}
	(4.39)cd	(3.99)^{d} 8.33	233.00 (15.26)^{cd}		1.19^{bcd}
13.00		(2.88)^{e} 7.00	221.33 (14.87)^{e}	1108.66	1.10^{cde}
T3: Velum prime @ 750 ml/ha		(2.64)^{e} 7.33	219.00 (14.79^{e}		1.03^{cde}
	(3.60)e	(2.70)^{e} 35.00	219.33 (14.81)^{e}	1293.33	1.09^{cde}
12.66		(5.91)^{a}	1466.33		7.86^{a}
T4: Velum Prime @ 1000 ml/ha			(38.28)^{a}	1197.66	
	(3.55)e				
20.66				1109.66	
T5:Nimitz® @ 0.5 kg/ha	(4.54)bc				
17.66				1040.33	
T6: Nimitz® @ 1.0 kg/ha	(4.20)d				
13.33				1098.66	
T7:Nimitz® @ 2.0 kg/ha	(3.64)e				
12.00				7868.33	
T8:Nimitz® @ 2.5 kg/ha	(3.46)e				
12.33					
T9: Carbofuran 3%CG @3.0kg a.i./ha					
	(3.51)e				
35.66					
T10: Control	(5.97)a				
S.Ed. (±)	0.15	0.11	0.19	0.79	0.06
C.D(P=0.00)	0.31	0.24	0.41	1.67	0.12

Values of number of females, egg masses, larval population and total population within the parentheses are square root ($\sqrt{x} + 0.5$) transformed data. Mean followed by the same letter in the superscript (s) are statistically *at par*