International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 1145-1150

Received: 26-11-2018
Accepted: 30-12-2018

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Evaluation of new molecules against thrips of capsicum under protected cultivation

Sruthi Mirala and JB Gopali

Abstract
The experiment was conducted to evaluate some newer molecules against capsicum thrips, *Scirtothrips dorsalis* Hood under polyhouse condition. Among the evaluated insecticides thiamethoxam 25 WG at 0.20 g per litre found to be superior and reduced the thrips population with maximum yield (47.8 t /ha) and net returns (Rs. 1863700/ha) with highest B:C ratio (2.86) suggesting thiamethoxam 25 WG is cost effective and economically feasible.

Keywords: capsicum thrips, *Scirtothrips dorsalis*, new molecules

Introduction
Capsicum (*Capsicum annum* var *grossum.* Sendt.) is one of the major vegetable crop more particularly grown in polyhouse, which belongs to the family Solanaceae with chromosome number 2n=24. Capsicum is also known as sweet pepper, bell pepper or shimla mirch. It is a rich source of Vitamin A (8493IU), Vitamin C (283 mg) and minerals like Calcium (13.4 mg), Magnesium (14.9 mg), Phosphorus (28.3 mg) and Potassium (263.7 mg) per 100 g fresh weight.

One of the important limiting factors in the cultivation of capsicum is damage caused by pests. Butani (1976) [3] reported over 20 insect species on chillies (*Capsicum* spp.) from India of which thrips, *Scirtothrips dorsalis* Hood and mite, *Polyphagotarsonemus latus* Banks are the most damaging pests (Ananthakrishnan, 1971 Kumar 1995 and Moorthy *et al*., 2013) [1, 9, 14]. Quantitative yield loss is to an extent of 11-32% where as quality loss is 88-92% (Kumar, 1995) [9]. Reddy and Kumar (2006a) [16] estimated crop loss of 40 to 60 tons per ha of capsicum when the crop was not subjected to insecticidal control. The conventional insecticides like organophosphates and carbamates were extensively used to control these pests which resulted in development of resistance to the most of the common insecticides used in capsicum ecosystem, besides several hazards like elimination of natural fauna, resurgence and residues. In this contest, the newer molecules are used at lowest dosage with highest efficacy compared to the conventional insecticides in reducing the pesticide load on the environment and in the fruits. In this background, new molecules were evaluated against the sucking pest complex under protected cultivation. Hence, from the present investigation, these new molecules are going to reduce the frequency of sprays, toxic load to the environment with least pesticide residues and more effective management practices that can be adaptable as they are economical and easily acceptable by the farmers.

Material and Methods
Layout of the experiment
The experiment was laid out in a Randomized Block Design (RBD) in a polyhouse with ten treatments including untreated control were replicated thrice. The size of each treatment was 4m x 1m length and breadth. The bed was 16 m length, 100 cm width and 15 - 22 cm height. Between the beds working space of 75 cm was provided. A popular capsicum hybrid, *Indus* (Indus Pvt. Ltd.,) was selected for the study.

Experimentation on thrips
The first spray was imposed against the thrips as per the treatments mentioned in the Table 1, when the pest population reached the Economic threshold levels (ETL - two thrips/leaf).

Sprays were taken up using high volume knapsack sprayer. Totally, five rounds of sprays were imposed against thrips and two rounds of acaricides *viz*., spiromesifen 240 SC at 1.0 ml per litre and another spray of Vertimec 1.9 EC at 0.5 ml per litre were imposed as common sprays to combat the mite population.

Observations on thrips

Both nymphs and adult population were counted on top three young leaves from five randomly selected plants. The thrips were directly counted using 10 x magnification lens in the polyhouse. The observations thus recorded on one day before spray and one, three, seven and fourteen days after each spray entered into computer for computing average number of thrips population per plant, square root transformations and subjected to statistical analysis for ANOVA and DMRT using statistical software (WASP).

Leaf curl index

Five plants were randomly selected and visually rated for thrips damage based on upward leaf curling. The rating was recorded at 30 days intervals with visual symptoms on leaves using 0-4 scale rating as per the standard procedure (Niles, 1980) [15]. Totally five observations were made during the peak activity of population after transplanting. The data were subjected to statistical analysis.

Standard scoring procedure for leaf curl index (LCI) thrips and mites

LCI score on 0-4 scale	Symptoms
0	No symptoms
1	1-25 percent leaves/plant show curling, less damage
2	26-50 percent leaves/plant show curling and moderately damaged
3	51-75 percent leaves/plant show curling, heavily damaged, malformation of growing points and reduction in plant height
4	>75 percent leaves/plant show curling, severe and complete destruction of growing points and drastic reduction in plant height and severe malformation

(Niles, 1980) [15]

Criteria for evaluation

The per cent reduction in fruit damage (PRFD) over control and per cent increase in yield over control were calculated by using following formulae.

$$PRFD = \frac{FDUP - FDTP}{FDUP} \times 100$$

Where,

FDTP = Fruits Damage in Treated Plot, FDUP = Fruits Damage in Untreated Plot

$$\text{Increase in yield (\%)} = \frac{T - U}{T} \times 100$$

Where,

T = Treated plot yield, U = Untreated plot yield

Fresh fruit yield

Totally nine pickings of green capsicum was performed during 2017-18 *Kharif and Rabi* season. The total fruit yield from each plot was taken and expressed in terms of fresh fruit yield per hectare basis and subjected for statistical analysis.

Cost economics

The fruit yield per plot was recorded and computed to quintal or ton per hectare. The data thus tabulated, pooled and ranked on the basis of their yield performance. The benefit cost ratio (B:C ratio) of different treatments was worked out by estimating different cost of cultivation and return from fruit yield after converting them to one hectare basis. The average market price of green capsicum was rupees 60 per kg during the experimentation. The following formulae were used for calculation of B:C ratio.

1. Gross return = Yield x Market price of fresh green capsicum (Rs. 6000/q)
2. Net Returns = Gross Return - Total Cost
3. B:C ratio = Gross Return / Total Cost

Statistical analysis

The data on mean population of sucking pests were transformed to √x+1 and per cent damage was transformed to arcsine transformation and then subjected to ANOVA using M-STATC ® software package. The treatment effect was compared by following Duncan's Multiple Range Test (DMRT).

Table 1: Efficacy of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation (First Spray)

Treatments	Dosage (per litre)	Mean number of thrips per leaf											
		Precount		1 DAS		3 DAS		7 DAS		14 DAS		Mean	
T1 - Imidacloprid 17.8 SL	0.3 ml	2.89	(1.84)^{a}	1.84	(1.53)^{b}	1.01	(1.23)^{b}	0.47	(0.98)^{ab}	0.29	(0.89)^{a}	0.90	(1.16)^{b}
T2 - Thiamethoxam 25 WG	0.2 g	2.73	(1.80)^{a}	0.97	(1.21)^{a}	0.48	(0.99)^{a}	0.29	(0.89)^{a}	0.24	(0.86)^{a}	0.50	(0.99)^{a}
T3 - Thiacloprid 21.7 SC	0.2 ml	2.52	(1.74)^{a}	1.85	(1.53)^{b}	1.03	(1.24)^{b}	0.50	(1.00)^{b}	0.35	(0.92)^{a}	0.93	(1.17)^{b}
T4 - Cyantraniliprole 10 OD	1.5 g	2.61	(1.76)^{a}	1.02	(1.23)^{c}	0.49	(0.99)^{a}	0.31	(0.90)^{a}	0.23	(0.85)^{a}	0.51	(1.00)^{a}
T5 - Dimethoate 30 EC	1.7 ml	2.90	(1.84)^{a}	1.54	(1.43)^{b}	1.14	(1.28)^{b}	0.79	(1.14)^{c}	0.36	(0.93)^{a}	0.96	(1.19)^{b}
T6 - Fipronil 5 SC	1.0 ml	2.79	(1.81)^{a}	1.64	(1.46)^{b}	0.92	(1.19)^{b}	0.42	(0.96)^{ab}	0.24	(0.86)^{a}	0.80	(1.12)^{b}
T7 - *L. lecanii* ($1x10^{8}$ CFU/g)	5.0 g	2.65	(1.77)^{a}	2.53	(1.74)^{c}	2.01	(1.58)^{c}	1.10	(1.26)^{d}	0.63	(1.06)^{b}	1.57	(1.41)^{c}
T8 - Azadirachtin 10000 ppm	1.0 ml	2.75	(1.80)^{a}	2.64	(1.77)^{c}	1.85	(1.53)^{c}	1.17	(1.29)^{d}	0.69	(1.09)^{b}	1.59	(1.42)^{c}
T9 - *L.lecanii*+ Azadirachtin	5.0g+1.0ml	2.78	(1.81)^{a}	1.56	(1.44)^{b}	0.86	(1.17)^{b}	0.39	(0.94)^{ab}	0.26	(0.87)^{a}	0.77	(1.10)^{b}
T10 - Untreated check	---	2.80	(1.82)^{a}	3.21	(1.93)^{d}	3.43	(1.98)^{d}	3.74	(2.06)^{ce}	4.19	(2.16)^{c}	3.64	(2.03)^{d}
S. Em ±		NS		0.05		0.04		0.03		0.03		0.04	
C.D. at 5%		---		0.15		0.12		0.10		0.09		0.11	

DAS: Days After Spraying. Figures in the parenthesis are √x + 0.5 transformed values

In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 2: Efficacy of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation (Second Spray)

Treatments	Dosage (per litre)	Mean number of thrips per leaf											
		Precount		1 DAS		3 DAS		7 DAS		14 DAS		Mean	
T1 - Imidacloprid 17.8 SL	0.3 ml	2.73	(1.80)^{a}	1.78	(1.51)^{ab}	1.47	(1.40)^{bc}	0.83	(1.15)^{bc}	0.48	(0.99)^{bc}	1.14	(1.26)^{bc}
T2 - Thiamethoxam 25 WG	0.2 g	2.98	(1.87)^{a}	1.44	(1.39)^{a}	0.89	(1.18)^{a}	0.51	(1.00)^{a}	0.21	(0.84)^{a}	0.76	(1.11)^{a}
T3 - Thiacloprid 21.7 SC	0.2 ml	3.04	(1.88)^{a}	1.82	(1.52)^{ab}	0.91	(1.19)^{a}	0.90	(1.19)^{bc}	0.51	(1.01)^{c}	1.04	(1.23)^{ab}
T4 - Cyantraniliprole 10 OD	1.5 g	2.93	(1.85)^{a}	1.44	(1.39)^{a}	0.70	(1.09)^{a}	0.52	(1.01)^{a}	0.32	(0.90)^{ab}	0.74	(1.10)^{a}
T5 - Dimethoate 30 EC	1.7 ml	2.67	(1.78)^{a}	2.12	(1.62)^{bc}	1.95	(1.57)^{de}	1.36	(1.36)^{d}	0.93	(1.20)^{d}	1.59	(1.44)^{d}
T6 - Fipronil 5 SC	1.0 ml	2.91	(1.85)^{a}	1.84	(1.53)^{ab}	1.45	(1.40)^{bc}	0.71	(1.10)^{ab}	0.41	(0.95)^{bc}	1.10	(1.25)^{bc}
T7 -*L. lecanii* (1x10^{8} CFU/g)	5.0 g	3.02	(1.88)^{a}	2.58	(1.75)^{c}	1.30	(1.34)^{b}	0.94	(1.20)^{bc}	0.92	(1.19)^{d}	1.43	(1.37)^{cd}
T8 -Azadirachtin10000ppm	1.0 ml	3.39	(1.97)^{a}	2.60	(1.76)^{c}	2.33	(1.68)^{e}	1.02	(1.23)^{c}	0.96	(1.21)^{d}	1.73	(1.47)^{d}
T9- *L.lecanii*+ Azadirachtin	5.0g+1.0ml	3.41	(1.98)^{a}	2.02	(1.59)^{b}	1.73	(1.49)^{cd}	1.46	(1.40)^{d}	0.91	(1.19)^{d}	1.53	(1.42)^{d}
T10 - Untreated check	---	3.11	(1.90)^{a}	3.26	(1.94)^{d}	2.92	(1.85)^{f}	2.51	(1.73)^{e}	2.36	(1.69)^{e}	2.76	(1.80)^{e}
S. Em ±		NS		0.05		0.05		0.04		0.03		0.04	
C.D. at 5%		---		0.16		0.14		0.11		0.09		0.13	

DAS: Days After Spraying. Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 3: Efficacy of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation (Third Spray)

Treatments	Dosage (per litre)	Mean number of thrips per leaf											
		Pre count		1 DAS		3 DAS		7 DAS		14 DAS		Mean	
T1 - Imidacloprid 17.8 SL	0.3 ml	1.98	(1.57)^{a}	1.73	(1.49)^{d}	0.91	(1.19)^{de}	0.83	(1.15)^{de}	0.78	(1.13)^{f}	1.06	(1.24)^{ef}
T2 - Thiamethoxam 25 WG	0.2 g	1.03	(1.24)^{a}	0.24	(0.86)^{a}	0.14	(0.80)^{a}	0.12	(0.79)^{a}	0.11	(0.78)^{a}	0.15	(0.81)^{a}
T3 - Thiacloprid 21.7 SC	0.2 ml	1.09	(1.26)^{a}	0.77	(1.13)^{b}	0.55	(1.02)^{bc}	0.39	(0.95)^{b}	0.34	(0.91)^{cd}	0.51	(1.00)^{bc}
T4 - Cyantraniliprole 10 OD	1.5 g	1.95	(1.56)^{a}	0.24	(0.86)^{a}	0.14	(0.80)^{a}	0.14	(0.80)^{a}	0.11	(0.78)^{ab}	0.16	(0.81)^{a}
T5 - Dimethoate 30 EC	1.7 ml	1.72	(1.49)^{a}	1.23	(1.31)^{c}	0.91	(1.19)^{de}	0.79	(1.14)^{de}	0.71	(1.10)^{ef}	0.91	(1.18)^{de}
T6 - Fipronil 5 SC	1.0 ml	1.86	(1.54)^{a}	0.59	(1.05)^{b}	0.43	(0.97)^{b}	0.27	(0.88)^{b}	0.23	(0.85)^{bc}	0.38	(0.94)^{b}
T7 - *L. lecanii* (1x108 CFU/g)	5.0 g	2.56	(1.75)^{a}	2.32	(1.68)^{ef}	1.23	(1.31)^{f}	0.90	(1.18)^{e}	0.73	(1.11)^{ef}	1.30	(1.32)^{f}
T8 - Azadirachtin 10000ppm	1.0 ml	2.37	(1.69)^{a}	2.08	(1.61)^{e}	0.95	(1.21)^{e}	0.70	(1.10)^{cd}	0.58	(1.04)^{e}	1.08	(1.24)^{ef}
T9 - *L.lecanii*+ Azadirachtin	5.0g+1.0ml	2.41	(1.71)^{a}	1.13	(1.28)^{c}	0.72	(1.11)^{cd}	0.58	(1.04)^{c}	0.43	(0.96)^{d}	0.72	(1.10)^{cd}
T10 - Untreated check	---	2.67	(1.78)^{a}	2.63	(1.77)^{f}	2.54	(1.74)^{g}	1.96	(1.57)^{f}	1.68	(1.48)^{g}	2.20	(1.64)^{g}
S. Em ±		NS		0.04		0.03		0.03		0.02		0.04	
C.D. at 5%		----		0.11		0.09		0.08		0.07		0.09	

DAS: Days After Spraying. Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 4: Efficacy of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation (Fourth Spray)

Treatments	Dosage (per litre)	Mean number of thrips per leaf											
		Precount		1 DAS		3 DAS		7 DAS		14 DAS		Mean	
T1 - Imidacloprid 17.8 SL	0.3 ml	1.85	(1.53)^{a}	0.55	(1.02)^{b}	0.36	(0.93)^{bc}	0.25	(0.86)^{b}	0.21	(0.84)^{b}	0.34	(0.92)^{bc}
T2 - Thiamethoxam 25 WG	0.2 g	0.77	(1.13)^{a}	0.18	(0.83)^{a}	0.10	(0.78)^{a}	0.07	(0.76)^{a}	0.05	(0.74)^{a}	0.10	(0.78)^{a}
T3 - Thiacloprid 21.7 SC	0.2 ml	0.87	(1.17)^{a}	0.56	(1.03)^{b}	0.41	(0.95)^{bc}	0.29	(0.89)^{bc}	0.25	(0.87)^{bc}	0.38	(0.94)^{bc}
T4 - Cyantraniliprole 10 OD	1.5 g	0.74	(1.11)^{a}	0.28	(0.89)^{a}	0.10	(0.77)^{a}	0.05	(0.74)^{a}	0.04	(0.74)^{a}	0.12	(0.78)^{a}
T5 - Dimethoate 30 EC	1.7 ml	1.67	(1.47)^{a}	0.54	(1.02)^{b}	0.44	(0.97)^{c}	0.37	(0.93)^{cd}	0.22	(0.85)^{b}	0.39	(0.94)^{c}
T6 - Fipronil 5 SC	1.0 ml	0.67	(1.08)^{a}	0.45	(0.97)^{b}	0.32	(0.91)^{b}	0.21	(0.84)^{b}	0.17	(0.82)^{b}	0.29	(0.89)^{bc}
T7- *L. lecanii* (1x10^{8} CFU/g)	5.0 g	1.99	(1.58)^{a}	0.76	(1.12)^{c}	0.65	(1.07)^{d}	0.45	(0.97)^{de}	0.32	(0.91)^{c}	0.54	(1.02)^{d}
T8 - Azadirachtin 10000ppm	1.0 ml	1.97	(1.57)^{a}	0.81	(1.14)^{c}	0.70	(1.10)^{d}	0.52	(1.01)^{e}	0.44	(0.97)^{d}	0.62	(1.06)^{d}
T 9- *L.lecanii*+ Azadirachtin	5.0g+1.0ml	1.73	(1.49)^{a}	0.43	(0.97)^{b}	0.31	(0.90)^{b}	0.21	(0.84)^{b}	0.17	(0.82)^{b}	0.28	(0.88)^{b}
T10 - Untreated check	---	2.13	(1.62)^{a}	1.25	(1.32)^{d}	1.18	(1.30)^{e}	1.39	(1.38)^{f}	1.29	(1.34)^{e}	1.28	(1.33)^{e}
S. Em ±		NS		0.02		0.02		0.02		0.02		0.02	
C.D. at 5%		---		0.07		0.06		0.05		0.05		0.06	

DAS: Days After Spraying. Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 5: Efficacy of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation (Fifth Spray)

Treatments	Dosage (per litre)	Mean number of thrips per leaf											
		Precount		1 DAS		3 DAS		7 DAS		14 DAS		Mean	
T1 - Imidacloprid 17.8 SL	0.3 ml	0.97	(1.21)^{a}	0.29	(0.89)^{c}	0.19	(0.83)^{b}	0.13	(0.79)^{b}	0.11	(0.78)^{c}	0.18	(0.82)^{b}
T2 - Thiamethoxam 25 WG	0.2 g	0.24	(0.86)^{a}	0.14	(0.80)^{ab}	0.03	(0.73)^{a}	0.02	(0.72)^{a}	0.02	(0.72)^{a}	0.05	(0.74)^{a}
T3 - Thiacloprid 21.7 SC	0.2 ml	0.29	(0.89)^{a}	0.30	(0.89)^{c}	0.22	(0.85)^{b}	0.16	(0.81)^{b}	0.13	(0.80)^{cd}	0.20	(0.84)^{b}
T4 - Cyantraniliprole 10 OD	1.5 g	0.22	(0.85)^{a}	0.04	(0.74)^{a}	0.03	(0.73)^{a}	0.02	(0.72)^{a}	0.02	(0.72)^{ab}	0.03	(0.73)^{a}
T5 - Dimethoate 30 EC	1.7 ml	0.88	(1.18)^{a}	0.68	(1.09)^{de}	0.53	(1.02)^{d}	0.49	(1.00)^{c}	0.32	(0.90)^{e}	0.51	(1.00)^{d}
T6 - Fipronil 5 SC	1.0 ml	0.38	(0.94)^{a}	0.23	(0.85)^{bc}	0.18	(0.82)^{b}	0.13	(0.79)^{b}	0.09	(0.77)^{bc}	0.16	(0.81)^{b}
T7 -*L. lecanii* (1x10^{8} CFU/g)	5.0 g	0.94	(1.20)^{a}	0.80	(1.14)^{ef}	0.74	(1.11)^{d}	0.64	(1.07)^{d}	0.57	(1.03)^{f}	0.69	(1.09)^{e}
T8 - Azadirachtin 10000ppm	1.0 ml	1.04	(1.24)^{a}	0.93	(1.19)^{f}	0.87	(1.17)^{e}	0.78	(1.13)^{e}	0.63	(1.06)^{f}	0.80	(1.14)^{e}
T9 - *L.lecanii*+ Azadirachtin	5.0g+1.0ml	1.07	(1.25)^{a}	0.53	(1.01)^{d}	0.37	(0.93)^{c}	0.21	(0.84)^{b}	0.19	(0.83)^{d}	0.32	(0.90)^{c}
T10 - Untreated check	---	1.72	(1.49)^{a}	1.66	(1.47)^{g}	1.22	(1.31)^{f}	1.03	(1.24)^{f}	0.88	(1.18)^{g}	1.20	(1.30)^{f}

S. Em ±		NS	0.02	0.02	0.02	0.01	0.02
C.D. at 5%		---	0.07	0.06	0.05	0.04	0.05

DAS: Days After Spraying. Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 6: Efficacy of new molecules on leaf curl index due to capsicum thrips, *Scirtothrips dorsalis* under protected cultivation

Treatments	Dosage (per litre)	LCI due to thrips per plant after								
		First spray	Second spray	Third spray	Fourth spray	Fifth spray	Mean	% reduction over control	Yield (t/ha)	% increase in yield over control
T1 - Imidacloprid 17.8 SL	0.3 ml	2.59^{bc}	1.79^{c}	2.04^{c}	1.22^{c}	0.87^{c}	1.70^{cd}	46.93	39.2^{abc}	31.12
T2 - Thiamethoxam 25 WG	0.2 g	1.47^{a}	0.75^{a}	0.55^{a}	0.30^{a}	0.05^{a}	0.62^{a}	80.54	47.8^{a}	43.46
T3 - Thiacloprid 21.7 SC	0.2 ml	3.03^{bc}	1.40^{bc}	0.84^{a}	0.75^{b}	0.42^{b}	1.29^{bc}	59.83	38.9^{abc}	30.59
T4 - Cyantraniliprole 10 OD	1.5 g	1.53^{a}	0.64^{a}	0.49^{a}	0.28^{a}	0.05^{a}	0.60^{a}	81.36	46.0^{ab}	41.30
T5 - Dimethoate 30 EC	1.7 ml	3.08^{c}	2.46^{d}	2.11^{c}	1.81^{d}	1.19^{d}	2.13^{de}	33.53	35.6^{bcd}	24.16
T6 - Fipronil 5 SC	1.0 ml	2.38^{b}	1.00^{ab}	0.61^{a}	0.50^{ab}	0.22^{ab}	0.94^{ab}	70.59	45.7^{ab}	40.92
T7 - *L. lecanii* ($1x10^{8}$ CFU/g)	5.0 g	2.48^{bc}	3.20^{e}	2.16^{c}	2.19^{e}	1.81^{f}	2.37^{e}	26.15	35.0^{bcd}	22.86
T8 - Azadirachtin 10000ppm	1.0 ml	3.10^{c}	3.33^{e}	2.41^{c}	2.14^{de}	1.56^{e}	2.51^{e}	21.70	32.6^{cd}	17.05
T9 - *L.lecanii*+ Azadirachtin	5.0g+1.0ml	2.35^{b}	1.66^{c}	1.47^{b}	1.27^{c}	0.21^{ab}	1.39^{bc}	56.50	45.2^{ab}	40.27
T10 - Untreated check	---	3.96^{d}	3.72^{e}	3.80^{d}	2.91^{f}	1.65^{ef}	3.21^{f}	0.00	27.0^{d}	0.00
S.Em ±	--	0.23	0.18	0.15	0.12	0.21	0.15	--	1.84	--
C.D. at 5%	--	0.69	0.53	0.47	0.37	0.23	0.45	--	5.53	--

LCI: Leaf Curl Index, Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

Table 7: Cost economics of new molecules against capsicum thrips, *Scirtothrips dorsalis* under protected cultivation

Treatments	Dosage (per litre)	Yield (t/ha)	Cost of plant protection (Rs/ha)	Other production cost (Rs/ha)	Total cost of production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
T1 - Imidacloprid 17.8 SL	0.3 ml	39.2	4870	1000000	1004870	2352000	1347130	2.34
T2 - Thiamethoxam 25 WG	0.2 g	47.8	1300	1000000	1001300	2865000	1863700	2.86
T3 - Thiacloprid 21.7 SC	0.2 ml	38.9	1400	1000000	1001400	2334000	1332600	2.33
T4 - Cyantraniliprole 10 OD	1.5 g	46.0	28950	1000000	1028950	2760000	1731050	2.68
T5 - Dimethoate 30 EC	1.7 ml	35.6	2000	1000000	1002000	2136000	1134000	2.13
T6 - Fipronil 5 SC	1.0 ml	45.7	2540	1000000	1002540	2742000	1739460	2.74
T7 - *L. lecanii* (1x108 CFU/g)	5.0 g	35.0	1000	1000000	1001000	2100000	1099000	2.10
T8 - Azadirachtin 10000ppm	1.0 ml	32.6	5375	1000000	1005375	1953000	947625	1.94
T9 - *L.lecanii*+ Azadirachtin	5.0g+1.0ml	45.2	2880	1000000	1002880	2712000	1709120	2.70
T10 - Untreated check	---	27.0	0	* 995000	995000	1620000	625000	1.63

Gross return = Yield x Market price of capsicum (Rs. 60/kg) Net Returns = Gross returns - Total cost of production
B:C ratio = Gross returns / Total cost *spraying cost excluded

Result and Discussion

The results revealed that cyantraniliprole10 OD at 1.50 g per litre recorded significantly lowest population of thrips after first, second, third, fourth and fifth spray during the experimentation with 0.03 thrips per plant which was at par with thiamethoxam 25 WG at 0.20 g per litre (0.18 thrips/plant) indicating the superiority of both the treatments against capsicum thrips. Further, per cent reduction over control indicated that both cyantraniliprole10 OD at 1.50 g per litre and thiamethoxam 25 WG at 0.20 g per litre registered more than 80 per cent reduction in thrips damage. Whereas, other new molecules (fipronil 5 SC and thiacloprid 21.7SC) and bio pesticides *Lecanicilium lecani* and azadirachtin recorded more than 55 per cent reduction due to thrips damage indicating moderate in their efficacy (Table 6).

Similarly, the yield data clearly indicated that highest fresh capsicum yield was registered in thiamethoxam 25 WG at 0.20 g per litre (47.8 t/ ha) which was statistically on par with cyantraniliprole 10 OD at 1.50 g per litre (46.0 t /ha) indicating both the molecules were equally effective in recording highest yield. The per cent increase in yield over control indicated that both in thiamethoxam 25 WG at 0.20 g per litre and cyantraniliprole 10 OD at 1.50 g per litre registered more than 40 per cent increase in yield. Whereas, fipronil 5 SC at 1.0 ml per litre and *Lecanicilium lecani* at 5.0 g + azadirachtin at 1.0 ml per litre registered 40 per cent increase in yield over control. Cost economics of different treatments indicated that thiamethoxam 25 WG at 0.20 at 5.0 g per litre registered maximum net returns (Rs. 1863700/ha) with highest B:C ratio (2.86) followed by fipronil 5 SC, cyantraniliprole 10 OD at 1.50 g per litre with higher net returns of (Rs.1739460 and Rs. 1731050), suggesting thiamethoxam 25 WG is cost effective and most feasible followed by fipronil and cyantraniliprole (Table 7). Further, data also revealed that *Lecanicilium lecani* at 5.0 g +azadirachtin at 1.0 ml per litre, imidacloprid 17.8 SL at 0.30 ml per litre and thiacloprid 21.7 SC at 0.2 ml per litre were next best new molecules in suppressing the thrips population. Provided, conventional insecticides such as dimethoate 30 EC at1.7 ml per litre, *L. lecanii* (1×10^{8} CFU /g) at 5.0 g per litre and azadirachtin 10,000 ppm at 1.0 ml per litre registered lowest net returns and B:C ratio indicating not profitable as compared to new molecules (Table 7). The results of present investigation conclusively revealed that thiamethoxam 25 WG at 0.20 g per litre is most economical, feasible and adoptable by the farming community.

The present investigations on efficacy of new molecules against capsicum thrips are in agreement with the results of carried out by Ghosh *et al.* (2009) who recorded thiamethoxam (90.1 %) as most effective insecticide followed by acetamiprid (89.8 %), fipronil (88.8 %), clothianidin (87.4 %) and oxydemeton-methyl (76.9 %). The newer, safer and effective insecticide is the need of the hour for sustainable management of the insect. The efficacy of thiamethoxam 25

WG may be attributed due to its unique mode of action against thrips as it is a thionicotinyl compound which acts as agonists of nicotinic acetylcholine receptor. In insects, acetylcholine is the major excitatory neurotransmitter in brain. Neonicotinoids mimic Ach to activate nAChRs, causes an influx of Na^+ ions and generation of action potentials. Normally the synaptic action of Ach is terminated by acetylcholine esterase enzyme, which rapidly hydrolyses the neurotransmitter. These insecticides are not hydrolyzed by AchE owing to its persistent activation leads to an overstimulation of cholinergic synapses. This results in hyper excitation and paralysis, death of insect. (Zewen Liu *et al*., 2008) [18]. Nicotinic acetylcholine receptors (nAChRs) are ligand-gated ion channels which mediate fast cholinergic synaptic transmission in insect nervous systems. Jadhav *et al*. (2004) [8] reported that fipronil 5 SC at 100 g a.i per ha recorded lowest population of sucking pests and the highest yield. The bio efficacy of fipronil 5 SC in reducing the thrips on chillies was also reported by Mahalingappa *et al.* (2008) [11]. Fipronil is contact and systemic insecticide with new mode of action and wide spectrum of activities. Rapid knock down mortality were generally found against various types of insect pests. Many workers (Maity *et al*., 2015 [12] and Halder jayadeep *et al.*, 2015 [6]) [12, 6] opined that fipronil recorded the lowest thrips incidence in chilli.

Similarly, cyantraniliprole 10 OD is a second-generation anthranilic diamide insecticide discovered by DuPont Crop Protection. This insecticide is currently registered under the active ingredient trade name Cyazypyr™ (Benevia), controlling insect pests that are resistant to other insecticides. Anthranilic diamides have a unique and novel mode of action that involves activating ryanodine receptors (RyR), which play a critical role in muscle function. Cyantraniliprole 10 OD bind to the RyR, causes uncontrolled release and depletion of calcium (Ca_2^{++} ions) from muscle cells, thus preventing further muscle contraction and ultimately leading to death. It has root systemic and translaminar activity against a broad spectrum of sucking and chewing insects (Cordova *et al.* 2006) [4]. This is an important differentiating feature of cyantraniliprole compared to most synthetic pyrethroid, organo-phosphate and neonicotinoid insecticides that are currently used. It has very low toxicity for mammals, high intrinsic activity on target pests, strong ovicidal and larvicidal properties, long lasting crop protection and no cross-resistance to any existing insecticide. Due to selective mode of action, it is effective against thrips while safe to non-target arthropods and conserves natural parasitoids, predators and pollinators. The present findings are in corroborated with Misra (2012) [13], Balikai and Mallapur (2015) [2], Lodaya *et al.* (2017) [10] and Singh and Rishi (2017) [17] who reported that cyantraniliprole 10 OD is effective in reducing the thrips population.

Further, combination of *Verticilium lecanii at* 5.0 g + Azadirachtin10000 ppm at 1.0 ml per litre proved to be superior in reducing the thrips population in capsicum under protected cultivation. Mycoinsecticides may be most effective in pest managements programs integrating beneficial arthropods, or in greenhouse crops where favourable environmental conditions (high humidity and low UV exposure) can be manipulated (Jacobson *et al*., 2001; Down *et al*., 2009) [7, 5].

Conclusion

Among various insecticides tested against thrips, thiamethoxam 25 WG at 0.2 g per litre and cyantraniliprole 10 OD at 1.50 g per litre recorded significantly lowest population of thrips after first, second, third and fourth spray during the experimentation which were at par with each other indicating the superiority of both the treatments against capsicum thrips. Cost economics of different treatments indicated that thiamethoxam 25 WG at 0.20 g per litre registered the maximum yield (47.8 t/ha) and net returns (Rs. 1863700/ha) with highest B:C ratio (2.86) suggesting thiamethoxam 25 WG is cost effective and economically feasible.

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