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Field efficacy of insecticides against chilli thrips (*Scirtothrips dorsalis)* and their effect on coccinellids

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ABSTRACT

Considering the economic significance of *S. dorsalis* in chilli crop, a study was carried out at the ICAR-Research Complex for Eastern Region, Farming System Research Centre for Hill and Plateau Region, Ranchi, Jharkhand during the spring season of 2019 and 2020 to find out the effective chemical molecules for managing this pest. Effectiveness of 8 modern insecticides against *S. dorsalis* and their effect on coccinellid predators was evaluated. Efficacy of insecticides was determined by comparing number of thrips, immature stages and adults of natural enemies, marketable yield in insecticide treated versus untreated control plots. Application of spinosad @70 g *a.i.*/ha, Emamectin benzoate 5 SG @11 g *a.i.*/ha, Imidacloprid 200 SL @40 g *a.i.*/ha and Fipronil 5 SC @30 g *a.i.*/ha were found to be effective against *S. dorsalis* in chilli. Other insecticides were inconsistent in effectiveness against *S. dorsalis* population. Fenpropathrin followed by Imidacloprid were found to cause maximum reduction and Spinosad and Emamectin benzoate caused lowest reduction of coccinellid population. Thus, based on the present study, Spinosad, Emamectin benzoate, Fipronil and Imidacloprid are recommended to manage *S. dorsalis* on rotational basis in chilli ecosystem.

Keywords: Bioefficacy, Chilli, Natural enemies, *Scirtothrips dorsalis*

Chilli thrips [*Scirtothrips dorsalis* (Hood)] is reported to be a serious insect pest of chilli (*Capsicum annuum* L. and *Capsicum frutescens* L.) in India (Kumar *et al.* 2014, Moanaro and Choudhary 2018). Nymphs and adults suck the sap from tender leaves, growing buds, flowers, and young fruits by scraping surface and by piercing plant cells, which lead to upward curling of the leaves (Seal and Kumar 2010, Moanaro and Choudhary 2016). Chilli thrips complex is reported to be causing yield losses to the extent of 50–90% in India (Sireesha *et al.* 2021). In addition, *S. dorsalis* is also a vector of several viruses such as tomato spotted wilt tospo virus, tobacco streak virus, peanut chlorotic fan-spot virus, acacia bunchy top virus and bud necrosis, and bacterial leaf spot bacterium (Rotenberg *et al.* 2015). Beside chilli, *S. dorsalis* causes economic damage to banana, bean, cotton, eggplant, grapes, litchi, melon, onion, peach, tomato and several ornamental plants (Kumar *et al.* 2014).

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Inappropriate use of the insecticides in vegetables for managing insect pests is a common practice among the farmers (Weinberger and Srinivasan 2009). In India, *S. dorsalis* have reported resistance to a wide range of insecticides like organo-chlorines, organophosphates, and carbamate insecticides (Rao *et al.* 2019). Small size, mobility, numerous generations in a year, high level of damage capacity and availability of host plants throughout the year are major reasons, which make management of *S. dorsalis* difficult. Considering economic importance of *S. dorsalis* on fruits, vegetables, commercial crops and ornamental plants, development of efficient management programme has become necessary. Several insecticides have been reported effective against chilli thrips however, evidence of resistance and negative effects on non-target beneficial arthropods has highlighted the need for screening of alternative products that can be incorporated into the successful integrated pest management (IPM) programmes (Rao *et al.* 2019). Information on effective and eco-friendly alternative insecticides that can singly or in combination with other novel insecticides, safely manage *S. dorsalis* in chilli crop is very important. Thus, the present study was aimed to report a comparative effectiveness of various insecticides against chilli thrips (*S. dorsalis*) and their effects on coccinellids predators.

MATERIALS AND METHODS

Field experiments were conducted at the Research Farm of ICAR Research Complex for Eastern Region, Farming System Research Centre for Hill and Plateau Region, Ranchi (23^{o} 45’ N, 85^{o}30’E, altitude 620 m amsl) Jharkhand, during spring season of 2019 and 2020. Seedlings of 40 days old chilli variety Swarna Praphulya were prepared in the plastic pro-trays and were transplanted in 3.0 m × 2.5 m size plot with spacing of 60 cm × 50 cm. Seedlings were transplanted during 3rd week of March during both years. All the recommended agronomic practices were followed according to Singh and Kumar (2006) except plant protection to raising the good cropping. Experiment consisted of eight chemical insecticides representing different IRAC mode of action groups, i.e. nAChR allosteric, nAChR agonist, respiration targets, chitin synthetase inhibitors (Sparks and Nauen 2015). Details of each insecticide such as trade name and dosage of its active ingredient are given in Table 1 and 2. Treatments were applied at time of fruiting stage of crop on crossing economic threshold level (ETL) of thrips twice at 10 days interval. Treatments were arranged in randomized block design (RBD) with three replications. Small handheld sprayer was used for application of treatments on foliage. Sprayer was thoroughly washed after application of each treatment. Treatments were evaluated carefully from five randomly selected plants in each plot using a 10x-hand lens. Total number of adults and larvae found on growing tips and flowers per plant were counted. First observation was counted on same day before the application of treatment. Post-spray observation was made at 24 and 96 h after application of both sprays. Similarly, number of grubs and adult of coccinellids (*Cheilomenes sexmaculata* (Fabricius)) per plant were counted and total five randomly selected plants were taken into the consideration for observation of pre-spray and after 24 h of treatment application (post-spray) from each plot. Marketable/economic yields from each plot were weighed to assess the impact of treatments on chilli fruit yield. Square root transformations were applied to the data before further analysis. Transformed data were analyzed using one way analysis of variance (ANOVA) and means were separated, when F-test was significant at 5% probability by using Tukey’s honest significant difference (HSD) test in SPSS version 21 program. Additionally, principal component analysis (PCA) was done through XLSTAT using pooled data to find the affinities between per cent reduction of thrips over the control, yield data and natural enemies’ population in different treatments (Gowda *et al.* 2019).

RESULTS AND DISCUSSION

Incidence of chilli thrips was encountered in chilli crop during both the years of study. Pre-treatment population of thrips at the time of first spraying ranged from 4.78–6.0 and 4.11–5.78 thrips per plant during 2019 and 2020, respectively (Table 1 and 2) and range of thrips number was statistically non-significant among treatments. After 24 h of first spraying, there was significant variation of thrips population among treatments except the control. It was ranged in between 0.22–6.11 ($F_{(8, 64)}$ =30.10, P<0.0001) and 0.11–5.44 ($F_{(8, 64)}$ =10.67, P<0.0001) for 2019 and 2020, respectively. Application of fipronil @30 g *a.i.*/ha resulted in the highest reduction of *S. dorsalis* during both the seasons. Treatments of spinosad and imidacloprid along with fipronil were also equally effective during the second year. Among the treatments, buprofenzin and fenpropathrin caused the least reduction of thrips after 96 h of application.

Table 1 Effect of foliar sprays of different insecticides on mean numbers of *S. dorsalis* (adults+larvae) (year 2019) on chilli plants

Treatment	Trade name and formulation	Dosage gm a.i./ ha) *	Mean number of *S. dorsalis*±S.E./plant					
			Pre-spray	24 hrs after 1st spray	96 hrs after 1st spray	10 days after spray	24 hrs after 2nd spray	96 hrs after 2nd spray
Spinosad	Tracer®45 SC	70	4.89±0.6^{a}	0.67±0.3^{bc}	0.67±0.2^{b}	3.33±0.5^{b}	0.33±0.2^{b}	0.78±0.3^{bc}
Thiacloprid	Alanto®240 SC	65	4.78±0.7^{a}	1.00±0.2^{bc}	1.78±0.2^{b}	5.22±0.5^{b}	1.00±0.3^{b}	1.56±0.3^{bc}
Spiromesifen	Oberon®240 SC	100	5.00±0.6^{a}	1.11±0.3^{bc}	1.33±0.3^{b}	4.56±0.5^{b}	1.11±0.3^{b}	1.89±0.5^{bc}
Fipronil	Regent® 5 SC	30	5.11±0.6^{a}	0.22±0.1^{c}	0.89±0.2^{b}	3.56±0.3^{b}	0.11±0.1^{c}	0.89±0.4^{bc}
Buprofezin	Apple® 25 SC	125	6.00±1.0^{a}	1.44±0.3^{b}	1.78±0.3^{b}	5.22±1.0^{b}	1.33±0.4^{b}	1.89±0.6^{bc}
Emamectin benzoate	Proclaim® 5 SG	11	6.00±0.8^{a}	0.67±0.2^{bc}	1.00±0.2^{b}	3.78±0.5^{b}	0.89±0.5^{b}	0.44±0.2^{c}
Fenpropathrin	Fenthrin® 30 EC	75	5.56±0.7^{a}	1.11±0.2^{bc}	2.00±0.5^{b}	5.44±0.9^{b}	1.22±0.4^{b}	2.22±0.5^{b}
Imidacloprid	Confidor® 200 SL	40	5.56±0.6^{a}	0.56±0.2^{bc}	1.44±1.0^{b}	3.11±0.6^{b}	0.56±0.2^{b}	0.33±0.2^{c}
Control	Water		6.00±0.5^{a}	6.11±0.7^{a}	7.33±1.1^{a}	11.89±1.0^{a}	10.44±0.8^{a}	10.67±0.9^{a}
Statistical analysis								
F cal			0.60	30.10	11.34	13.86	60.81	39.66
df			8, 64	8, 64	8, 64	8, 64	8, 64	8, 64
CD (P=0.05)			0.78	0.0001	0.0001	0.0001	0.0001	0.0001

Means within a column followed by a similar letter(s) do not differ significantly (P>0.05; DMRT). *All sprays were applied in water solutions at 500 l/ha (50 ml/m^{2}).

Table 2 Effect of foliar sprays of different insecticides on mean numbers of *S. dorsalis* (adults+larvae) (year 2020) on chilli plants

Treatment	Trade name and formulation	Dosage gm a.i./ ha) *	Mean number of *S. dorsalis*±S.E./plant					
			Pre-spray	24 hrs after 1st spray	96 hrs after 1st spray	10 days after spray	24 hrs after 2nd spray	96 hrs after 2nd spray
Spinosad	Tracer®45 SC	70	5.33±0.8^{a}	0.33±0.2^{c}	0.56±0.3^{b}	3.44±0.9^{c}	0.11±0.1^{c}	0.67±0.4^{bc}
Thiacloprid	Alanto®240 SC	65	5.78±1.0^{a}	1.33±0.3^{bc}	1.78±0.4^{b}	5.11±1.2^{bc}	1.89±0.6^{bc}	2.33±0.8^{bc}
Spiromesifen	Oberon®240 SC	100	5.56±1.2^{a}	1.67±0.6^{bc}	1.89±0.6^{b}	5.33±1.1^{bc}	1.78±0.8^{bc}	2.56±0.6^{bc}
Fipronil	Regent® 5 SC	30	5.22±1.4^{a}	0.11±0.1^{c}	1.11±0.4^{b}	4.11±0.8^{c}	0.00±0.0^{c}	0.56±0.3^{bc}
Buprofezin	Apple® 25 SC	125	5.67±1.3^{a}	2.11±0.5^{b}	2.67±0.9^{ab}	8.67±1.9^{ab}	2.33±0.8^{b}	2.78±1.0^{b}
Emamectin benzoate	Proclaim® 5 SG	11	4.89±0.9^{a}	0.56±0.2^{bc}	1.00±0.5^{b}	3.80±0.9^{c}	0.11±0.1^{c}	0.78±0.5^{bc}
Fenpropathrin	Fenthrin® 30 EC	75	4.56±1.1^{a}	0.89±0.4^{bc}	2.44±0.9^{ab}	7.11±1.1^{abc}	2.11±0.9^{bc}	2.89±0.9^{b}
Imidacloprid	Confidor® 200 SL	40	4.11±1.0^{a}	0.44±0.2^{c}	1.89±1.7^{b}	3.12±0.7^{c}	0.44±0.2^{bc}	0.33±0.2^{c}
Control	Water		5.11±1.0^{a}	5.44±1.1^{a}	5.11±1.2^{a}	9.44±2.3^{a}	8.22±1.1^{a}	7.89±1.1^{a}
Statistical analysis								
F cal			0.29	10.67	2.23	3.19	14.65	10.12
df			8, 64	8, 64	8, 64	8, 64	8, 64	8, 64
CD (P=0.05)			0.97	0.0001	0.001	0.04	0.0001	0.0001

Means within a column followed by a similar letter(s) do not differ significantly (P>0.05; DMRT). *All sprays were applied in water solutions at 500 l/ha (50 ml/m^2).

After 10 days of application, none of the insecticides were found to be effective against *S. dorsalis* (($F_{(8, 64)}$=13.86, <0.001) and ($F_{(8, 64)}$=3.19, P=0.04)). Second spray of fipronil, spinosad and emamectin benzoate significantly suppressed thrips population at 24 h of application (Table 2). However, level of suppression by fipronil, spinosad and emamectin benzoate did not differ significantly from that of emamectin benzoate and spiromesifen after 96 h of second spray. Application of imidacloprid @40 gm *a.i.*/ha as second spray had maximum suppression of thrips during both the years. Sucking sap by thrips definitely causes some damage to chilli plants but vector of leaf curl virus causes greater damage in significance. Application of the synthetic insecticide have always been main form of pest management strategy amongst chilli growers because low damage threshold of chilli plants due to many pests associated as vector of virus diseases. For management of sucking pests, several chemistries with novel modes of action have been introduced with most significant being the neonicotinoids, spiromesifen, pymetrozine (Palumbo 2009). Present study was initiated to evaluate the potentially suitable insecticides with different modes of action that could be used as curative measures for suppression of *S. dorsalis* in chilli. Eight chemical insecticides representing seven different modes of action groups defined by Insecticide Resistance Action Committee (IRAC) were considered for evaluation (Sparks and Nauen 2015). Based on mortality and suppression of thrips population insecticides, spinosad @70 g *a.i.*/ha, emamectin benzoate @11 g *a.i.*/ha, imidacloprid @40 g *a.i* /ha and fipronil @30 g *a.i.*/ha were observed effective during both the seasons. In line of the present study, Seal *et al.* (2006) reported second foliar application of chlorfenapyr, spinosad, imidacloprid, and abamectin significantly reduced the larval populations of *S. dorsalis*. Similar results on efficacy of spinosad for *S. dorsalis* management were reported by Seal and Kumar (2010), indicating it is still one of most effective tools for management of *S. dorsalis*. One application of emamectin benzoate/chlorfenapyr along with some plant products was found to be much better in suppression of leaf curling intensity in chilli (Chakraborti *et al.* 2015). Effectiveness of emamectin benzoate in the present study was also supported by study conducted by Ravikumar *et al.* (2016), where they reported that emamectin benzoate 5 SG @0.4 g per litre of water was very effective against chilli thrips, *S. dorsalis.* A study conducted on efficacy of biorational insecticides against chilli thrips, *S. dorsalis* by Aristizábal *et al.* (2017) was also consistent with present study where consistent use of spinosad was the most effective treatment against chilli thrips.

Chilli thrips (*S. dorsalis*) populations have been found to be resistant to a range of conventional chemical insecticides classes including organochlorine (DDT, BHC, endosulfan), organophosphate (acephate, dimethoate, phosalone, methyl-o-demeton and triazophos) and carbamate insecticide (carbaryl) (Rao *et al.* 2019). Thus, it is imperative to evaluate the newer classes of insecticides and integrate them in a management program. Effective insecticide imidacloprid is a neonicotinoid precursor that is converted to clothianidin in insects and plants. It is a second-generation neonicotinoid compound that disrupts binding of insect neurotransmitter acetylcholine at its nicotinic acetylcholine receptors present at the post-synaptic cell junctures. Imidacloprid is a broad-spectrum insecticide known for its activity against many sucking pests, including thrips (McKenzie *et al.* 2015). Spinosad is altering function of nicotinic and GABA-gated ion channels, causing rapid excitation of insect nervous

Table 3 Coccinellids, *C. sexmaculata* (adult+grubs) numbers in different applied insecticides during 2019 and 2020

Treatment	2019 (Number of coccinellids/plant)		2020 (Number of coccinellids/plant)	
	Pre-spray	After spray	Pre-spray	After spray
Spinosad	0.22±0.1^{a} (0.85)	0.67±0.2^{b} (1.08)	0.44±0.2^{a} (0.97)	0.56±0.2^{ab} (1.03)
Thiacloprid	0.33±0.2^{a} (0.91)	0.22±0.1^{a} (0.85)	0.22±0.1^{a} (0.85)	0.44±0.2^{ab} (0.97)
Spiromesifen	0.22±0.1^{a} (0.85)	0.56±0.2^{ab} (1.03)	0.33±0.2^{a} (0.91)	0.56±0.2^{ab} (1.03)
Fipronil	0.44±0.2^{a} (0.97)	0.44±0.2^{ab} (0.97)	0.11±0.1^{a} (0.78)	0.33±0.2^{a} (0.91)
Buprofezin	0.33±0.2^{a} (0.91)	0.67±0.2^{b} (1.08)	0.11±0.1^{a} (0.78)	0.78±0.3^{b} (1.13)
Emamectin benzoate	0.22±0.1^{a} (0.85)	0.78±0.2^{b} (1.13)	0.33±0.2^{a} (0.91)	0.78±0.3^{b} (1.13)
Fenpropathrin	0.56±0.2^{a} (1.03)	0.0±0.0^{a} (0.71)	0.22±0.1^{a} (0.85)	0.11±0.1^{a} (0.78)
Imidacloprid	0.44±0.2^{a} (0.97)	0.11±0.1^{a} (0.78)	0.33±0.2^{a} (0.91)	0.22±0.1^{a} (0.85)
Control	0.11±0.1^{a} (0.78)	0.89±0.3^{b} (1.18)	0.56±0.2^{a} (1.03)	1.00±0.4^{b} (1.22)
Statistical analysis				
F cal	0.62	2.30	0.67	2.38
df	8, 64	8, 64	8, 64	8, 64
CD (P=0.05)	0.77	0.03	0.71	0.02

Figure in the parentheses are √x+0.5 values.

system. It belongs to the naturalyte class of insecticides (Zhao *et al.* 2006). Emamectin benzoate is a semisynthetic and second generation avermectin insecticides, which was registered to control lepidopteran pests and/or leaf miners in cole crops, leafy and fruiting vegetables at low rates (Zhao *et al.* 2006). Fipronil is a member of fiproles, who acts on chloride channels blocking activation of GABA. So, these effective insecticides from multiple modes of action groups with rotational options are available for regulating thrips population in chilli crop.

Coccinellids, *C. sexmaculata* was observed as major natural enemy in chilli ecosystem. Differential toxicity of various applied insecticides on coccinellids, *C. sexmaculata* is presented in Table 3. Mean number of coccinellids before application of insecticides did not differ statistically among the treatments, which ranged from 0.11 to 0.56 coccinellids per plant (($F_{(8, 64)}$= 0.62, P=0.77) and ($F_{(8, 64)}$ = 0.67, P=0.71) during 2019 and 2020, respectively. After application of insecticides, mean numbers of coccinellids decreased significantly in fenpropathrin treated plants followed by imidacloprid and thiacloprid treated plants ($F_{(8, 64)}$=2.30 and 2.36, P=0.03 and 0.02 in 2019 and 2020, respectively). Mean numbers of coccinellids in spinosad and emamectin benzoate treatments did not differ statistically from those in control. Mean number of coccinellids in fipronil and spiromesifen treated plants differed significantly in between control plants and fenpropathrin treated plants. In comparison with conventional insecticides (fenpropathrin), novel molecules (spinosad and emamectin benzoate) were found to be safer to natural enemies in the present study. Previous study by Dhanalakshmi and Mallapur (2008) also reported that emamectin benzoate and spinosad were comparatively safer to natural enemies. Reduction in coccinellid and spider population following application of broad-spectrum insecticides i.e. chlorpyriphos, deltamethrin and lambda-cyhalothrin might be due to non-targeted impacts on their biology, growth and reproduction. Toxic effect of the synthetic pyrethroid (fenpropathrin) on coccinellids was also observed in the present study. Similarly, application of synthetic pyrethroid (deltamethrin) was reported as the most detrimental compound with 100% mortality of coccinellid species, *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) (Garzon *et al.* 2015). The present results are in accordance with findings of Sujay Anand *et al.* (2013), who reported sudden decrease in number of coccinellids after spraying of neonicotinoid group of insecticides namely thiamethoxam and acetamiprid in brinjal ecosystem.

Principal components were extracted from different insecticidal treatments in relation to yield and coccinellids population for scree plot with eigen value>1.0. The cumulative data of coccinellid population and yield on different insecticidal treatments is presented in Fig 1. PC1

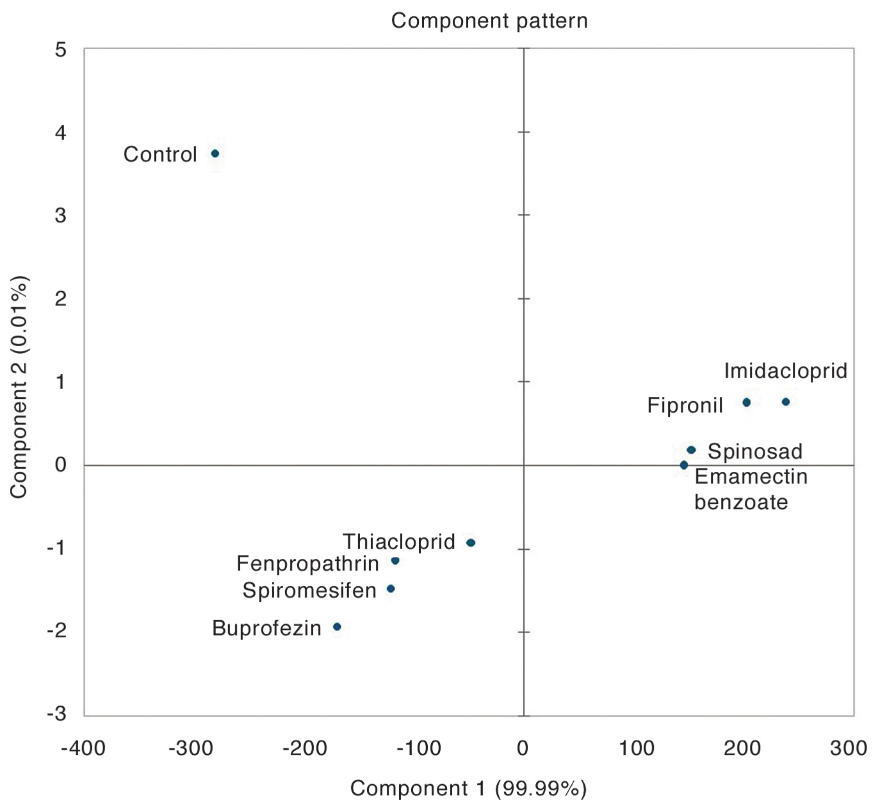

Fig 1 Principal component analysis based on mean population of thrips after application of treatments, coccinelid and marketable yield among the insecticidal treatments.

depicted a variation of 99.99% and PC2 depicted variation of 0.01%. Among the tested chemicals in PC1, spinosad has strong relation with emamectin benzoate followed with fipronil and imidacloprid. Affinity of these insecticides is biased due to high yield of chilli in treated plots. Insecticides i.e. thiacloprid, fenpropathrin, spiromesifen and buprofenzin were separated from other chemicals and control. Even though, imidacloprid and thiacloprid are same group of insecticides but in principal component analysis, they showed low affinity with each other. This was resulted due to high yield variation and thrips population dynamics in respective plant. Variation in yield of green chilli after application of treatments was explained earlier by several workers (Chatterjee and Mondal 2012, Kumar and Sarada 2015). Chatterjee and Mondal (2012) reported increase in the yield of chilli on application of chlorfenapyr and emamectin benzoate. Similarly, Kumar and Sarada (2015) found higher cost:benefit ratio of emamectin benzoate followed by chlorfenapyr against the chickpea pests. These researchers findings about other crops and pests have somewhat validated the present investigation.

In conclusion, present study provides a valuable information on management of chilli thrips, *S. dorsalis* using the various chemical insecticides and their effect on coccinellid predator. Insecticide, fipronil was the most effective in controlling *S. dorsalis* population followed by spinosad, imidacloprid and emamectin benzoate. Imidacloprid was moderately harmful and fipronil was slightly harmful to coccinellids population. Most effective insecticides used for *S. dorsalis* management did not reduce the coccinellid population significantly except imidacloprid, which had lower population than control. Spinosad and emamectin benzoate were least harmful to coccinellids in chilli agro-ecosystem. Based on the component analysis of effectiveness of insecticides, toxicity to coccinellids and yields of treated plots suggest that application of spinosad @70 g *a.i.*/ha, emamectin benzoate @11 g *a.i.*/ha, imidacloprid @40 g *a.i*/ha and fipronil @30 g *a.i.*/ha may be followed in chilli ecosystem against *S. dorsalis* management. Repeat spray of suggested insecticides may be needed at 7-day intervals in rotation with different modes of action, which will delay development of resistance in *S. dorsalis* against any of these specific insecticides.

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