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Effect of newer insecticides against chilli thrips, *Scirtothrips dorsalis* (Hood)

K Vanisree, S Upendhar, P Rajasekhar and G Ramachandra Rao

Abstract
The field experiment conducted during *Kharif* 2008-09 and 2009-10 on the evaluation of certain new insecticides indicated that spinosad 0.015% was found most effective in reducing the population of *S. dorsalis* as well as in increasing yields. It attains highest cost benefit ratio followed by diafenthiuron 0.045%, pymetrozine 0.02% and fipronil 0.01%. Indoxacarb 0.015% and flubendiamide 0.012%. Further flubendiamide recorded the lowest mean% reduction over untreated check indicating their poor efficacy against *S. dorsalis* on chillies.

Keywords: Chilli thrips, novel insecticides, management, chemical control

1. Introduction
India has emerged today as the foremost producer and exporter of chillies contributing to almost one fourth of the world's production. In India, chilli is grown in an area of 7.43 L ha, with a production of 14.53 L tons (Agricultural Statistics at a glance, 2015) [1]. The important chilli growing states in India are Andhra Pradesh, Orissa, Maharashtra, Karnataka and also in a number of other states as a round the year crop. In Andhra Pradesh, chilli is cultivated in an area of 1.89 L hectares with a production of 2.08 L tons. Guntur district in Andhra Pradesh alone contributes to over 35% in the area under chilli crop in India.
The important pests are thrips, *Scirtothrips dorsalis* (Hood), white mite, *Polyphagotarsonemus latus* (Banks), aphids, *Aphis gossypii* Glover and *Myzus persicae* Sulzer as sucking complex and tobacco caterpillar, *Spodoptera litura* (Fabricius) and pod borer, *Helicoverpa armigera* (Hubner) as pod borers (Rao and Ahmed, 1985) [9]. Chilli thrips, *Scirtothrips dorsalis* (Hood) (Thysanoptera: Thripidae) is a serious pest of *Capsicum annuum* L. in India, responsible for leaf curling (Ananthakrishnan, 1971) [2]. It multiplies appreciably at a faster rate during dry weather periods and the yield loss caused by the thrips is reported to range from 30-90% (Borah, 1987 and Varadharajan, 1994) [3, 11].
Guntur district in Andhra Pradesh is traditionally a chilli growing district with an area of 63,573 ha with high input usage under monocropping conditions. Further, intensive cultivation of input responsive high yielding varieties and hybrids and sole reliance on insecticides are the common features of chilli cultivation in Guntur district. The excessive dependence on insecticides, their over use and abuse has accelerated insect control problems through the development of insecticide resistance (Reddy *et al*., 1992) [10], pest resurgence, pesticide residues (Joia *et al*., 2001) [6], reduction in natural enemy population and environmental contamination. Moreover, several of the chilli consignments meant for export were rejected stating higher insecticide residues being the culprit, thus lots of foreign exchange lost by way of rejections. Further there were several reports from farmers experiencing difficulties in pest control. Many conventional insecticides are being used to manage these pests with which many folds of resistance was reported in pests like *S. litura* (Prasad *et al*., 2008), *Spodoptera exigua* (Hubner) (Wang *et al.*, 2002) [12], *H. armigera* (Kranthi *et al*., 2002) [7] *etc*. The occurrence of insecticide resistance strains can be reduced or delayed by reducing the selection pressure and by adopting insecticide resistance management strategies and alternate insecticides with a novel mode of action. In view of the above constraints in chilli cultivation, it is felt high time to estimate the current status of insecticide resistance so as to corrologate with field control problems besides evaluating newer insecticides with novel mode of action both under laboratory and field conditions so as to have better option on hand that could mitigate the present control failures and residue problems plausing the farming community.

2. Materials and Methods

The experiment was laid in a simple randomized block design with twelve treatments including untreated check, replicated thrice. Each plot measured 18m^2 and the gross area of the management trial was 800m^2. Different group of insecticides fipronil (Phenyl pyrazole), Pymetrozine (Pyridine Azomethines), Imidacloprid (Neonecotinoid), Diafenthiuron (Thiourea), Vertimec and Emamectin benzoate (Avermectins), Spinosad (Spinosyn), Indoxacarb (Oxadiazine), Flubendiamide (Phthalic acid diamide), Clothianidin (Neonecotinoid) and Chlorfenapyr (pyrrole compound) was evaluated against *S. dorsalis*. A measured quantity of insecticidal solution or powder was mixed with a little quantity of water and stirred well, after which the remaining quantity of water was added to obtain the required concentration of spray fluid. Sprayings were given by using a hand compression knapsack high volume sprayer during morning hours. The plot in each treatment was sprayed with respective insecticides ensuring uniform coverage of insecticide. The sprayer and the accessories were thoroughly washed before changing the insecticides and also rinsed with the spray fluid of the chemical to be applied next. The first spraying was given at 45 days after transplanting, when the incidence of thrips population was sufficiently built up in the experimental plots. A total of five sprays were given during the course of the season at fortnightly interval. Observations on the pest incidence were recorded one day before the spraying as pre-treatment count and first, third, seventh and fourteenth day after spraying as the post- treatment counts. The population of both nymphs and adults of thrips were counted during early morning hours on terminal six leaves from 5 randomly selected plants in each plot to get a representative sample of that plot and the plants were tagged leaving the border rows. The matured green pods were harvested four times in all treatments at 15 days interval during crop period and the cumulative yield of all the pickings were recorded plot wise and expressed in kg/ net plot. From this the yield per hectare was calculated. The% reduction in thrips population over control was calculated by modified abbott's formula followed by Flemming and Retnakaran, 1985) [5].

$$\text{Percentage population reduction} = \left(1 - \left(\frac{\text{Post treatment population in treatment}}{\text{Pre treatment population in treatment}} \times \frac{\text{Pre treatment population in untreated control}}{\text{Post treatment population in untreated control}}\right)\right) \times 100$$

These percentages were transformed to the corresponding arc sine values and the data was subjected to statistical analysis. The yield data in each treatment was recorded separately and subjected to statistical analysis to test the significance of mean yield in different treatments.

The percent increase in yield over control in various treatments was calculated by using the following formula.

$$\text{Percent increase of Yield in treatment Over control} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

3. Results and Discussion

3.1 Kharif 2008-2009

The results with regard to the mean efficacy of the treatments after the five rounds of application are presented in Table 1.

Table 1: Mean Efficacy of treatments against *S. dorsalis* on chilli during *Kharif* 2008-2009

Treatments	Conc. (%)	PTC (Mean no. of thrips/ leaf)	Mean per cent reduction over control				
			1 DAS	3 DAS	7 DAS	14 DAS	Overall
Fipronil	0.01	4.29	77.48 (61.68)^{d}	86.67 (68.61)^{c}	77.52 (61.71)^{d}	62.40 (52.18)^{c}	76.02 (60.69)^{d}
Pymetrozine	0.02	4.00	78.64 (62.49)^{c}	87.32 (69.18)^{c}	79.32 (62.96)^{c}	64.22 (53.26)^{b}	77.38 (61.61)^{c}
Imidacloprid	0.005	4.43	67.52 (55.26)^{e}	75.51 (60.35)^{d}	66.38 (54.57)^{f}	47.53 (43.58)^{d}	64.24 (53.28)^{e}
Diafenthiuron	0.045	4.10	81.26 (64.37)^{b}	92.00 (73.63)^{b}	85.23 (67.43)^{b}	68.17 (55.66)^{a}	81.66 (64.66)^{b}
Vertimec	0.001	4.93	56.29 (48.61)^{g}	59.32 (50.37)^{g}	58.29 (49.77)^{h}	40.24 (39.37)^{f}	53.53 (47.03)^{h}
Spinosad	0.015	3.58	82.43 (65.24)^{a}	93.49 (75.31)^{a}	87.38 (69.23)^{a}	67.69 (55.36)^{a}	82.75 (65.48)^{a}
Emamectin benzoate	0.003	5.05	52.61 (46.50)^{h}	57.60 (49.38)^{h}	56.41 (48.68)^{i}	37.45 (37.73)^{g}	51.02 (45.58)^{i}
Indoxacarb	0.015	5.11	47.52 (43.58)^{i}	52.37 (46.36)^{i}	50.46 (45.26)^{j}	35.53 (36.59)^{h}	46.47 (42.97)^{j}
Flubendiamide	0.012	5.16	43.25 (41.12)^{j}	46.88 (43.21)^{j}	45.45 (42.39)^{k}	32.90 (35.00)^{i}	42.12 (40.46)^{k}
Clothianidin	0.003	4.98	57.60 (49.37)^{g}	62.55 (52.27)^{f}	60.55 (51.09)^{g}	42.13 (40.47)^{e}	55.71 (48.28)^{g}
Chlorfenapyr	0.01	4.85	59.38 (50.41)^{f}	67.42 (55.20)^{e}	69.56 (56.52)^{e}	46.53 (43.01)^{d}	60.72 (51.19)^{f}
Untreated check	-	8.44	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
F-test		NS	Sig.	Sig.	Sig.	Sig.	Sig.
SEd		-	0.39	0.45	0.35	0.33	0.30
CD (p=0.05)		-	0.80	0.92	0.72	0.69	0.63

Figures in parentheses are angular transformed values

Numbers followed by the same letter in each column are not significantly different

The data recorded one day after imposition of treatments indicated that spinosad 0.015% was the most effective and significantly superior over all other treatments by recording the highest reduction in the population of 82.43% over untreated check. The next best treatments were diafenthiuron 0.045%, pymetrozine 0.02% and fipronil 0.01% with 81.26, 78.64 and 77.48% reduction in population over untreated check respectively in the descending order of efficacy with more than 77% mean reduction over control was being significantly superior to remaining treatments. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 67.52, 59.38, 57.60, 56.29 and 52.61% reduction in thrips population over the untreated check, respectively. Among the treatments, indoxacarb 0.015% (47.52%) and flubendiamide 0.012% (43.25%) showed poor efficacy with less than 48% reduction in population. However, all the treatments were significantly superior to control in bringing down the population of *S. dorsalis* on chillies.

The data recorded at three days after treatment showed that the most effective treatment was spinosad 0.015% with 93.49% reduction in the population of *S. dorsalis* over control and was significantly superior to all the other treatments. The next best treatment was diafenthiuron 0.045% with 92.00% reduction in population over untreated check. The treatments pymetrozine 0.02% (87.32%) and fipronil 0.01% (86.67%) being on par with more than 86% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 75.51, 67.42, 62.55, 59.32 and 57.60% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (52.37%) and flubendiamide 0.012% (46.88%) were found to be least effective with less than 53% reduction in population over untreated check. However, all the treatments were effective and significant in reducing the population of *S. dorsalis* over control.

The data recorded at seven days after five sprayings showed that spinosad 0.015% was the most effective and significantly superior over all the other treatments by recording the highest reduction in the population of 87.38% over untreated check. The next best treatment was diafenthiuron 0.045% with 85.23% reduction in population and was significantly superior to the rest of the treatments. Closely behind was pymetrozine 0.02% with 79.32% reduction in population over untreated check. The treatment, fipronil 0.01% came next and was also significantly superior to the rest with 77.52% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were chlorfenapyr 0.01%, imidacloprid 0.005%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 69.56, 66.38, 60.55, 58.29 and 56.41% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (50.46%) and flubendiamide 0.012% (45.45%) were found least effective with less than 51% reduction in population over untreated check. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis.*

The post treatment data at fourteen days after spraying showed that diafenthiuron 0.045% was the most effective and significantly superior over all the other treatments with 68.17% reduction in population over the untreated check, which was on par with spinosad 0.015% with 67.69% reduction in population over untreated check. The next best treatment was pymetrozine 0.02% being significantly superior to the rest of the treatments with 64.22% reduction over untreated check. The treatment, fipronil 0.01% came next and was also significantly superior over the rest with 62.40% reduction in population over untreated check.The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 47.53, 46.53, 42.13, 40.24 and 37.45% reduction in thrips population over the untreated check, respectively. Among the treatments, indoxacarb 0.015% (35.53%) and flubendiamide 0.012% (32.90%) were found to be the least effective with less than 36% reduction in population over control. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis.*

The data pertaining to the overall mean efficacy of the treatments after the imposition of five sprays revealed that the most effective and the best treatment was spinosad 0.015% with 82.75% reduction in the population of *S. dorsalis* over the untreated check and was significantly superior to all the other treatments. The next best treatment was diafenthiuron 0.045% with 81.66% reduction in population over untreated check. Next came, pymetrozine 0.02% with 77.38% reduction in population and was significantly superior to the rest of the treatments. The other treatment that has shown a good degree of control with more than 76% reduction over control was fipronil 0.01% (76.02%) being significantly superior to remaining treatments. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 64.24, 60.72, 55.71, 53.53 and 51.02% reduction in thrips population over the untreated check, respectively. Among the treatments, indoxacarb 0.015% (46.47%) and flubendiamide 0.012% (42.12%) were found least effective with less than 47% reduction in population over untreated check. However, all the treatments were significantly superior over the untreated control in reducing the population of *S. dorsalis* on chillies after the five rounds of sprays during *Kharif* 2008-2009.

3.2 Kharif 2009-2010

The results with regard to the mean efficacy of the treatments after the five rounds of application are presented in Table 2.The data recorded one day after imposition of treatments indicated that spinosad 0.015% was the most effective and significantly superior over all other treatments by recording the highest reduction in population of 81.22% over untreated control, which was on par with diafenthiuron 0.045% with 80.06% reduction in population and was significantly superior to the rest of the treatments. The next best treatments were pymetrozine 0.02% (77.44%) and fipronil 0.01% (76.27%) being on par with more than 76% reduction in population over untreated check. The treatment, imidacloprid 0.005% came next and was also significantly superior to the rest with 66.32% reduction in population over untreated check. The treatments chlorfenapyr 0.01% (58.18%), clothianidin 0.003% (56.40%) and vertimec 0.001% (55.08%) being on par with more than 55% mean reduction in population over untreated check. The treatments emamectin benzoate 0.003% (51.41%) and indoxacarb 0.015% (46.32%) were also significantly superior to the rest of the treatments with more than 46% mean reduction in population over control. The remaining treatment, flubendiamide 0.012% (42.05%) showed poor

efficacy with less than 43% reduction in population. However, all the treatments were significantly superior over control in bringing down the population of *S. dorsalis* on chillies during *Kharif* 2009-2010 at one day after spraying.

The data recorded at three days after treatment showed that the most effective treatment was spinosad 0.015% with 92.81% reduction in population of *S. dorsalis* over control and was significantly superior over all the other treatments. The next best treatment was diafenthiuron 0.045% with 91.32% reduction in population and was significantly superior to the rest of the treatments. The next best treatments were pymetrozine 0.02% (86.64%) and fipronil 0.01% (85.99%) being on par with more than 85% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 74.83, 66.74, 61.87, 58.64 and 56.92% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (51.69%) and flubendiamide 0.012% (46.20%) were found to be the least effective with less than 52% mean reduction in population over control. However, all the treatments were effective and significant in reducing the population of *S. dorsalis* over control at three days after spraying.

The post treatment data at seven days after five sprayings showed that spinosad 0.015% was the most effective and significantly superior over all the other treatments by recording the highest reduction in the population of 86.67% over untreated control. The next best treatment was diafenthiuron 0.045% with 84.52% reduction in population and was significantly superior to the rest of the treatments. Closely behind were pymetrozine 0.02% (78.61%) and fipronil 0.01% (76.81%) being on par with more than 76% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were chlorfenapyr 0.01%, imidacloprid 0.005%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 68.85, 65.67, 59.84, 57.58 and 55.70% reduction in thrips population over the untreated check, respectively. Among the treatments, indoxacarb 0.015% (49.75%) and flubendiamide 0.012% (44.74%) were found to be the least effective with less than 50% mean reduction in population over untreated check. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis* at seven days after spraying.

The post treatment data at fourteen days after spraying showed that diafenthiuron 0.045% was the most effective and significantly superior over all the other treatments with 67.55% reduction in the population over untreated control, which was on par with spinosad 0.015% with 67.07% reduction in population and was significantly superior to the rest of the treatments. The next best treatments were pymetrozine 0.02% (63.60%) and fipronil 0.01% (61.78%) being on par with more than 61% reduction in population over untreated check. The treatments imidacloprid 0.005% (46.91%) and chlorfenapyr 0.01% (45.91%) being on par with more than 45% reduction in population and significantly superior over untreated check. The treatments clothianidin 0.003% (41.51%) and vertimec 0.001% (39.62%) being on par with more than 39% reduction in population over untreated check. The treatments emamectin benzoate 0.003% (36.83%) and indoxacarb 0.015% (34.91%) being on par with a mean reduction in population of more than 34% when compared to control. The remaining treatment, flubendiamide 0.012% (32.28%) showed poor efficacy with less than 33% reduction in population over untreated control. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis* at fourteen days after spraying.

Table 2: Mean Efficacy of treatments against *S. dorsalis* on chilli during *Kharif* 2009-2010

Treatments	Conc. (%)	PTC (Mean no. of thrips/ leaf)	Mean per cent reduction over control				
			1 DAS	3 DAS	7 DAS	14 DAS	Overall
Fipronil	0.01	4.08	76.27 (60.89)^{b}	85.99 (68.09)^{c}	76.81 (61.25)^{c}	61.78 (51.82)^{b}	75.21 (60.17)^{b}
Pymetrozine	0.02	4.12	77.44 (61.69)^{b}	86.64 (68.64)^{c}	78.61 (62.50)^{c}	63.60 (52.91)^{b}	76.57 (61.09)^{b}
Imidacloprid	0.005	4.13	66.32 (54.55)^{c}	74.83 (59.92)^{d}	65.67 (54.15)^{e}	46.91 (43.23)^{c}	63.43 (52.81)^{c}
Diafenthiuron	0.045	3.88	80.06 (63.53)^{a}	91.32 (73.03)^{b}	84.52 (66.92)^{b}	67.55 (55.30)^{a}	80.86 (64.12)^{a}
Vertimec	0.001	4.11	55.08 (47.92)^{e}	58.64 (49.98)^{g}	57.58 (49.36)^{g}	39.62 (39.00)^{d}	52.73 (46.57)^{f}
Spinosad	0.015	3.71	81.22 (64.39)^{a}	92.81 (74.66)^{a}	86.67 (68.70)^{a}	67.07 (55.00)^{a}	81.94 (64.92)^{a}
Emamectin benzoate	0.003	4.40	51.41 (45.81)^{f}	56.92 (48.98)^{g}	55.70 (48.28)^{g}	36.83 (37.35)^{e}	50.22 (45.12)^{g}
Indoxacarb	0.015	4.51	46.32 (42.89)^{g}	51.69 (45.97)^{h}	49.75 (44.86)^{h}	34.91 (36.20)^{e}	45.67 (42.51)^{h}
Flubendiamide	0.012	4.67	42.05 (40.42)^{h}	46.20 (42.82)^{i}	44.74 (41.97)^{i}	32.28 (34.60)^{f}	41.32 (39.99)^{i}
Clothianidin	0.003	4.14	56.40 (48.68)^{de}	61.87 (51.87)^{f}	59.84 (50.68)^{f}	41.51 (40.11)^{d}	54.90 (47.82)^{e}
Chlorfenapyr	0.01	4.31	58.18 (49.71)^{d}	66.74 (54.80)^{e}	68.85 (56.09)^{d}	45.91 (42.65)^{c}	59.92 (50.73)^{d}
Untreated check	-	8.46	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
F-test		NS	Sig.	Sig.	Sig.	Sig.	Sig.
SEd		-	0.60	0.70	0.60	0.56	0.54
CD (p=0.05)		-	1.25	1.45	1.25	1.17	1.11

Figures in parentheses are angular transformed values

Numbers followed by same letter in each column are not significantly different

The data pertaining to the overall mean efficacy of the treatments after the imposition of five sprays revealed that the most effective treatment was spinosad 0.015% with 81.94% reduction in population of *S. dorsalis* over untreated control and was significantly superior over all the other treatments, which was on par with diafenthiuron 0.045% with 80.86% reduction in population and was significantly superior to the rest of the treatments. The next best treatments were pymetrozine 0.02% (76.57%) and fipronil 0.01% (75.21%) being on par with more than 75% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 63.43, 59.92, 54.90, 52.73 and 50.22% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (45.67%) and flubendiamide 0.012% (41.32%) were found to be the least effective with less than 46% reduction in population over control. However, all the treatments were significantly superior over the untreated control in reducing the population of *S. dorsalis* on chillies after the five rounds of sprays during *Kharif* 2009-2010.

3.3 Overall cumulative mean efficacy of treatments during both the seasons

The results with regard to the overall cumulative mean efficacy of the treatments during both the years are presented in Table 3.The mean data recorded one day after imposition of treatments indicated that spinosad 0.015% was the most effective and significantly superior over all other treatments by recording the highest reduction in population of 81.83% over untreated check, which was on par with diafenthiuron 0.045% with 80.66% reduction in population and was significantly superior to the rest of the treatments. The next best treatments were pymetrozine 0.02% (78.04%) and fipronil 0.01% (76.87%) being on par with more than 76% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 66.92, 58.78, 57.00, 55.69 and 52.01% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (46.92%) and flubendiamide 0.012% (42.65%) showed poor efficacy with less than 47% reduction in population. However, all the treatments were significantly superior over control in bringing down the population of *S. dorsalis* on chillies at one day after spraying.

Table 3: Mean efficacy of treatments against *S. dorsalis* on chilli during *Kharif* 2008-09 and 09-10 (Pooled data)

Treatments	Conc. (%)	PTC (Mean no. of thrips/ leaf)	Mean per cent reduction over control				
			1 DAS	3 DAS	7 DAS	14 DAS	Overall
Fipronil	0.01	4.19	76.87 (61.28)^{b}	86.33 (68.35)^{c}	77.17 (61.48)^{d}	62.09 (52.00)^{c}	75.62 (60.42)^{c}
Pymetrozine	0.02	4.06	78.04 (62.08)^{b}	86.98 (68.90)^{c}	78.96 (62.72)^{c}	63.91 (53.08)^{b}	76.97 (61.35)^{b}
Imidacloprid	0.005	4.28	66.92 (54.90)^{c}	75.17 (60.13)^{d}	66.03 (54.36)^{f}	47.22 (43.40)^{d}	63.83 (53.04)^{d}
Diafenthiuron	0.045	3.99	80.66 (63.94)^{a}	91.66 (73.32)^{b}	84.88 (67.17)^{b}	67.86 (55.48)^{a}	81.26 (64.39)^{a}
Vertimec	0.001	4.52	55.69 (48.27)^{e}	58.98 (50.18)^{g}	57.93 (49.57)^{h}	39.93 (39.18)^{f}	53.13 (46.80)^{g}
Spinosad	0.015	3.64	81.83 (64.81)^{a}	93.15 (74.97)^{a}	87.03 (68.95)^{a}	67.38 (55.18)^{a}	82.35 (65.19)^{a}
Emamectin benzoate	0.003	4.72	52.01 (46.15)^{f}	57.26 (49.18)^{g}	56.06 (48.48)^{i}	37.14 (37.54)^{g}	50.62 (45.35)^{h}
Indoxacarb	0.015	4.81	46.92 (43.23)^{g}	52.03 (46.16)^{h}	50.11 (45.06)^{j}	35.22 (36.39)^{h}	46.07 (42.74)^{i}
Flubendiamide	0.012	4.92	42.65 (40.77)^{h}	46.54 (43.01)^{i}	45.09 (42.18)^{k}	32.59 (34.80)^{i}	41.72 (40.23)^{j}
Clothianidin	0.003	4.56	57.00 (49.03)^{e}	62.21 (52.07)^{f}	60.20 (50.89)^{g}	41.82 (40.29)^{e}	55.31 (48.05)^{f}
Chlorfenapyr	0.01	4.58	58.78 (50.06)^{d}	67.08 (55.00)^{e}	69.20 (56.31)^{e}	46.22 (42.83)^{d}	60.32 (50.96)^{e}
Untreated check	-	8.45	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
F-test		NS	Sig.	Sig.	Sig.	Sig.	Sig.
SEd		-	0.48	0.56	0.46	0.43	0.41
CD (p=0.05)		-	1.00	1.17	0.96	0.90	0.85

Figures in parentheses are angular transformed values
Numbers followed by same letter in each column are not significantly different

The mean data recorded at three days after treatment showed that the most effective treatment was spinosad 0.015% with 93.15% reduction in population of *S. dorsalis* over untreated check and was significantly superior over all the other treatments. The next best treatment was diafenthiuron 0.045% with 91.66% reduction in population and was significantly superior to the rest of the treatments. The treatments pymetrozine 0.02% (86.98%) and fipronil 0.01% (86.33%) being on par with more than 86% reduction in population and significantly superior over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 75.17, 67.08, 62.21, 58.98 and 57.26% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (52.03%) and

flubendiamide 0.012% (46.54%) were found to be the least effective with less than 53% mean reduction in population over untreated check. However, all the treatments were effective and significant in reducing the population of *S. dorsalis* over control at three days after spraying.

The mean data at seven days after sprayings showed that among the treatments, spinosad 0.015% was the most effective followed by diafenthiuron 0.045%, pymetrozine 0.02% and fipronil 0.01% with 87.03, 84.88, 78.96 and 77.17% reduction over untreated check. The other treatments that followed in the descending order of efficacy were chlorfenapyr 0.01%, imidacloprid 0.005%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 69.20, 66.03, 60.20, 57.93 and 56.06% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (50.11%) and flubendiamide 0.012% (45.09%) showed poor efficacy with less than 51% reduction in population over control. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis* at seven days after spraying.

The mean data at fourteen days after spraying showed that among the treatments, diafenthiuron 0.045% was the most effective followed by spinosad 0.015%, pymetrozine 0.02% and fipronil 0.01% with 67.86, 67.38, 63.91 and 62.09% reduction over untreated check. The next best treatments were imidacloprid 0.005% (47.22%) and chlorfenapyr 0.01% (46.22%) being on par with more than 46% reduction in population over untreated check. The other treatments that followed in the descending order of efficacy were clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 41.82, 39.93 and 37.14% reduction in thrips population over the untreated check, respectively. Among the treatments, indoxacarb 0.015% (35.22%) and flubendiamide 0.012% (32.59%) were found to be the least effective with less than 36% mean reduction in population over untreated check. However, all the treatments were effective and significantly superior over the untreated control in bringing down the population of *S. dorsalis* at fourteen days after spraying.

The data pertaining to the overall cumulative mean efficacy of the treatments during both the seasons revealed that among the treatments, spinosad 0.015% was the most effective followed by diafenthiuron 0.045%, pymetrozine 0.02% and fipronil 0.01% with 82.35, 81.26, 76.97 and 75.62% reduction over untreated check. The other treatments that followed in the descending order of efficacy were imidacloprid 0.005%, chlorfenapyr 0.01%, clothianidin 0.003%, vertimec 0.001% and emamectin benzoate 0.003% with 63.83, 60.32, 55.31, 53.13 and 50.62% reduction in thrips population over untreated check, respectively. Among the treatments, indoxacarb 0.015% (46.07%) and flubendiamide 0.012% (41.72%) were found to be the least effective with less than 47% reduction in population over control. However, all the treatments were significantly superior over the untreated control in reducing the population of *S. dorsalis* on chillies.

3.4 Effect of Treatments on Yield of Green Chillies

3.4.1Kharif 2008-2009

The data pertaining to the yield of chilli presented in Table 4 indicated that the yield obtained from all the plots ranged between 5.04 to 16.10 kg plot^{-1} including the untreated check. Among the treatments spinosad recorded the highest yield of 16.10 kg plot^{-1} (8942.26 kg ha^{-1}) with an increase of 219.37% yield over the untreated check and was found significantly superior to all the other treatments. Treatments that were moderately better in recording the higher yields were diafenthiuron (15.88 kg plot^{-1} or 8822.28 kg ha^{-1}), pymetrozine (14.83 kg plot^{-1} or 8236.36 kg ha^{-1}), fipronil (14.44 kg plot^{-1} or 8024.88 kg ha^{-1}), imidacloprid (13.91kg plot or 7728.24 kg ha^{-1}), chlorfenapyr (13.52 kg plot^{-1} or 7512.13 kg ha^{-1}), clothianidin (13.26 kg plot^{-1} or 7365.22 kg ha^{-1}), vertimec (12.80 kg plot^{-1} or 7113.12 kg ha^{-1}) and emamectin benzoate (10.42 kg plot^{-1} or 5788.24kg ha^{-1}) being on par with each other resulting in 215.08, 194.16, 186.60, 176.01, 168.29, 163.04, 154.04 and 106.72% increase in yield respectively over untreated check. Among the treatments, indoxacarb (9.56 kg plot^{-1} or 5313.14 kg ha^{-1}) and flubendiamide (8.97 kg plot^{-1} or 4982.66 kg ha^{-1}) were on par with each other and recorded significantly less yield with 89.76 and 77.95% increase in yield but was significantly superior over untreated check. The untreated control recorded the lowest yield (5.04 kg plot^{-1} or 2800 kg ha^{-1}) and was found inferior to all other treatments. However, from the point of cost benefit ratio (CBR) highest CBR 1: 2.20 was recorded in spinosad followed by diafenthiuron (1: 2.19), fipronil (1: 2.00), imidacloprid (1: 1.93), chlorfenapyr (1: 1.87), clothianidin (1: 1.85), vertimec (1: 1.76), emamectin benzoate (1: 1.42), indoxacarb (1: 1.30) and flubendiamide (1: 1.22).

Table 4: Effect of treatments on yield of green chillies during *Kharif* 2008-09

Treatments	Conc. (%)	Kg/plot	Kg/ha	% increase over control	Gross returns Rs/ha	Cost Benefit ratio
Fipronil	0.01	14.44^{b}	8024.88	186.60	160497.60	1:2.00
Pymetrozine	0.02	14.83^{b}	8236.36	194.16	164727.20	-
Imidacloprid	0.005	13.91^{bc}	7728.24	176.01	154564.80	1:1.93
Diafenthiuron	0.045	15.88^{a}	8822.28	215.08	176445.60	1:2.19
Vertimec	0.001	12.80^{d}	7113.12	154.04	142262.40	1:1.76
Spinosad	0.015	16.10^{a}	8942.26	219.37	178845.20	1:2.20
Emamectin benzoate	0.003	10.42^{e}	5788.24	106.72	115764.80	1:1.42
Indoxacarb	0.015	9.56^{ef}	5313.14	89.76	106262.80	1:1.30
Flubendiamide	0.012	8.97^{f}	4982.66	77.95	99653.20	1:1.22
Clothianidin	0.003	13.26^{cd}	7365.22	163.04	147304.40	1:1.85
Chlorfenapyr	0.01	13.52^{cd}	7512.13	168.29	150242.60	1:1.87
Untreated check	-	5.04^{g}	2800.00	-	56000.00	1:0.70
F-test		Sig.				
SEd		0.49				
CD (p=0.05)		1.03				

Numbers followed by the same letter in each column are not significantly different

3.4.2 Kharif 2009-2010

The data pertaining to the yield of chilli presented in Table 5 indicated that the yield obtained from all the plots ranged between 5.44 to 16.49 kg plot^{-1} including untreated control. Among the treatments spinosad recorded the highest yield of 16.49 kg plot^{-1} (9162.31 kg ha^{-1}) with an increase of 203.38% yield over control and was found significantly superior to all the other treatments. Treatments that were moderately better in recording the higher yields were diafenthiuron (16.28 kg plot^{-1} or 9042.33 kg ha^{-1}), pymetrozine (15.22 kg plot^{-1} or 8456.41 kg ha^{-1}), fipronil (14.84 kg plot^{-1} or 8244.93 kg ha^{-1}), imidacloprid (14.31 kg plot^{-1} or 7948.29 kg ha^{-1}), chlorfenapyr (13.92 kg plot^{-1} or 7732.18 kg ha^{-1}), clothianidin (13.65 kg plot^{-1} or 7585.27 kg ha^{-1}), vertimec (13.20 kg plot^{-1} or 7333.17 kg ha^{-1}) and emamectin benzoate (10.81 kg plot^{-1} or 6008.29 kg ha^{-1}) being on par with each other resulting in 199.41, 180.01, 173.01, 163.18, 156.03, 151.16, 142.82 and 98.95% increase in yield respectively over control. Among the treatments, indoxacarb (9.96 kg plot^{-1} or 5533.19 kg ha^{-1}) and flubendiamide (9.36 kg plot^{-1} or 5202.71 kg ha^{-1}) were on par with each other and recorded significantly less yield with 83.22 and 72.27% increase in yield but was significantly superior over control. The untreated control recorded the lowest yield (5.44 kg plot^{-1} or 3020.05 kg ha^{-1}) and was found inferior to all other treatments. However, from the point of cost benefit ratio (CBR) highest CBR 1: 2.23 was recorded in spinosad followed by diafenthiuron (1: 2.21), fipronil (1: 2.03), imidacloprid (1: 1.96), chlorfenapyr (1: 1.90), clothianidin (1: 1.88), vertimec (1: 1.79), emamectin benzoate (1: 1.46), indoxacarb (1: 1.34) and flubendiamide (1: 1.26).

Table 5: Effect of treatments on yield of green chillies during *Kharif* 2009-10

Treatments	Conc. (%)	Kg/plot	Kg/ha	% increase over control	Gross returns Rs/ha	Cost Benefit ratio
Fipronil	0.01	14.84^{cd}	8244.93	173.01	164898.60	1:2.03
Pymetrozine	0.02	15.22^{bc}	8456.41	180.01	169128.20	-
Imidacloprid	0.005	14.31^{cde}	7948.29	163.18	158965.80	1:1.96
Diafenthiuron	0.045	16.28^{ab}	9042.33	199.41	180846.60	1:2.21
Vertimec	0.001	13.20^{f}	7333.17	142.82	146663.40	1:1.79
Spinosad	0.015	16.49^{a}	9162.31	203.38	183246.20	1:2.23
Emamectin benzoate	0.003	10.81^{g}	6008.29	98.95	120165.80	1:1.46
Indoxacarb	0.015	9.96^{gh}	5533.19	83.22	110663.80	1:1.34
Flubendiamide	0.012	9.36^{h}	5202.71	72.27	104054.20	1:1.26
Clothianidin	0.003	13.65ef	7585.27	151.16	151705.40	1:1.88
Chlorfenapyr	0.01	13.92^{def}	7732.18	156.03	154643.60	1:1.90
Untreated check	-	5.44^{i}	3020.05	-	60401.00	1:0.75
F-test		Sig.				
SEd		0.53				
CD (p=0.05)		1.10				

Numbers followed by the same letter in each column are not significantly different

3.4.3 Mean yield for Kharif 2008-09 and 09-10

The mean data pertaining to the yield of chilli presented in Table 6 indicated that the yield obtained from all the plots ranged between 5.24 to 16.29 kg plot^{-1} including untreated control.

Table 6: Effect of treatments on yield of green chillies during *Kharif* 2008-09 and 09-10 (pooled data)

Treatments	Conc. (%)	Kg/plot	Kg/ha	% increase over control	Gross returns Rs/ha	Cost Benefit ratio
Fipronil	0.01	14.64^{bc}	8134.97	179.55	162699.40	1:2.01
Pymetrozine	0.02	15.02^{b}	8346.45	186.81	166929.04	-
Imidacloprid	0.005	14.11^{cd}	7838.33	169.35	156766.55	1:1.95
Diafenthiuron	0.045	16.08^{a}	8932.38	206.95	178647.53	1:2.20
Vertimec	0.001	13.00^{e}	7223.20	148.22	144464.06	1:1.78
Spinosad	0.015	16.29^{a}	9052.36	211.07	181047.15	1:2.22
Emamectin benzoate	0.003	10.62^{f}	5898.31	102.69	117966.24	1:1.44
Indoxacarb	0.015	9.76f^{g}	5423.21	86.36	108464.17	1:1.32
Flubendiamide	0.012	9.17^{g}	5092.73	75.00	101854.51	1:1.24
Clothianidin	0.003	13.46^{de}	7475.30	156.88	149506.10	1:1.86
Chlorfenapyr	0.01	13.72^{de}	7622.22	161.93	152444.32	1:1.89
Untreated check	-	5.24^{h}	2910.05	-	58200.97	1:0.73
F-test		Sig.				
SEd		0.43				
CD (p=0.05)		0.88				

Numbers followed by the same letter in each column are not significantly different

Among the treatments spinosad recorded the highest yield of 16.29 kg plot^{-1} (9052.36 kg ha^{-1}) with an increase of 211.07% yield over control and was found significantly superior to all the other treatments. Treatments that were moderately better in recording the higher yields were diafenthiuron (16.08 kg plot^{-1} or 8932.38 kg ha^{-1}), pymetrozine (15.02 kg plot^{-1} or 8346.45 kg ha^{-1}), fipronil (14.64 kg plot^{-1} or 8134.97 kg ha^{-1}), imidacloprid (14.11 kg plot^{-1} or 7838.33 kg ha^{-1}), chlorfenapyr (13.72 kg plot^{-1} or 7622.22 kg ha^{-1}), clothianidin (13.46 kg plot^{-1} or 7475.30 kg ha^{-1}), vertimec (13.00 kg plot^{-1} or 7223.20 kg ha^{-1}) and emamectin benzoate (10.62 kg plot^{-1} or 5898.31 kg ha^{-1}) being on par with each other resulting in 206.95, 186.81, 179.55, 169.35, 161.93, 156.88, 148.22 and 102.69% increase in yield respectively over control. Among the treatments, indoxacarb (9.76 kg plot^{-1} or 5423.21 kg ha^{-1}) and flubendiamide (9.17 kg plot^{-1} or 5092.73 kg ha^{-1}) were on par with each other and recorded significantly less yield with 86.36 and 75.00% increase in yield but was significantly

superior over control. The untreated control recorded the lowest yield (5.24 kg plot^{-1} or 2910.05 kg ha^{-1}) and was found inferior to all other treatments. However, from the point of cost benefit ratio (CBR) highest CBR 1: 2.22 was recorded in spinosad followed by diafenthiuron (1: 2.20), fipronil (1: 2.01), imidacloprid (1: 1.95), chlorfenapyr (1: 1.89), clothianidin (1: 1.86), vertimec (1: 1.78), emamectin benzoate (1: 1.44), indoxacarb (1: 1.32) and flubendiamide (1: 1.24).

4. Conclusions

The overall cumulative efficacy of the observations made at one, three, ten and fourteen days after each of five sprayings at fourteen days intervals during both the years showed that spinosad was significantly superior over rest of the treatments and showed 82.35% mean reduction of thrips population. This is probably due to its recent introduction in to chilli ecosystem which had novel mode of action. It acts on the central nervous system by activation of nicotinic acetylcholine receptors and also effects on GABA receptor. The second best treatment was found to be diafenthiuron with 81.26% mean reduction of thrips population. This is probably due to diafenthiuron is a new molecule belonging to thiourea group and it inhibits the mitochondrial ATP synthesis. The next best treatment was pymetrozine with 76.97% mean reduction of thrips population. This is probably due to pymetrozine is a new molecule belonging to pyridine azomethines group and it blocks the stylet penetration. The next best treatment was found to be fipronil with 75.62% mean reduction of thrips population. This is probably due to fipronil is a new molecule belonging to phenyl pyrazole group. It acts on central nervous system by blocking GABA receptors (Walunj *et al*., 2000).

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