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Screening of insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

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Abstract

The present investigations on “Screening of insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith)” were conducted in the toxicology laboratory of Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, and Akola (M.S.) during the year 2019-20. The insecticides used as a treatments included, Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC, Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC, Pyriproxyfen 5% EC + Fenpropathrin 15% EC, Beta cyfluthrin 90 + Imidacloprid 210 OD, Spinetorum 11.7% SC and Quinalphos 20% EC + Cypermethrin 3% EC along with untreated control. For mass rearing of fall armyworm, *S. frugiperda* method described by Sisay *et al.* (2019) was followed with slight modifications with respect to rearing materials and food. The results on relative toxicity studies at LC_{50} values revealed that Spinetorum 11.7% SC is highly toxic to the third instar larvae of *S. frugiperda* than rest of the other insecticides tested. At LC_{50} level the results on relative toxicities of six insecticides can be summarized in decreasing order of toxicities as [Spinetorum 11.7% SC] > [Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC] > [Pyriproxyfen 5% EC + Fenpropathrin 15% EC] > [Beta cyfluthrin 90 + Imidacloprid 210 OD] > [Quinalphos 20% + Cypermethrin 3% EC] > [Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC]. The results on relative toxicity studies at LC_{90} level revealed that Spinetorum 11.7% SC is highly toxic to the third instar larvae of *S. frugiperda* than all other insecticides tested. At LC_{90} level the results on relative toxicities of six insecticides can be summarized in decreasing order of toxicities as [Spinetorum 11.7% SC] > [Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC] > [Beta cyfluthrin 90 + Imidacloprid 210 OD] > [Quinalphos 20% + Cypermethrin 3% EC] > [Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC] > [Pyriproxyfen 5% EC + Fenpropathrin 15% EC].

Keywords: Screening, laboratory, bioassay, *Spodoptera frugiperda* (J. E. Smith)

1. Introduction

Maize (*Zea mays* L.) belongs to family Poaceae is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India maize is emerging as third most important crop after rice and wheat. Its importance lies in the fact that it is not only used as human food and animal feed but at the same time it is also widely used in corn starch industry, corn oil production and as baby corn in different recipes [16]. It contains various major phytochemicals such as carotenoids, phenolic compounds and phyto sterols which are useful in the prevention of some chronic diseases. It is believed to have potential anti HIV activity due to the presence of *Galanthus nivalis* agglutinin (GNA) lectin or GNA maize [14]. The production of maize in 2017-18 was 20,118 MT in *Kharif* and 8,634 MT in Rabi with a total production of 28,753 MT in India. After the entry of fall armyworm, the production is reduced to 19,410 MT in *Kharif* and 8300 MT in Rabi with a total of 27,720 MT in 2018-19 [4]. Amongst several insect pests damaging this crop, the one fall armyworm, *Spodoptera frugiperda* (J. E. Smith) is an occasional but sometimes serious pest observed on this crop. This pest commonly referred to as FAW is a native of America. However, it was first formally reported in West Africa in January, 2016 and has spread to several countries across Africa except a few countries in North Africa [13]. In India, the pest has been reported for the first time in India in Karnataka in July 2018 and subsequently in a few other states such as Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra and Odisha. Based on results of surveys conducted between 9-18 July 2018 that recorded more than 70% prevalence of the FAW in a maize field in Chikkaballapur, Karnataka [2]. In India, Rabi maize was sown in around 15.56 lakh ha as of 22nd February, 2019 which was lower than 17.28 lakh ha during corresponding period last year. All India Rabi maize production is estimated by at 5.67 MMT for the year 2018-19 [3]. The fall armyworm damage has been the highest in maize while several other crops such as sorghum, sugarcane, millets, vegetable and cotton are also vulnerable to the attack [13]. Maize crop is subjected to attack by over 130 insect pests during different growth stages of crop. The FAW moth populations are capable of migrating very fast (almost 100 km per night and nearly 500 km before laying eggs) and thus, can invade new areas quickly [8]. The pest completes its life cycle in about 30-45 days (depending on weather conditions). In cooler temperatures the life cycle may extend up to 60-90 days. The female moth lays on an average about 1500 eggs attaching them to the foliage. The egg stage lasts for only 2 to 3 days in warmer weather. The FAW in general has six larval instars (stages) before it goes for pupation. The entire larval stage lasts for 14 to 30 days depending on the weather conditions especially temperature and humidity [13]. The occurrence of this pest is relatively new in India which spends most of its life span under cryptic conditions. Considering the behavioral habit of this pest appropriate insecticide with proper delivery systems needs to be explored for effective management of this pest. At present a very few label claim insecticides are available for use against this pest. Similarly, information on relative toxicity of these newer pesticides molecules is wanting. Most of the insect pests belonging to Noctuidae family of Lepidoptera show strong resistance against an array of insecticides. Currently, some new insecticides insecticide formulations like Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC, Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC, Pyriproxyfen 5% EC + Fenpropathrin 15% EC, Beta cyfluthrin 90 + Imidacloprid 210 OD and Spinetorum 11.7% SC are readily available in the market. At present, there is very little information available on bioefficacy and relative toxicity of these ready mix insecticide products against fall armyworm, *Spodoptera frugiperda* (J. E. Smith). Taking into account the need an experiment was framed to know the relative toxicity of some new insecticide formulations against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on maize.

2. Materials and Methods

The present investigations on "Screening of insecticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith)" were conducted in the Toxicology laboratory of Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, and Akola (M.S.) during the year 2019-20. The details of the experiments conducted are given under.

2.1 Experimental details

a. Type of experiment : Laboratory experiment
b. Test insect : *Spodoptera frugiperda* (J. E. Smith) (Noctuidae: Lepidoptera)
c. Season : Kharif, 2019
d. No. of insecticides used : 06
e. No. of replications : 03
f. Laboratory conditions : Ambiant

The materials used and methodology followed in the present investigations are described under respective subheads.

2.2 Materials used

2.2.1 Insecticides used for treatments and their availability

The details of insecticides used in the experiment and their availability are given in table 1. These insecticides were procured from local market from authorized suppliers and stored in toxicology laboratory under appropriate storage conditions throughout the period of the experiment. They were handled with at most care with all safety tools and precautions.

Plate 1: Growing of food plants for *S. frugiperda* (J. E. Smith)

Table 1: Insecticides used for treatments and their availability

Sr. No.	Insecticides	Trade name	Dose (ml / acre)	Manufacturers
1	Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC	Alika	60	Syngenta, India
2	Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC	Ampligo	80 – 100	Syngenta, India
3	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	Sumiprempt^tm	250	Sumitomo chemical, India
4.	Beta cyfluthrin 90 + Imidacloprid 210 OD	Solomon	140	Bayre Crop Science, India
5	Spinetorum 11.7% SC	Summit	100	UPL India Ltd.
6	Quinalphos 20% EC+ Cypermethrin 3% EC	Viraat	400-500	UPL India Ltd.

2.3 Test insect used

The third instar larvae of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) were used for laboratory bioassay and determination of relative toxicities of insecticides. For biology studies first instar larvae were used.

2.4 Plastic and glass wares used

1. Glass petriplates (50 ml), 2. Glass beljars (15 cm diameter and 25 cm height) for adult mating and oviposition, 3. Measuring cylinder, 4. Glass beakers (250 ml), 5. Plastic jars (16 cm diameter and 18 cm height) as incubation chamber, 6. Conical flasks (250 ml), 7. Plastic containers (25 cm diameter and 10 cm height) with rubber band for larval rearing, 8. Plastic boxes (10 cm height X 16 cm width X 25 cm length), 9. Glass test tubes (25 ml) for relative toxicity studies.

2.5 Chemicals used

1. Sodium hypochlorite solution (0.2%) in water for disinfection of tools and table tops, 2. Formaldehyde solution (2%) for disinfection of insect rearing room, 3. Alcohol (70%) solution in water for disinfection of scissors, brushes and washing of hands, etc.

Plate 2: Maize leaves infested by *S. frugiperda* (J. E. Smith)

Plate 3: Domestically prepared mating chambers for *S. frugiperda* (J. E. Smith)

2.6 Equipment's used

1. Hot air oven (Lab Hosp. Make), 2. Refrigerator (Make Godrej, 170 Lit.), 3. Stereozoom Microscope (Make Nilcon), 4. Digital balance (Contach make, 500 g capacity) 5. Accupippettee (Cap. 1 to 1000 µl), 6. BOD incubator (Make - Sanco), 7. Air conditioner (Make Hitachi), etc.

2.7 Other material and accessories used

1. Glass marking pens, 2. Sterile distilled water, 3. Muslin cloth, 4. Forceps, 5. Cotton thread, 6. Hand lens (10 x), 7. Absorbent cotton, 8. Needle, 9. Scissor, 10. Tissue paper, 11. Paper towel, 12. Black paper sheets, 13. Honey (Dabur), 14. Camel hair brush, 15. Fresh maize leaves as larval food, etc.

2.8 Methods adopted

2.8.1 Growing of food plants for fall armyworm, *S. frugiperda* (J. E. Smith)

Sowing of maize (local variety) in isolation was under taken in the field of Department of Agricultural Entomology by following recommended tillage practices (Plate 1). In order to ensure continuous and fresh availability of food throughout the experimental period, staggered sowing of maize seeds was followed. Since the crop is served as food source for laboratory reared population of *S. frugiperda*, every precaution was taken to keep the plot free from insecticide contamination and possible drifts from neighboring plots. The fresh tender leaves of maize from this plot were used for feeding *S. frugiperda* larvae in the laboratory.

2.8.2 Mass rearing of *S. frugiperda* in laboratory

For mass rearing of fall armyworm, *S. frugiperda* method described by Sisay *et al.* (2019) [15] was followed with slight modifications with respect to rearing materials and food. Initially, FAW starter colony was collected from an unsprayed maize field in the university campus and brought to the laboratory. In order to avoid cannibalism the larvae were placed individually in ventilated plastic jars and fed with fresh tender maize leaves from the food plot grown in the field. The full grown larvae were transferred to a plastic jar one third filled with soil and were allowed to undergo pupation. The pupae were collected and placed in a moistened petri dish in an oviposition cage (Plate 3). Sterile cotton soaked in a honey based adult diet solution was placed in a petri dish inside the oviposition cage as a food source for the emerging adults.

The walls of the cages were lined with wax paper as an oviposition substrate. A photoperiod of 12L: 12D was maintained for oviposition. After 2-3 days, old egg batches were collected from the oviposition cages and placed in sterile plastic jars. Eggs were monitored daily for hatching. The neonates were used for conducting biology studies on different foods, while the third instar larvae from this laboratory culture were used for bioassay experiments. The rearing was performed at ambient temperature and RH conditions in laboratory.

2.9 Relative toxicity studies

2.9.1 Preparation of insecticide doses

The stock solution was prepared by adding formulated insecticides in distilled water from which 5-6 concentrations were prepared and used for bioassay.

2.10 Insecticide bioassay

A bioassay procedure modified from Temple *et al*. (2009) [18] was followed. Fresh maize leaves (prewashed in 0.01% sodium hypochlorite solution) were cut in to small pieces of approximately 5 cm to 7.5 cm size. They were placed in glass petri dishes lined with a circular cut tissue paper. Ten third instar larvae of *S. frugiperda* (prestarved for 3 h) from the laboratory grown culture were placed in the petridish and spraying was made using a hand sprayer (Precalibrated at 0.15 ml per spray) to ensure that the leaves, larvae and tissue paper in a petri dish thoroughly covered with insecticidal spray.

The treated larvae were kept for 6 hr in treated petri dishes. They were separated in multicellular trays and fed with normal diet. The diet was changed every day.

Plate 4: Third instar larvae of *S. frugiperda* (J. E. Smith)

Plate 5: Bioassay with direct application of insecticide to larvae

2.11 Recording of observations

The mortality observations on each treatment were recorded after 24 hrs up to 72 hrs. About 10-15 third instar larvae were used per treatment and each treatment was replicated thrice. A control (without treatment) was also maintained. The larvae were considered as dead if they do not respond to gentle touch with a camel hair brush.

2.12 Working out relative toxicity (RT) values

The results were expressed as percentage mortality on each concentration from which corrected mortalities were worked out (Abott, 1925) [1] and used for probit analysis (Finney, 1971) [6] verified using software available in the Department. The relative toxicities for each insecticide was worked out as per Mankar *et al*. (2019) [11] and depicted in tables as results.

3. Results and Discussions

3.1 Laboratory bioassay against *S. frugiperda* (J. E. Smith)

The bioassay was conducted at ambient laboratory conditions for determination of relative toxicities of some new insecticide formulations using bioassay method suggested by Temple *et al*. (2009) [18]. The toxicities of different insecticides were determined by computing LC_{50} values. The relative toxicities at LC_{50} and LC_{90} were determined taking into account the lowest toxic compound as unity. The results of the bioassay studies have depicted in following tables and discussed in light of available literature under respective subheads.

3.1.1 Relative toxicity (RT) of insecticides in relation to LC_{50} against *S. frugiperda* (J. E. Smith)

The results on relative toxicity studies at LC_{50} values depicted in Table 2 and graphically illustrated in Fig. 1**,** revealed that Spinetorum 11.7% SC with lowest LC_{50} value of 0.01% proved highly toxic to the third instar larvae of *S. frugiperda* than all other insecticides tested. The slope of Probit test for all the six new insecticides was in the range of 0.96 to 2.67 which indicated homogeneity in the larval population used for bioassay studies. The relative toxicities were determined by comparing LC_{50} values with least toxic insecticide product (i.e. Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC). It was observed that Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC with LC_{50} of 0.02%, Pyriproxifen 5% EC + Fenpropathrin 15% EC with LC_{50} of 0.06%, Beta cyfluthrin 90 + Imidacloprid 210 OD with LC_{50} of 0.07% Spinetorum 11.7% SC with LC_{50} of 0.01% and Quinalphos 20% + Cypermethrin 3% EC with LC_{50} of 0.09% were found 7.50, 2.50, 2.14, 15.00 and 1.67 fold more toxic over Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC insecticide combination product. From these results the six insecticides studied for their relative toxicities can be arranged in their decreasing order of toxicities at LC_{50} as [Spinetorum 11.7% SC] > [Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC] > [Pyriproxifen 5% EC + Fenpropathrin 15% EC] > [Beta cyfluthrin 90 + Imidacloprid 210 OD] > [Quinalphos 20% + Cypermethrin 3% EC] > [Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC].

Table 2: Relative toxicity (RT) of insecticides in relation to LC_{50} against *S. frugiperda* (J. E. Smith)

Sr. No.	Insecticides	LC_{50} (%)	Fiducial limits (at 50%)	Slop	RT	ORT
1	Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC	0.15	0.08 - 0.21	1.68	1.00	6
2	Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC	0.02	0.01 - 0.03	1.14	7.50	2
3	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	0.06	0.03 - 0.11	0.96	2.50	3
4	Beta cyfluthrin 90 + Imidacloprid 210 OD	0.07	0.05 - 0.09	2.31	2.14	4
5	Spinetorum 11.7% SC	0.01	0.01 - 0.02	2.67	15.00	1
6	Quinalphos 20% EC+ Cypermethrin 3% EC	0.09	0.06 - 0.12	1.73	1.67	5

RT - Relative Toxicity ORT - Order of Relative Toxicity

Table 3: Relative toxicity (RT) of insecticides in relation to LC_{90} against *S. frugiperda* (J. E. Smith)

Sr. No.	Insecticides	LC_{90} (%)	Fiducial limits (at 90%)	Slop	RT	ORT
1	Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC	0.89	0.54 -3.60	1.68	1.58	5
2	Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC	0.25	0.10 – 3.98	1.14	5.55	2
3	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	1.41	0.51 - 24.12	0.96	1.00	6
4	Beta cyfluthrin 90 + Imidacloprid 210 OD	0.26	0.17 -0.80	2.31	5.42	3
5	Spinetorum 11.7% SC	0.04	0.02 – 0.12	2.67	35.25	1
6	Quinalphos 20% EC+ Cypermethrin 3% EC	0.50	0.29 – 2.21	1.73	2.82	4

RT - Relative Toxicity ORT - Order of Relative Toxicity

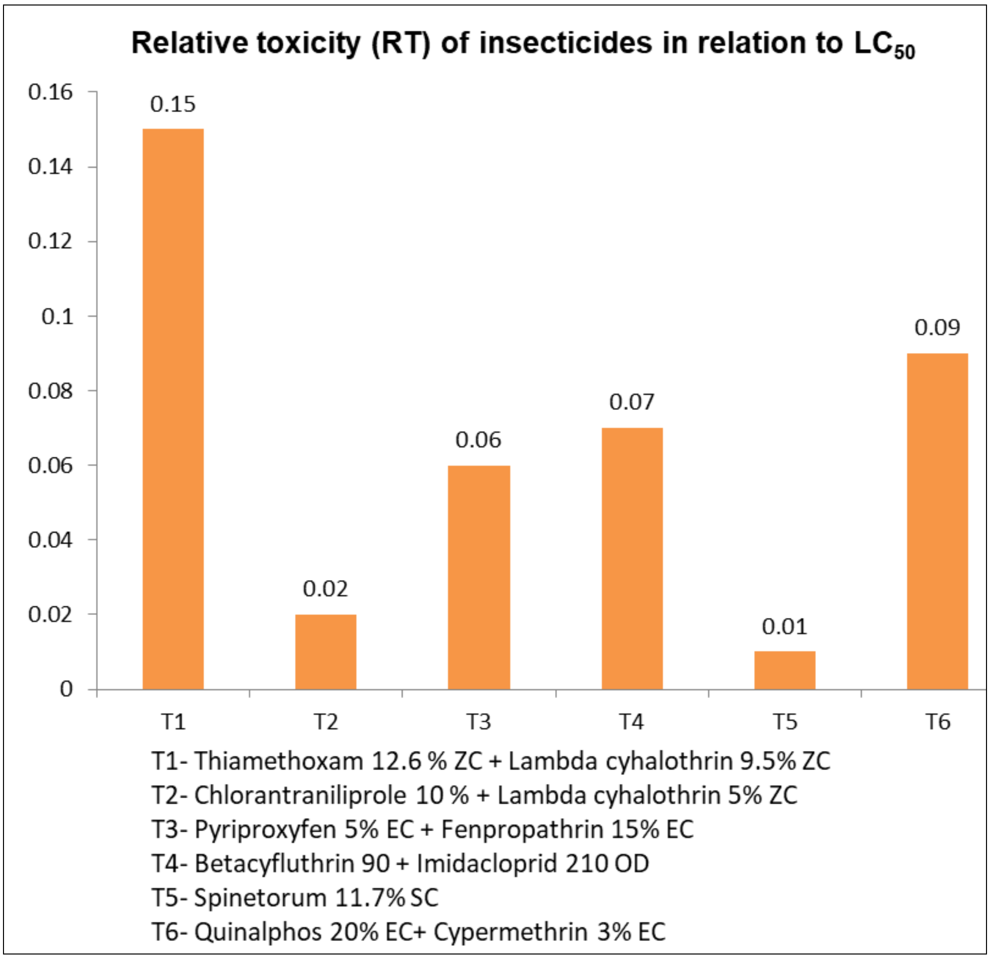

Fig 1: Relative toxicity (RT) of insecticides in relation to LC_{50} against *S. frugiperda* (J. E. Smith)

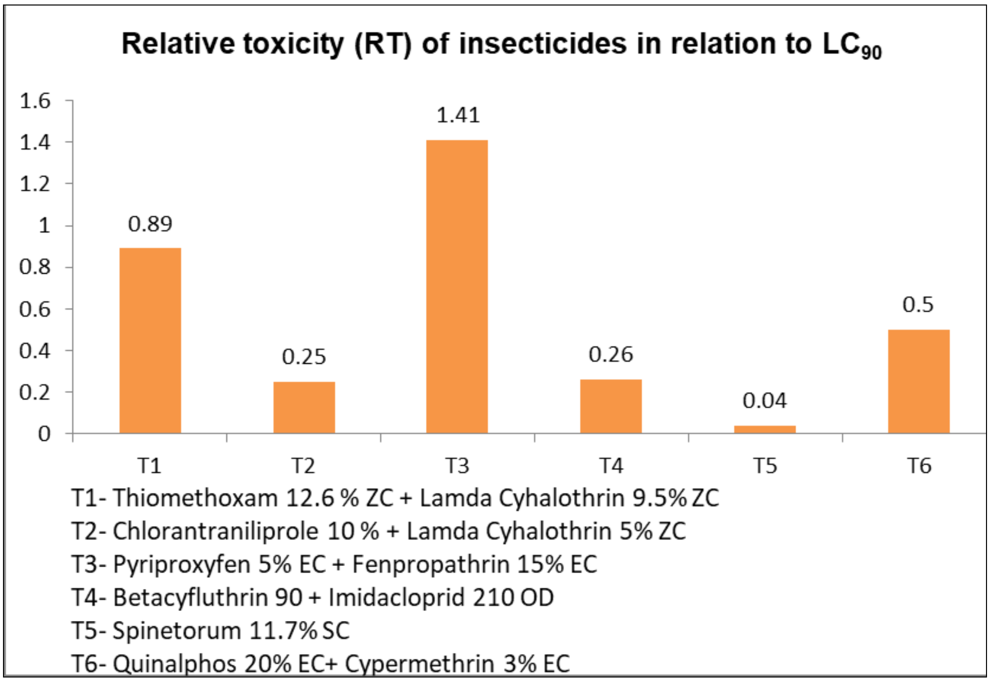

Fig 2: Relative toxicity (RT) of insecticides in relation to LC_{90} against *S. frugiperda* (J. E. Smith)

3.1.2 Relative toxicity (RT) of insecticides in relation to LC_{90} against *S. frugiperda* (J. E. Smith)

The results on relative toxicity studies at LC_{90} values depicted in Table 3 and graphically illustrated in fig. 2**,** revealed that Spinetorum 11.7% SC with lowest LC_{90} value of 0.04% proved highly toxic to the third instar larvae of *S. frugiperda* than all other insecticides tested. The slope of Probit test for all the six new insecticides was in the range of 0.96 to 2.67 which indicated homogeneity in the larval population used for bioassay studies. The relative toxicities were determined by comparing LC_{90} values with least toxic insecticide product (i.e. Pyriproxyfen 5% EC + Fenpropathrin 15% EC). It was observed that Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC with LC_{90} of 0.89%, Chlorantraniliprole

10% + Lambda cyhalothrin 5% ZC with LC_{90} of 0.14%, Beta cyfluthrin 90 + Imidacloprid 210 OD with LC_{90} of 0.26% Spinetorum 11.7% SC with LC_{90} of 0.04% and Quinalphos 20% + Cypermethrin 3% EC with LC_{90} of 0.50% were found 1.58, 5.55, 5.42, 35.25 and 2.82 fold more toxic over Pyriproxyfen 5% EC + Fenpropathrin 15% EC insecticide product. From these results the six insecticides studied for their relative toxicities at LC_{90} level can be arranged in their decreasing order of toxicities as [Spinetorum 11.7% SC] > [Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC] > [Beta cyfluthrin 90 + Imidacloprid 210 OD] > [Quinalphos 20% + Cypermethrin 3% EC] > [Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC] > [Pyriproxifen 5% EC + Fenpropathrin 15% EC]. Spinetorum 11.7% SC and Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC was found as most effective insecticides in the present studies with ORT of 1 and 2 at both LC_{50} and LC_{90} levels found supports of Hardke *et al.* (2011) [7] who reported that the LC_{50} values of Chlorantranilprole and Spinetoram were significantly lower than the LC_{50} of other insecticides tested using diet incorporated assays against fall armyworm, *S. frugiperda.* Sisay *et al.* (2019) [15] from laboratory studies reported that Spinetoram caused the highest mortality of 96.7% 48 h after treatment application and 100% mortality 72 h after treatment application, while Lambda cyhalothrin caused 96.7% mortality 48 h and 72 h after treatment application. Spinetoram 11.7 SC was also reported as effective molecule against *S. frugiperda* in laboratory and field by Mallapur *et al*. (2019) [12] while Thiamethoaxam 0.25% WG as least effective which supports the findings in the present studies. Temple *et al.* (2009) [18], Su *et al*. (2012) [17] and Karuppaiah and Srivastava (2013) [9] reported Chlorantraniliprole (Rynaxypyr®) as highly toxic to fall armyworm, *Spodoptera frugiperda* (J. E. Smith) from laboratory bioassay studies, which supports the findings in the present studies. Quinalphos is found as less effective in the present studies which founds support of Lingaraj *et al*. (2009) [10] who reported less relative toxicity of Quinalphos as compared to 6 other insecticides. This is first attempt to evaluate relative toxicities of new combination insecticide products against *Spodoptera frugiperda* (J. E. Smith) in laboratory. The results as such on the relative toxicity studies of combination products used in the present studies, however, could not be discussed due to lack of literature. Prolonged use of insecticides with similar mode of action may induce low levels of larval mortality in fall armyworm *S. frugiperda* (Viteri *et al*., 2019) [19]. According to Belay *et al.* (2012) [5] since control of fall armyworm *S. frugiperda* has been fully dependent on insecticides, as a result the pest has developed resistance to major classes of insecticides in several locations. The less toxicity of some combination products used in the present studies containing Lambda cyhalothrin, Imidacloprid, Quinalphos, Cypermethrin and Thiamethoxam insecticides may be attributed to these facts.

4. Conclusions

The laboratory bioassay studies indicated that Spinetorum 11.7% SC as most toxic insecticide for the third instar larvae *S. frugiperda*, The relative toxicity studies revealed that Spinetorum 11.7% SC was found 15 fold more toxic than Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC at LC_{50} level, while it was 35.25 fold more toxic over Pyriproxyfen 5% EC + Fenpropathrin 15% EC at LC_{90} level. Amongst the combination products Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC was found as promising which is 7.50 fold more toxic over Thiamethoxam 12.6% ZC + Lambda cyhalothrin 9.5% ZC at LC_{50} level, while it was 5.55 fold more toxic over Pyriproxyfen 5% EC + Fenpropathrin 15% EC at LC_{90} level. Amongst insecticides tested Spinetorum 11.7% SC and a combination product Chlorantraniliprole 10% + Lambda cyhalothrin 5% ZC are promising against the third instar larvae of *S. frugiperda*.

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