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Research Article

Comparative Study of Two Synthetic Insecticides Spiromesifen and Thiamethoxam to Determine their Acute and Residual Toxicity against Lynx Spider (*Oxyopes javanus*)

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Authors' Contributions
HN conducted research, drafted manuscript and analyzed the data. AB presented the concept for study, interpreted the data and proofread the manuscript.

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Acute toxicity, *Oxyopes javanus*, Residual toxicity, Spiromesifen, Thiamethoxam

Abstract | Integration of biological and chemical control methods are required to successfully manage insect pests. Along with insect pests, many predators of these pests are also present in crops and affected by these management activities. Spiders are the most abundant predators of insect pests in the agroecosystem. The present study was designed to assess and compare acute and residual toxicity of two insecticides *i.e* Spiromesifen and Thiamethoxam on the lynx spider *Oxyopes javanus* Thorell, 1887 under laboratory conditions. The field rate of both insecticides caused approximately 50% mortality in the population of *O. javanus*. Toxicity data showed that these insecticides are slightly harmful (caused < 80% mortality) towards studied spider. Insecticide residues of different ages were used to evaluate the residual toxicity of both insecticides. Mortality in exposed spiders decreased with the increased age of the residues. The results of both assays showed that male spiders were more susceptible than female spiders in both acute and residual toxicity tests. The residues study data showed that spiromesifen is short- lived (< 5 days aged residues cause < 30% mortality) and that thiamethoxam is slightly persistent (5–15 days aged residues cause < 30% mortality).

Novelty Statement | The acute and residual toxicity of the tested insecticides, Spiromesifen and Thiamethox-am is determined first time on the male, female and total population of lynix spider *Oxyopes javanus*.

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Introduction

To meet the increasing demand of food, insecticides are used for the management of agricultural insect pests throughout the world (Tilman *et al.*, 2001; Gupta *et al.*, 2019). But the use of insecticides have adversed affectes on the density and diversity of natural predators in agroecosystems by killing them directly or by reducing their prey and leading to starvation (Pekar, 2012; Zhang *et al.*, 2015). Extensive use of insecticides decline the population of pollinators (Henry *et al.*, 2012; Whitehorn *et al.*, 2012), seed dispersers (Donald *et al.*, 2001) and biological control agents in agroecosystems (Geiger *et al.*, 2010). As a result, natural enemies cannot perform up to their full potential in integrated pest management programs. The situation is even worse in developing countries where banned or restricted insecticides are available in the market and still use in crop fields (Ekstrom and Ekbom, 2011).

Spiders are most diverse and abundant generalist predators in many agroecosystems (Suenaga and Hamamura, 2015; Birkhofer *et al.*, 2016). They are extremely effective in the management of insect pest population and ultimately controlling the damage to the crops (Bucher *et al.*, 2014; Beleznai *et al.*, 2017). Spiders cause direct mortality of pests through their consumptive

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effect (Lefebvre *et al*., 2017). They capture and kill more prey than they actually consume. This high rate of capture can reduce the pest number more significantly in the fields (Michalko *et al*., 2017). Spiders also cause indirect mortality in insects through their non-consumptive effect. They dislodge insect pests (aphids and caterpillars); which increased the mortality of insect pests due to their exposure to harsh environmental conditions and other predators (Sunderland, 1999).

Spiders can also control prey populations because they often capture and kill more prey than they consume. Riechert and Lockley (1984) report that a spider may kill as many as 50 times the number of prey it consumes.

Insecticides have acute as well as chronic effects on spiders. In case of acute poisoning, contact or ingestion of insecticides cause the death of individual. Many field and laboratory studies reported mortality in spiders when exposed to different insecticides (Deng *et al*., 2006; Pekar and Benes, 2008; Elzen and Pfannenstiel, 2009; Marko *et al*., 2009; Hanna and Hanna, 2014). Chronic exposure to insecticides not only causes the death directly; but it also bring several behavioral and physiological changes in spiders (El Hassani *et al*., 2008). Sub lethal effects of insecticides disturb the activity level of spiders (Wrinn *et al*., 2012), courtship behaviors (Griesinger *et al*., 2011), development time (Deng *et al*., 2006), reproductive rate (Desneux *et al*., 2007) and modify their web structure (Benamu *et al*., 2013; Pasquet *et al*,. 2016).

There are many factors that affect the mortality of spiders due to application of insecticides in the field *i.e.* concentration or dose, exposure duration, abiotic conditions and insecticide bioavailability. In agroecosystems, possible routes of uptake of insecticides by spiders are via contact with droplets of spray (Haughton *et al*., 2001), via oral uptake by feeding on insecticide contaminated prey (Navarro-Silva *et al*., 2010) and via residual contact (Dinter, 1995; Amalin *et al*., 2000). Some insecticides have long residual activity like chlorinated hydrocarbons, organophosphates and pyrethroids (Sherma, 2001). However, residual effect of few insecticides on spiders is also known but require more investigation (Mansour *et al*., 1992; Pekar and Haddad, 2005; Pekar and Benes, 2008).

Thiamethoxam is a second generation neonicotinoid. It belongs to thianicotinoil sub class and affect acetylcholine receptors of insect nervous system (Maiensfisch *et al*., 2001). It has both contact and systemic activity and used for drench, foliar, soil and seed treatment (Maiensfisch *et al*., 2001). It is very effective for the control of aphid, leafhopper and white fly in agroecosystem (Torres *et al*., 2003; Acda, 2007). However, it is toxic for naturel enemies like *Serangium japonicum* (Yao *et al*., 2015), *Hippodamia convergens, Coleomegilla maculate* (Moscardini *et al*., 2015), *Coccinella septempunctata* (Shankarganesh *et al*., 2015), *Chrysoperla carnea* (Gontijo *et al*., 2014) *and stink bug* (Torres *et al*., 2003). The sublethal concentrations of thiamethoxam adversely affect life table parameters of predatory beetle *Hippodamia variegata* (Rahmani and Bandani, 2013) and *Coccinella septempunctata* (Jiang *et al*., 2018). It impairs the navigation and homing ability of honey bee (Tosi *et al*., 2017). It also reduces colony initiation in bumble bees (Elston *et al*., 2013).

Spiromesifen (tetronicacid derivative) is a growth regulator, acts as an inhibitor of lipid biosynthesis (Sparks and Nauen, 2015). Spiromesifen is very effective against sucking insect pests in many cropping systems including vegetables, cotton and ornamentals (Liu, 2004; Palumbo, 2009). It causes lethal and sublethal effects on natural enemies e.g. predatory mite *Neoseiulus californicus*, (Kaplan *et al*., 2012; Salman and Ay, 2014; Mollaloo *et al*., 2016). It affects the life table parameters of predatory mite (Sarbaz *et al*., 2017). It reduces reproductive potential of *Galendromus occidentalis* (Irigaray and Zalom, 2007).

Oxyopes javanus (Oxyopidae) is an abundant lynx spiders in many agroecosystems throughout the world including rice (Tahir and Butt, 2008), wheat (Butt and Sherawat, 2012), tea fields (Das *et al*., 2010; Basnet and Mukhopadhyay, 2015) and cotton (Taqi *et al*., 2019). It is the predator of many important insect pest species including white back planthopper, armyworm, pink graminous stem borer, cereal aphids, leafhoppers, grasshopper nymphs and tea mosquito bug (Tahir and Butt, 2009; Sherawat and Butt, 2014; Basnet and Mukhopadhyay, 2014; Butt and Xaaceph, 2015).

Spiromesifen and thiamethoxam both insecticides are widely used in Pakistan to control insect pests in different agroecosystems (Naveed *et al*., 2010; Khan *et al*., 2013, 2015; Ma *et al*., 2019; Khan, 2019). The present study was designed to assess the acute and residual toxicity of insecticides spiromesifen and thiamethoxam on the population of *O. javanus*.

Materials and Methods

Specimens

Specimens of *O. javanus* were randomly collected from chemically untreated wheat fields of University of the Punjab, Lahore, Pakistan by sweep net and direct hand picking. Collected spiders were transferred to the laboratory and placed singly in glass container (50 mm height and 25 mm diameter). For acclimation with laboratory conditions, spiders were kept in laboratory at 27 ± 5 ˚C room temperature, 60-65 % relative humidity and 14:10 h light and dark period for atleast two days. To each spider three larvae of drosophila were provided daily as food until used in experiment. Water was continuously provided via moistened cotton wicks.

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Table 1: Tested insecticides; grouped by MOA (Mode of action) on the bases of classification by Insecticide Resistance Action Committee (IRAC), their commercial name, active ingredient (A.I) content and formulation type.

Commercial name	Chemical sub-group	Active ingredient (A.I)	Mode of action (MOA group)	Formulation	FR/ Hectare
Actara	Neonicotinoids	Thiamethoxam	Nicotinic Acetylcholine receptor (nAChR) agonists Nerve action (4)	250 g A.I/ Kg WG [a]	80 g
Oberon	Tetronic acid derivatives	Spiromesifen	Inhibitors of acetyl CoA carboxylase, Lipid synthesis. Growth regulation chemical (23)	228.6 g A.I/ L SC[b]	250 ml

[a] SC, Suspension concentrate; [b]WG, Wettable granules.

Insecticides

Commercial formulations of thiamethoxam (Actara® 25 WG by Syngenta) and spiromesifen (Oberon® SC by Bayer crop science) were purchased from local market (Table 1).

Acute toxicity assay

To check the acute toxicity, spiders were exposed directly to the insecticides by dipping method as describe by Tanaka *et al.* (2000). To prepare stock solution (spiomesifen 10 ml/ 500 ml and thiamethoxam 10g/ 500 ml), insecticide was dissolved in acetone and required concentrations (Field Rate, ½ Field Rate, ¼ Field Rate, 1/8 Field Rate and 1/16 Field Rate) were prepared by diluting this stock solution in water. A plastic vial with screen lid was used for dipping the specimens in the insecticide solution for 10 seconds. Spiders in control group were treated with the water that contain acetone in the same quantity as present in the field rate concentration. After treatment spiders were shifted into their containers with paper towel to absorb dripping insecticide and were placed in the laboratory.

Prior to experiment preliminary range finding tests were carried out to find appropriate concentration range that produce zero to 99% mortality and six doses were selected to perform experiment. Tests for all concentrations were performed simultaneously. Mortality of the spiders was assessed at 2, 4, 8, 16, 24, 36, 48, 60, and 72 hours after exposure. Absence of any response in spiders after being stimulated by fine camel hair brush was declared as dead (Sherawat *et al.*, 2015). All tests were replicated thrice and in each replicate ten spiders were present. No food was offered to spiders during the experiment.

Residual toxicity assay

To assess the residual toxicity of both insecticides against *O. javanus,* 1 L solution of tested insecticide was prepared according to maximum field application rate Table 1 (Pekar and Benes, 2008). Whatman (No. 2) filter paper sheets (10 × 10) were dipped into solution of tested insecticide for two minutes and dried. Toxicity of both insecticides residues of age <1, 5, 10 and 20 days old was assessed. For this purpose, insecticide treated sheet was rolled in the form of tubes. A single spider was released into a roll of filter paper and ends of the roll were folded to ensure permanent contact with insecticide residues. The mortality of the spiders exposed to the residues of tested insecticides was checked for three consecutive days at regular intervals *i.e.,* after 6, 12, 24, 36 48, 60 and 72 hours. For the control group similar test was performed using water. All tests were replicated thrice and in each replicate ten spiders were present.

Statistical analysis

For analysis, mortality data was divided in three groups i.e., only adult male, only adult female and whole population (65% immature of all instars, 25% adult female and 10% adult male). Population structure was based on our field collection. LC_{50} and LT_{50} was calculated for all the three groups. Concentration-mortality data was subjected to logistic model of probit analysis to calculate LC_{50} and residues age-mortality data to loglogistic model to calculate LT_{50}. The formula of probit analysis (Finney, 1971) is as following:

$$P = \alpha + \beta[\log10\ (Dose)]$$

Toxicity and Persistance categories for laboratory bioassays are given in Table 4. Toxicity and persistence of these insecticides was categorised according to IOBC (Sterk *et al.*, 1999).

The susceptibilities of male, female and whole population of spiders towards both insecticides were analysed by Complete Randomized Design One-way ANOVA following Tukeys post hoc test. Normality of the data was tested using Shapiro-Wilk test. To perform all statistical analysis Minitab 16 was used.

Results

Acute toxicity

Median lethal concentration (LC_{50}) of tested insecticides after 24 hours of application against *O. javanus* is given in Table 2.

At field rate of spiromesifen, only 75 % mortality was recorded after 72 hours of treatment. LC_{50} values showed least tolerance of males than female and whole population

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against spiromesifen ($F_{2,6}$ = 452.73; P < 0.001). According to IOBC classification, spiromesifen appeared slightly harmful towards *O. javanus* as it has caused less than 80% mortality (Table 4). Survival rate of the spiromesifen treated spiders is shown in Figure 1A.

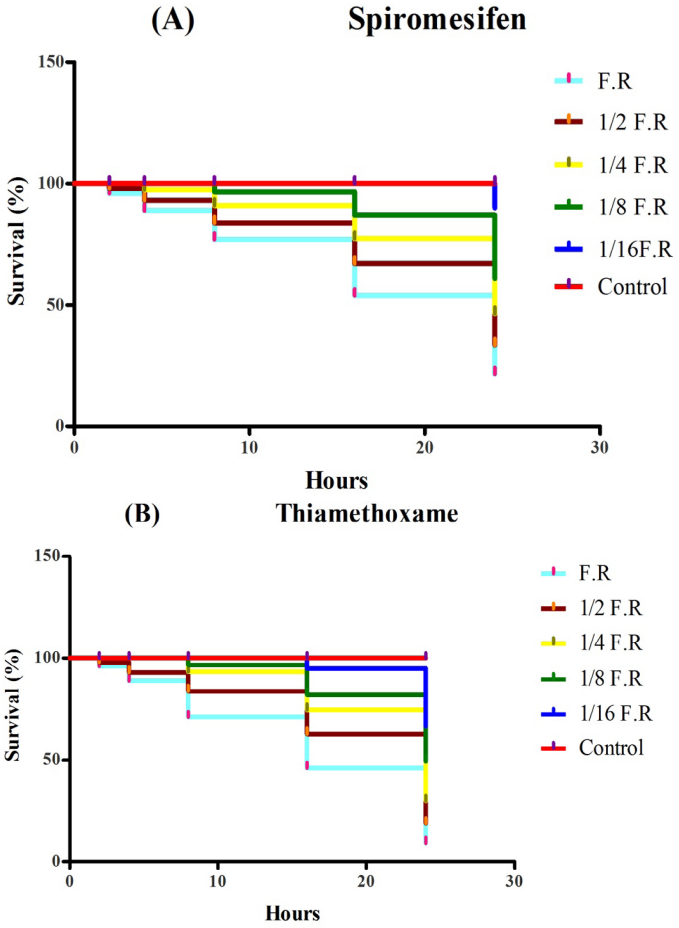

Figure 1B: Survival (%) of *Oxyopes javanus* population when exposed to different concentrarion of Spiromesifen (A) and Thiamethoxam (B).

Application of thiamethoxam at recommended field rate caused 100% mortality of spiders after 72 hours of treatment. Highest susceptibility was recorded in male spiders followed by total population and female spiders ($F_{2,6}$ = 109.15; P < 0.001). According to IOBC classification, thiamethoxam also appeared slightly harmful towards *O. javanus* (Table 4). Survival rate of Thiamethoxam treated spiders is shown in Figure 1B.

The assessment of LC_{50} values as fraction of maximum field recommended concentrations ranges approximately from 0.7 to 1.0 for both insecticides. It also showed that both insecticides are slightly harmfull for this spider (Table 2). Survival of the control group was 100% after 24 hours of treatment (Figure 1A, 1B).

Residual toxicity

In residual contact bioassays, mortality decrease in spider when exposed to more aged residues of both insecticides, in all categories of spiders *i.e* male, female and whole population, Table 3.

The effect of different aged residues of spiromesifen was significantly different on all categories (residue age, $F_{3,35}$ = 115.51, P < 0.001 , categories of spiders, $F_{3,35}$ = 11.93, P < 0.001). The female spiders were least affected by aged residues of spiromesifen as 10 days old residues did not caused mortality in this category. According to IOBC classification spiromesifen was placed in class A *i.e.,* short lived insecticide because its 5 days old residues produced < 30% mortality in *O. javanus* (Table 4, Figure 2A).

The effect of different aged residues of thiamethoxam on all tested categories was significantly different (residue age, $F_{3,35}$ = 460.49, P < 0.001 ; categories of spiders, $F_{3,35}$ = 258.25, P < 0.001). Female spiders were least effected by aged residues of thiamethoxam as 20 days old residues did not caused any mortality in spiders. According to IOBC classification thiamethoxam was placed in class B *i.e.* slightly persistent because less than 30 % mortality was recorded in *O. javanus* at 5-15 days old residues (Table 4, Figure 2B).

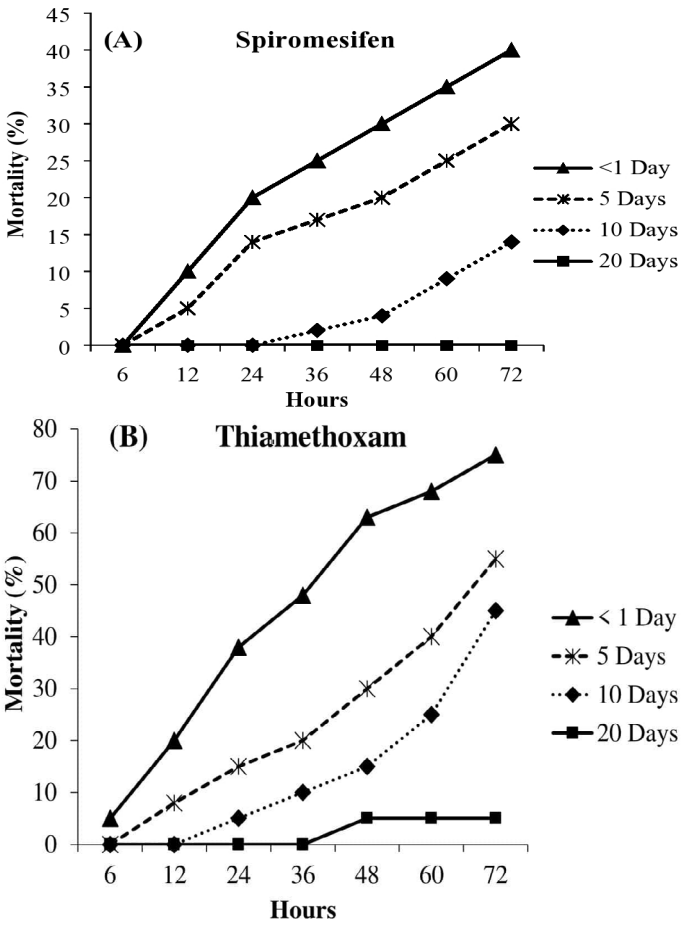

Figure 2: Mortality (%) of *O. javanus* population when exposed to different age residues of Thiamethoxam (A) and spiromesifen (B).

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Table 2: Concentration of insecticide formulation tested for acute toxicity to male, female and total population of spiders.

Compound	Population sex number		Formulation Con.tested (ppm)	LC_{50} (ppm)	LC_{50} as-fraction of MFRC	LC_{90} as Fraction of MFRC	α	β	χ^2	P-value
	Male	180	63 – 2000	799.933[c]	0.799	1.913	1.579	0.002	31.742	< 0.001
Spiromesifen	Female	500	63 – 2000	1048.20[a]	1.048	2.407	1.695	0.002	29.149	< 0.001
	Population	800	63 – 2000	922.444[b]	0.922	2.160	1.637	0.002	30.187	< 0.001
	Male	180	18.9 – 600	212.027[c]	0.707	1.655	1.638	0.007	58.748	< 0.001
Thiamethoxam	Female	540	18.9 – 600	325.590[a]	1.085	2.277	1.999	0.006	30.926	< 0.001
	Population	900	18.9 – 600	2 266.399[b]	0.888	1.978	1.788	0.007	42.839	< 0.001

Median lethal toxicity (LC_{50}) after 24 hours of insecticide exposure, and LC_{50} as the fraction of the maximum field recommended concentration (MFRC), α is the intercept and β is the slope while χ^2 is showing goodness of fit of the model.

Table 3: Toxicity of aged insecticide residues of field rate concentration tested for male, female and total population of spiders, their median lethal time (LT_{50}) after exposure to insecticide residues, α is the intercept and β is the slope while χ^2 is showing goodness of fit of the model.

Insecticide	Population category number		Residue age (Days)	LT_{50} (Hours)	α	β	χ^2	P-value
Spiromesifen	**Male**	30	< 1	81.586	0.999	0.012	0.001	<0.001
		30	5	89.653	1.784	0.012	0.495	<0.001
		30	10	94.136	10.200	2.244	0.151	<0.001
		30	20	No mortality	-	-	-	-
	Female	30	< 1	147.153	5.477	1.097	0.613	<0.001
		30	5	258.470	6.117	1.101	0.038	<0.001
		30	10	No mortality	-	-	-	-
		30	20	No mortality	-	-	-	-
	Population	30	< 1	120.670	2.543	0.531	0.109	<0.001
		30	5	223.173	2.701	0.499	0.407	<0.001
		30	10	129.270	8.849	1.820	0.173	<0.001
		30	20	No mortality	-	-	-	-
Thiamethoxam	Male	30	< 1	29.214	2.693	0.798	2.334	<0.001
		30	5	58.077	4.010	0.987	0.416	<0.001
		30	10	79.843	5.180	1.182	4.388	<0.001
		30	20	216.680	5.539	1.030	4.683	<0.001
	Female	30	< 1	39.901	3.590	0.974	0.531	<0.001
		30	5	79.843	5.180	1.182	4.388	<0.001
		30	10	79.063	11.437	2.617	0.116	<0.001
		30	20	No mortality	-	-	-	-
	Population	30	< 1	33.587	3.148	0.896	0.014	<0.001
		30	5	69.109	4.444	1.049	1.811	<0.001
		30	10	84.051	6.453	1.456	3.142	<0.001
		30	20	392.461	5.353	0.896	2.362	<0.001

Discussion

Natural enemies are usually more sensitive to insecticides, because in them resistance against insecticides develop slowly as compared to their prey (Hill and Foster, 2000; Xu *et al*., 2001). In this study acute and residual toxicity of insecticides Thiaethoxam and Spiromesifen on hunting spider *O. javanus* was investigated. Both of these insecticides are used to control wide range of insect pests in various crop systems (Karmakar *et al*., 2009; Gontijo *et al*., 2014; Simon-Delso *et al*., 2015).

Lethal effect of any insecticide depends upon its type of active ingredient, dose and exposure time. In this study, commercial insecticides were used instead of their pure active ingredient, as this condition corresponds to field situation more closely. Thus, resulting toxicity effects cannot be solely referred to active ingredient, as it may be

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caused by additives present in composition of commercial insecticides (Pekar, 2012). The concentration mortality relationship for both insecticides was also studied. Such detailed analysis help to estimate mortality at other concentrations too, as concentration of insecticides vary among crops (Pekar, 2012).

Table 4: IOBC Classification based acute and persistence toxicity of tested insecticides.

Compound	IOBC Category* (Acute toxicity)	IOBC Category** (Residual toxicity)
Thiamethoxam	Slightly harmful	Slightly persistent
Spiromesifen	Slightly harmful	Short lived

* Harmless, < 30% mortality; slightly harmful, 30–79% mortality; moderately harmful, 80– 99% mortality; harmful, > 99% mortality.
** Harmless in <5 days, short lived; 5–15 days, slightly persistent; 16–30 days, moderately persistent and >30 days, persistent.

Results of present study showed that thiamethoxam is slightly harmfull for *O. javanus*. The LC_{50} value for population is near to its field application rate. Studies are available on the bad effect of thiamethoxam on naturel enemies (Cloyd and Bethke, 2011; Prabhaker *et al*., 2011; Tirello *et al*., 2013). Sabry *et al*. (2014) reported thiamethoxam toxicity to the natural enemies trichogramma, lacewing and seven spotted lady bird beetle. Amirzade *et al*. (2014) reported that thiamethoxam is less toxic to predatory ladybird beetles as compared to other neonicotinoids acetamaprid and imidacloprid. According to Van deVeire and Tirry (2003) thiamethoxam was harmful to predators *Orius laevigatus* and *Amblyseius californicus*. Thiamethoxam have potential to severely harm predatory bug *Macrolophus pygmaeus* (Rahmani *et al*., 2016). According to Yao *et al*. (2015) thiamethoxam is severely toxic for predator *Serangium japonicum*. Bostanian and Laurin (2008) reported that thiamethoxam was not toxic towards predator *Anystis baccarum*. Its application decrease the abundance of the soil Oribatida, Gamasida and Actinedida (El-Naggar and Zidan, 2013) So, thiamethoxam acute toxicity is vary from species to species of naturel enemies.

According to our findings thiamethoxam is slightly persistant in the form of residues and its residues also affect *O. javanus*. Bonmatin *et al*. (2015) reported that thiamethoxam is a persistent insecticide. The reported halflife of thiamethoxam is variable from 7–92 days (Wood and Goulson, 2017). Result of present study show that 5 days old residues of thiamethoxam are detrimental for *O. javanus*. The residues of thiamethoxam were found in various environmental components *e.g* water, nectar, pollen and soil (Girolami *et al*., 2009; Hladik *et al*., 2016). It is reported that residues of thiamethoxam inhibit feeding in adult and cause mortality in nymphs of predatory bug *Podisus maculiventris* (Tillman and Mullinix, 2004). Yao *et al*. (2015) reported that residues of thiamethoxam have slightly affected the predatory beetle *Serangium japonicum*. Thus residues of the thiamethoxam harm the nontarget organisms in different ways in agroecosystem.

Spiromesifen is a modern acaricide and insecticide used to control mites and sucking insects (Beers and Schmidt, 2014). It inhibits lipid biosynthesis and reduces the fertility in insects (Lefebvre *et al*., 2012). Our results indicate low of toxicity of spiromesifen towards *O. javanus* as compared to thiamethoxam. Shah *et al*. (2016) showed that spiromesifen was less toxic to mosquitos in comparison to pyrithroids and neonicotinoids. Wahengbam *et al*. (2018) reported that spiromesifen is harmless towards *Trichogramma* sp. Spiromesifen did not affected the parasitoid ability of *Eretmocerus mundus* white fly (Bielza *et al*., 2009). It reduces the number of thrips on pepper fruits (Srivastava *et al*., 2008). It is considered safe for pollinators (Nauen *et al*., 2002; Bielza *et al*., 2005). Wanumn *et al*. (2016) classified spiromesifen as slightly harmful towards two mirid predators *N. tenuis* and *M. basicornis*. Khan (2019) reported spiromesifen did not affect the parasitism ability of *Tricogramma chilonis* in laboratory.

This study showed short time bioavailability of insecticides spiromesifen for *O. javanus*. Residues of spiromesifen dissipate rapidly on fruit and vegetables but persist in soil for 15 days (Sharma *et al*., 2006, 2014). Wanumen *et al*. (2016) classified spiromesifen as shortlived insecticide because its thee days old residues did not caused significant mortality in mirid bug. Kutuk and Yigit (2009) reported the residue of spiromesifen was harmless towards adult lady bird *Serangium parcesetosum* but caused some mortality in larvae. Similar results were reported by Schmidt *et al*. (2005) towards larvae of the *Coccinella septempunctata* when exposed to spiromesifen.

In this study, age of the insecticide residue was positively correlated with survival of the *O. javanus*. However, residues of thiamethoxam were more toxic than the residues of spiromesifen. And thiamethoxam is slightly persistent. Wanumen *et al*. (2016) reported that neonicotinoids are more persistent and toxic than tetronic acid derivatives.

Spiders show variable response towards toxic chemicals depending upon size and sex of the spider (Shaw *et al*., 2005). In present study both acute and residual toxicity assays showed that male spiders were more vulnerable than female spiders. It may be due to lower weight to body area ratio of male spiders than females (Dinter and Poehling, 1995). Hof *et al*. (1995) reported lambda cyhalothrin affected male spider's more than female wolf spiders. Pekar (1999) reported application of permethrin causes mortality directly related to body size of spiders. VanErp *et al*. (2002) reported male spiders are more susceptible to application of chlorpyriphos and diazinon than female

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wolf spider. According to an assumption of IOBC working group insecticides found harmless for a particular predator in laboratory testing have great chance of being low risk to population in field (Bigler , 1994).

Unfortunately in developing countries, there is lack of up to date information that are required to measures the total economic and agronomic outcomes and benefits of insecticides against their potential hazards and drawbacks. IPM approaches help to use insecticides wisely. For that purpose field based analysis are required to get reliable results that enable the application of insecticide in real environmental situation. Similarities of our results with the results of other studies on predacious arthropods indicate that the impact of insecticides on the existing pest/natural enemy complex must be taken into consideration when insect pest management strategies are planned.

Conclusion

The broad-spectrum insecticides should be used carefully. Instead of their vide spread use, they must be applied at hot spots of pests to save the natural predators like spiders. Even though when these insecticides are slightly harmful for natural enemies like spiders, they can have advers sublethal effects on them. This will decrease their fumctional role in agroecosystem. That is why only those products should be used in agroecosystems which are more specific against target pests and harmless for beneficial organisms. This would be helpful to reduce long term detrimental effects of insecticides on naturel enemies.

Conflict of interest

The authors have declared no conflict of interest.

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