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Bio-efficacy, persistence and residual toxicity of different insecticides against soybean pod borer *Helicoverpa armigera* (Hubner) infesting soybean

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Abstract

The studies on the bio-efficacy, persistence and residual toxicity of different insecticides viz., chlorantraniliprole 0.004 per cent, ethion 0.100 per cent, triazophos 0.050 per cent, indoxacarb 0.010 per cent, emamectin benzoate 0.001 per cent, quinalphos 0.050 per cent and profenophos 0.100 per cent against *Helicoverpa armigera* (Hubner) infesting soybean were conducted at the Research Farm of Department of Agril. Entomology, College of Agriculture, Latur (MS). The overall result revealed that all the insecticidal treatments were significantly superior over untreated control in minimizing the larval population of *H. armigera* infesting soybean. Among the treatments, chlorantraniliprole 0.004 per cent was found to be the most effective insecticide in reducing larval population of *H. armigera* on soybean (1.22 and 1.44 larvae per mrl) followed by emamectin benzoate 0.001 per cent (1.33 and 1.78 larvae per mrl), indoxacarb 0.010 per cent (2.22 and 1.89 larvae per mrl), quinalphos 0.050 per cent (2.41 and 2.00 larvae per mrl), profenophos 0.100 per cent (3.67 and 2.22 larvae per mrl), triazophos 0.050 per cent (3.78 and 2.67 larvae per mrl) and ethion 0.100 per cent (4.11 and 2.78 larvae per mrl) after first and second spray, respectively. The highest soybean yield was achieved by chlorantraniliprole 0.004 per cent (34.87 q per ha) while quinalphos 0.050 per cent (1:19.72) registered highest incremental cost benefit ratio. The results on residual toxicity of different insecticides against *H. armigera* infesting soybean indicated that chlorantraniliprole 0.004 per cent and emamectin benzoate 0.001 per cent illustrated highest persistent toxicity index (PT) (953.68 and 913.48 and; 885.64 and 875.80, respectively) and LT₅₀ values (7.93 and 7.78 and; 7.06 and 7.09 days, respectively) against third instar larvae of *H. armigera* after first and second spray as compared to the other insecticides.

Keywords: Soybean, pod borer *Helicoverpa armigera* (Hubner), bio-efficacy, residual toxicity, persistence, LT₅₀

Introduction

Soybean (*Glycine max* (L.) Merrill) often described as the miracle golden bean, the pearl of the Orient, the Cinderella crop of the century, the meat that grows on vines, the protein hope of the future and the salvation crop among others is globally considered as nutritious meal with tremendous food value (Lawrence, 2011) [15]. It is world's most remarkable seed legume with the unique chemical composition which offers the health benefits not only to human being but also to animals, poultry birds and fishes. The key benefits are related to their excellent protein content (contains all 8 essential amino acids), high levels of essential fatty acids, numerous vitamins and minerals, isoflavones, and fiber (Dwevedi and Kayastha, 2011) [9].

Soybean placed first in the world as edible oil and occupies important place in the national economy of many developed and developing countries. About 85 per cent of the world's soybeans are processed annually into soybean meal and oil (Anonymous, 2020) [4]. Approximately 98 per cent of the soybean meal is crushed and further processed into animal feed with the balance used to make soy flour and proteins. Of the oil fraction, 95 per cent is consumed as edible oil; the rest is used for industrial products such as fatty acids, soaps and biodiesel (Dwevedi and Kayastha, 2011) [9].

Globally, soybean is cultivated on an area of 126.95 million ha with 362.64 million MT of total production and 2860 kg per ha of an average yield (USDA, 2020) [30]. In India, soybean crop covers 11.13 million ha area with 13.26 million MT of total production and an average yield of 1192 kg per ha (SOPA, 2020) [28]. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Gujarat and Chhattisgarh.

In Maharashtra, the area under soybean crop is 0.40 million ha with total production of 0.45 million MT and an average yield of 1125 kg per ha (SOPA, 2020) [28].

Several biotic and abiotic factors are found responsible for reduction in soybean yield under Indian conditions. The major biotic stresses which reduce soybean productivity are diseases and insect-pests (Agarwal *et al.* 2013) [2]. Soybean is attacked by 273 species of insect-pests (Rawat and Kapoor, 1968) [20], amongst 20 insect-pest species are important in India (Singh and Singh, 1990) [26] and 13 in Marathwada region of Maharashtra (Bhamare *et al.* 2018) [6]. These insect-pests of soybean inflicted 30.8 per cent avoidable losses in seed yield (Ahrwar *et al.* 2014) [3]. Whereas, 20 to 100 per cent yield losses were noticed in soybean due to individual disease or insect or weed species (Sharma *et al.* 2014) [25].

Soybean pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is an important pest capable of colonizing several species of cultivated plants, including soybean (Coelho *et al.* 2019) [7]. *H. armigera* represents a significant challenge to soybean cropping systems in many parts of the world (Fathipour and Sedratian, 2013) [10]. The larvae damage vegetative and reproductive plant stages by feeding on leaves, stems, shoots, inflorescence, pods and seeds resulting in variable economic loss (Rogers and Brier, 2010 a and b) [21] and Bhamare and Shetgar, 2015) [5]. The loss due to *H. armigera* in vegetable soybean varied from 38.49 to 45.04 per cent (Naik *et al.* 2020) [16]. However, the major damage due to *H. armigera* occurs during pod-filling reproductive stage of soybean. Even relatively low infestations of *H. armigera* during this stage can cause significant reductions for soybean (Stacke *et al.* 2018) [29].

Moreover, several chemical insecticides have been recommended by CIB and RC for the control of insect-pests infesting soybean in India. However, these label claimed insecticides need to be revalidated from time to time for the effective management of insect-pests. In addition, the residual toxicity resulting from foliar application of insecticides could be of great significance in indicating an effective periods over which an insecticide could persist in biologically active stage under field conditions. In this context, the present investigation was planned to investigate the bio-efficacy, persistence and residual toxicity of different insecticides against *H. armigera* infesting soybean.

Materials and Methods

Bio-efficacy of different insecticides against *H. armigera* infesting soybean

The field experiment was conducted using variety MAUS-71 in RBD comprised of eight treatments replicated thrice on bio-efficacy of different label recommended insecticides of soybean against *H. armigera* at the Research Farm of Department of Agril. Entomology, College of Agriculture, Latur (Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani) (MS)-India during *Kharif* 2015. Soybean was cultivated with all recommended package of practices recommended by VNMKV, Parbhani for raising the crop except insect-pest management. The first application of insecticide spray was done at ETL. The observations on total number of pod borer larvae, *H. armigera* were recorded on one meter row length from each treatment at three randomly selected places at one day before and 1, 3, 7 and 14 days after first and second application of insecticides. The data on larval population were transformed into square root transformation before statistical analysis to know the significance of

difference among different treatments. At maturity the crop was harvested and weight of grain per plot was recorded separated from each treatment. Plot wise yield was computed on hectare basis for statistical interpretation. The economics of the treatment was also computed based on grain yield and cost of protection. The incremental cost benefit ratio (ICBR) was computed based on cost of protection and gross profit. The data in respect of bio-efficacy and economics of different insecticides against *H. armigera* infesting soybean were statistically analyzed by standard 'analysis of variance'. The null hypothesis was tested by 'F' test of significance at 5 per cent level (Gomez and Gomez, 1984) [12].

Persistence and residual toxicity of different insecticides against *H. armigera* infesting soybean

The toxicity of different insecticides was investigated against third instar larvae of *H. armigera* at 1, 3, 7 and 14 days after first and second application of insecticides. Due care was taken to cover the entire plant while application of insecticides. The required numbers of leaves and pods receiving application of insecticides were tagged for investigations on residual toxicity of insecticides. The number of test insects used for the bioassay studies were ten for each treatment in each replication. The tagged leaves and pods were brought into the laboratory at the prescribed day intervals. The treated leaves and pods were kept into plastic containers separately. The stalk of leaves and pods was covered with moistened cotton wool in order to retain their turgidity for 24 hours. Then the laboratory reared third instar larvae of *H. armigera* were released on treated leaves and pods of soybean separately. The numbers of dead or moribund larvae of *H. armigera* were counted after 24 hours of exposure. Similarly control mortality of *H. armigera* larvae was also observed by releasing them on untreated substrate of soybean plant.

Correction on percentage mortality

The observations on mortality of *H. armigera* larvae were converted into percentage mortality. The average percentage mortality was calculated from the observations in 3 replications. The observations on percentage mortality thus obtained were corrected with Abbott's (1925) [1] formula as follows.

$$P = \frac{T - C}{100 - C} \times 100$$

Where as,

P = Corrected percentage mortality,
T = Percentage mortality in treatment,
C = Percentage mortality in control.

LT₅₀ values

The values of LT₅₀ (time required to give 50 per cent mortality) for different insecticides applied on soybean plants were calculated by using software of Probit analysis as suggested by Finney (1971) [11].

PT values

The product (PT) of average residual toxicity (T) and the period (P) for which the toxicity persisted was used as an index of persistent toxicity. The values of corrected percentage mortalities at various specified periods were added. This sum was then divided by number of observations

in order to obtain residual toxicity (T). The procedure followed by Saini (1959) [23] and elaborated further by

Pradhan (1967) [18], Sarup *et al.* (1970) [24] and; Sonune and Bhamare (2016) [27] was utilized.

Table 1: Effect of different insecticides on larval population of *H. armigera*, grain yield and ICBR of soybean

Treatments	Mean larval population of <i>H. armigera</i> per mrl										Main grain yield q/ha	ICBR
	I st spray					II nd spray						
	One day before spray	Days after spraying				One day before spray	Days after spraying					
	1	3	7	14		1	3	7	14			
Profenophos 0.100 per cent	4.00 (1.98)*	1.89 (1.37)	2.22 (1.48)	3.00 (1.72)	3.67 (1.91)	3.80 (1.94)	1.33 (1.14)	1.67 (1.28)	2.00 (1.40)	2.22 (1.48)	20.46	1:6.77
Triazophos 0.050 per cent	4.11 (2.01)	2.00 (1.40)	2.33 (1.52)	3.22 (1.78)	3.78 (1.93)	3.79 (1.94)	1.67 (1.27)	2.00 (1.40)	2.33 (1.52)	2.67 (1.62)	20.96	1:11.69
Quinalphos 0.050 per cent	4.34 (2.08)	1.47 (1.21)	1.67 (1.27)	1.89 (1.36)	2.41 (1.54)	3.00 (1.73)	1.00 (0.98)	1.33 (1.14)	1.67 (1.28)	2.00 (1.40)	29.63	1:19.72
Indoxacarb 0.010 per cent	4.89 (2.20)	1.29 (1.13)	1.55 (1.23)	1.77 (1.33)	2.22 (1.48)	3.33 (1.82)	0.78 (0.87)	1.00 (1.00)	1.56 (1.24)	1.89 (1.37)	31.25	1:11.24
Ethion 0.100 per cent	4.22 (2.05)	2.78 (1.66)	3.00 (1.72)	3.67 (1.90)	4.11 (2.02)	4.22 (2.05)	1.89 (1.37)	2.22 (1.48)	2.44 (1.55)	2.78 (1.66)	16.43	1:3.51
Chlorantraniliprole 0.004 per cent	4.22 (2.05)	0.44 (0.65)	1.00 (0.99)	1.07 (1.03)	1.22 (1.09)	1.80 (1.34)	0.33 (0.57)	0.78 (0.87)	1.11 (1.05)	1.44 (1.19)	34.87	1:7.95
Emamectin benzoate 0.001 per cent	3.67 (1.90)	0.89 (0.93)	1.11 (1.05)	1.14 (1.06)	1.33 (1.13)	2.00 (1.41)	0.66 (0.81)	0.89 (0.93)	1.33 (1.14)	1.78 (1.33)	31.55	1:9.87
Untreated Control	4.12 (2.02)	4.22 (2.05)	4.33 (2.08)	5.00 (2.23)	5.77 (2.40)	5.77 (2.38)	5.78 (2.40)	6.11 (2.47)	6.33 (2.51)	6.56 (2.55)	12.09	-
S.E \pm	-	0.05	0.08	0.09	0.09	-	0.06	0.04	0.04	0.04	0.02	-
C.D. at 5 per cent	NS	0.17	0.24	0.28	0.29	NS	0.18	0.13	0.14	0.13	0.08	-
C.V.	-	7.79	10.55	10.63	9.97	-	8.88	5.98	5.62	4.70	0.61	-

* Figures in parentheses are angular transformed values

N.S.: Non-significant

Results and Discussion

Effect of different insecticides on larval population of *H. armigera* infesting soybean

Data pertaining to effect of different insecticides on larval population of *H. armigera* on soybean after first and second spray are presented in Table 1.

First spray

The results revealed that all the insecticides were found to be significantly superior over untreated control in reducing larval population of soybean pod borer at 1, 3, 7 and 14 days after first spray of insecticides.

At one day after first spray, significantly minimum larval population of *H. armigera* (0.44 per mrl) was registered from the plots treated with chlorantraniliprole 0.004 per cent. The subsequent order of effectiveness was emamectin benzoate 0.001 per cent (0.89 larva per mrl), indoxacarb 0.010 per cent (1.29 larvae per mrl), quinalphos 0.050 per cent (1.47 larvae per mrl), profenophos 0.100 per cent (1.89 larvae per mrl), triazophos 0.050 per cent (2.00 larvae per mrl) and ethion 0.100 per cent (2.78 larvae per mrl).

At three days after first spray, chlorantraniliprole 0.004 per cent (1.00 per mrl), emamectin benzoate 0.001 per cent (1.11 per mrl) and indoxacarb 0.010 per cent (1.55 per mrl) registered significantly lowest larval population of *H. armigera*. All these treatments were statistically at par with each other. The next effective treatments were quinalphos 0.050 per cent (1.67 larvae per mrl), profenophos 0.100 per cent (2.22 larvae per mrl), triazophos 0.050 per cent (2.33 larvae per mrl) and ethion 0.100 per cent (3.00 larvae per mrl).

At seven days after first spraying, significantly minimum population of *H. armigera* (1.07 per mrl) was evidenced in the plots treated with chlorantraniliprole 0.004 per cent followed by emamectin benzoate 0.001 per cent (1.14 per mrl) and

indoxacarb 0.010 per cent (1.77 per mrl). All these treatments were statistically at par with each other. However, quinalphos 0.050 per cent, profenophos 0.100 per cent, triazophos 0.050 per cent and ethion 0.100 per cent were next effective treatments registered 1.89, 3.00, 3.22 and 3.67 larval population per mrl, respectively.

At 14 days after first spraying, significantly minimum larval population *H. armigera* was revealed in the plots treated with chlorantraniliprole 0.004 per cent (1.22 per mrl) and emamectin benzoate 0.001 per cent (1.33 per mrl). Nevertheless, indoxacarb 0.010 per cent (2.22 larvae per mrl), quinalphos 0.050 per cent (2.41 larvae per mrl), profenophos 0.100 per cent (3.67 larvae per mrl), triazophos 0.050 per cent (3.78 larvae per mrl) and ethion 0.100 per cent (4.11 larvae per mrl) were found to be subsequently effective treatments.

Second spray

The results revealed that all the insecticides were found to be significantly superior over untreated control in reducing larval population of *H. armigera* at 1, 3, 7 and 14 days after second application of insecticides.

At one day after second spray, significantly minimum larval population of *H. armigera* (0.33 per mrl) was registered from the plots treated with chlorantraniliprole 0.004 per cent. The next order of effectiveness was emamectin benzoate 0.001 per cent (0.66 larva per mrl), indoxacarb 0.010 per cent (0.78 larva per mrl) and quinalphos 0.050 per cent (1.00 larva per mrl). The subsequently efficient treatments in reducing larval population were profenophos 0.100 per cent (1.33 per mrl), triazophos 0.050 per cent (1.67 per mrl) and ethion 0.100 (1.89 per mrl).

At three days after second spray, chlorantraniliprole 0.004 per cent, emamectin benzoate 0.001 per cent and indoxacarb 0.010 per cent registered significantly lowest larval population of *H. armigera* on soybean to the extent of 0.78,

0.89 and 1.00 per mrl, respectively. All these treatments were statistically on par with each other. However, quinalphos 0.050, profenophos 0.100 per cent, triazophos 0.050 per cent and ethion 0.100 per cent were observed to be next effective treatments noticed 1.33, 1.67, 2.00 and 2.22 larvae per mrl, respectively.

At seven days after second spraying, significantly minimum larval population of *H. armigera* was evidenced from the plots treated with chlorantraniliprole 0.004 per cent (1.11 per mrl) and emamectin benzoate 0.001 per cent (1.33 per mrl). Both these treatments were statistically at par with each other. The subsequently effective treatments were indoxacarb 0.010 per cent (1.56 larvae per mrl), quinalphos 0.050 per cent (1.67 larvae per mrl), profenophos 0.100 per cent (2.00 larvae per mrl), triazophos 0.050 per cent (2.33 larvae per mrl) and ethion 0.100 per cent (2.44 larvae per mrl).

At 14 days after second spraying, chlorantraniliprole 0.004 per cent exhibited significantly lowest larval population of *H. armigera* (1.44 per mrl). However, emamectin benzoate 0.001 per cent (1.78 larvae per mrl), indoxacarb 0.010 per cent (1.89 larvae per mrl), quinalphos 0.050 per cent (2.00 larvae per mrl), profenophos 0.100 per cent (2.22 larvae per mrl), triazophos 0.050 per cent (2.67 larvae per mrl) and ethion 0.100 per cent (2.78 larvae per mrl) were subsequently effective treatments. The results of present investigation are in close conformity with the findings of Sagane (2015) [22] who revealed that rynaxypyr 20 SC, flubendiamide 39.35 SC, spinosad 45 SC and emamectin benzoate were most effective against defoliators and leaf miner of soybean. Keyhaniyan *et al.* (2009) [13] reported that indoxacarb SC 15 (250 ml per ha) and indoxacarb EC 15 (250 ml per ha) were most effective insecticides against *H. armigera* on soybean.

Effect of different insecticides on grain yield and incremental cost benefit ratio (ICBR) of soybean

The results in respect of effect of different insecticides on grain yield and ICBR of soybean are presented in Table 1. The data regarding grain yield of soybean revealed that all the treatments were statistically significant in increasing grain yield over untreated control. The grain yield of soybean due to different treatments varied from 12.09 to 34.87 q per ha.

The significantly highest grain yield of soybean was registered in chlorantraniliprole 0.004 per cent (34.87 q per ha) which was followed by emamectin benzoate 0.001 per cent (31.55 q per ha), indoxacarb 0.010 per cent (31.25 q per ha), quinalphos 0.050 per cent (29.63 q per ha), triazophos 0.050 per cent (20.96 q per), profenophos 0.100 per cent (20.46 q per ha) and ethion 0.100 per cent (16.43 q per ha). The result of present investigation are in agreement with the findings of Patil *et al.* (2014) [17] who reported that significantly highest seed yield of soybean (19.88 q per ha) was obtained in chlorantraniliprole (30 g a.i. per ha). Kothalkar *et al.* (2015) [14] revealed that emamectin benzoate 5 SG at the rate of 0.002 per cent + triazophos 40 EC at the rate of 0.06 per cent, emamectin benzoate 5 SG at the rate of 0.002 per cent, triazophos 40 EC at the rate of 0.06 per cent and flubendiamide 20 WG at the rate of 0.01 per cent + triazophos 40 EC at the rate of 0.06 per cent obtained comparatively highest yield. The data on ICBR revealed that all the insecticidal treatments were economical and most remunerative. Among all the treatments, highest incremental cost benefit ratio (1:19.72) was achieved by quinalphos 0.050 per cent which was followed by triazophos 0.050 per cent (1:11.69), indoxacarb 0.005 per cent (1:11.24), emamectin benzoate 0.001 per cent (1:9.87), chlorantraniliprole 0.004 per cent (1:7.95), profenophos 0.100 per cent (1:6.77) and ethion 0.100 per cent (1:3.51). These results are analogous to the findings of Wagh *et al.* (2015) [31] who documented that highest cost benefit ratio of 1:6.43 was observed in profenophos 0.100 EC followed by quinalphos (1:6.24) in soybean. Kothalkar *et al.* (2015) [14] revealed that emamectin benzoate 5 SG at the rate of 0.002 per cent + triazophos 40 EC at the rate of 0.06 per cent, emamectin benzoate 5 SG at the rate of 0.002 per cent, triazophos 40 EC at the rate of 0.06 per cent and flubendiamide 20 WG at the rate of 0.01 per cent + triazophos 40 EC at the rate of 0.06 per cent were obtained comparatively highest ICBR. Raghuvanshi *et al.* (2014) [19] observed highest ICBR (1:9.6) in triazophos; however, indoxacarb and emamectin benzoate noticed ICBR of 1: 4.5 and 1: 4.1, respectively. Thus, these results endorse the present finding.

Table 2: Persistence of different insecticides in leaves and pods of soybean applied as first and second spray against larvae of *H. armigera*

Treatments	I st spray									II nd spray								
	Corrected percentage mortality after different intervals (days)				P	T	PT	R.E	O.R.E	Corrected percentage mortality after different intervals (days)				P	T	PT	R.E	O.R.E.
	1	3	7	14						1	3	7	14					
Profenophos 0.100 per cent	89.29	64.34	55.22	13.85	55.67	14	779.45	1.11	5	82.73	71.13	42.79	10.81	51.86	14	726.11	1.11	5
Triazophos 0.050 per cent	85.67	62.56	51.70	13.83	53.44	14	748.16	1.07	6	79.31	67.88	42.79	10.81	50.19	14	702.76	1.07	6
Quinalphos 0.050 per cent	89.29	62.04	58.63	17.26	56.80	14	795.27	1.13	4	86.24	75.03	50.00	14.34	56.40	14	789.63	1.20	4
Indoxacarb 0.010 per cent	92.82	67.88	58.63	17.26	59.14	14	828.06	1.18	3	89.65	78.58	53.64	14.34	59.05	14	826.73	1.26	3
Ethion 0.100 per cent	82.11	58.63	48.29	10.34	49.84	14	697.79	1.00	7	75.90	64.34	39.29	7.17	46.67	14	653.38	1.00	7
Chlorantraniliprole 0.004 per cent	100.00	82.73	65.56	24.19	68.12	14	953.68	1.36	1	96.58	82.11	60.78	21.52	65.24	14	913.46	1.39	1
Emamectin benzoate 0.001 per cent	94.46	75.05	62.84	20.68	63.26	14	885.64	1.26	2	93.07	82.11	57.17	17.88	62.55	14	875.80	1.34	2

Residual toxicity of different insecticides against soybean pod borer, *H. armigera*

The data on the average percentage mortality of *H. armigera* larvae on soybean leaves and pods receiving first and second spray recorded at 1, 3, and 7 and 14 days intervals are presented in Table 2.

First spray

The result of first spray evident that chlorantraniliprole 0.004 per cent and emamectin benzoate 0.001 per cent concentrations exhibited comparatively high percentage mortality of *H. armigera* larvae to the tune of 24.19 and 20.68 per cent, respectively at 14 days after spraying. On the basis

of PT values the descending order of persistent toxicity was chlorantraniliprole 0.004 per cent (953.68) > emamectin benzoate 0.001 per cent (885.64) > indoxacarb 0.010 per cent (828.06) > quinalphos 0.050 per cent (795.27) > profenophos 0.100 per cent (779.45) > triazophos 0.050 per cent (748.16) > ethion 0.100 per cent (697.79).

The data pertaining to LT₅₀ values of insecticides against larvae of *H. armigera* on soybean leaves and pods are presented in Table 3.

The data revealed that chlorantraniliprole 0.004 per cent registered highest LT₅₀ value (7.93 days) against the larvae of *H. armigera* on soybean leaves and pods receiving first application of insecticides. The descending relative order of efficacy of insecticides in days was found to be chlorantraniliprole 0.004 per cent (7.93) > emamectin benzoate 0.001 per cent (7.06) > indoxacarb 0.010 per cent (6.21) > quinalphos 0.050 per cent (5.63) > profenophos 0.100 per cent (5.25) > triazophos 0.050 per cent (4.54) > ethion 0.100 per cent (4.05).

Second spray

The result of second spray evident that chlorantraniliprole 0.004 per cent and emamectin benzoate 0.001 per cent concentrations exhibited comparatively high percentage mortality of *H. armigera* larvae to the extent of 21.52 and 17.88 per cent, respectively at 14 days after spraying. On the basis of PT values the descending order of persistent toxicity was chlorantraniliprole 0.004 per cent (913.46) > emamectin benzoate 0.001 per cent (875.80) > indoxacarb 0.010 per cent (826.73) > quinalphos 0.050 per cent (789.63) > profenophos 0.100 per cent (726.11) > triazophos 0.050 per cent (702.76)

> ethion 0.100 per cent (653.38).

The data pertaining to LT₅₀ values of insecticides against larvae of *H. armigera* on soybean leaves and pods are presented in Table 3.

The data revealed that chlorantraniliprole 0.004 per cent registered highest LT₅₀ value (7.78 days) against the larvae of *H. armigera* on soybean leaves and pods receiving second application of insecticides. The descending relative order of efficacy of insecticides in days was found to be chlorantraniliprole 0.004 per cent (7.78) > emamectin benzoate 0.001 per cent (7.09) > indoxacarb 0.010 per cent (6.22) > quinalphos 0.050 per cent (5.65) > profenophos 0.100 per cent (4.87) > triazophos 0.050 per cent (4.36) > ethion 0.100 per cent (3.72).

Thus, it indicates that chlorantraniliprole 0.004 per cent and emamectin benzoate 0.001 per cent illustrated higher residual toxicity against the larvae of *H. armigera* as compare to other insecticides.

These findings are in agreement with the results of Sonune and Bhamare (2016) ^[27] who stated that that emamectin benzoate 0.0022 per cent and chlorantraniliprole 0.0055 per cent revealed the highest persistent toxicity index (PT) value of (925.08, 920.52 and 898.60 and; 864.36, 907.78 and 835.89) and LT₅₀ values (7.63, 7.52 and 7.27 and; 6.60, 7.32 and 6.23 days) against first instar larvae of pod borer after first, second and third spray, respectively as compared to the other insecticides. Dake *et al.* (2015) ^[8] reported that emamectin benzoate 0.002 per cent and chlorantraniliprole 0.005 per cent noticed highest PT (977.55 and 897.75) and LT₅₀ values (8.18 and 7.32 days) against head borer of sunflower.

Table 3: Relative efficacy of different insecticides against larvae of *H. armigera* on soybean leaves and pods applied as first and second spray

Treatments	I st Spray								II nd Spray							
	Heterogeneity		Regression	Log	LT ₅₀	Fiducial	R.E.	O.R.E.	Heterogeneity		Regression	Log	LT ₅₀	Fiducial	R.E.	O.R.E.
	d.f.	χ ²	Equation (y=.....)	LT ₅₀ ± S.Em	(days)	Limit (days)			d.f.	χ ²	Equation (y=.....)	LT ₅₀ ± S.Em	(days)	Limit (days)		
Profenophos 0.100 per cent	2	1.154	y=0.1273-1.8601x	0.7205±0.1275	5.25	1.09 12.37	1.29	5	2	1.191	y=0.1301-1.7019x	0.6882±0.1363	4.87	1.09 12.30	1.30	5
Triazophos 0.050 per cent	2	1.375	y=0.094-1.8081x	0.6570±0.1291	4.54	1.00 10.19	1.12	6	2	1.040	y=0.0779-1.5908x	0.6395±0.1350	4.36	1.05 11.28	1.17	6
Quinalphos 0.050 per cent	2	1.462	y=0.1802-1.8631x	0.7506±0.1285	5.63	1.14 13.82	1.39	4	2	0.984	y=0.1693-1.7611x	0.7526±0.1320	5.65	1.17 15.10	1.51	4
Indoxacarb 0.010 per cent	2	0.898	y=0.1755-2.0003x	0.7935±0.1232	6.21	1.17 14.93	1.53	3	2	1.065	y=0.2057-1.9331x	0.7984±0.1271	6.22	1.19 15.56	1.67	3
Ethion 0.100 per cent	2	1.186	y=-0.0423-1.6898x	0.6079±0.1364	4.05	0.96 9.30	1.00	7	2	1.245	y=-0.0327-1.5832x	0.5708±0.1444	3.72	0.94 8.83	1.00	7
Chlorantraniliprole 0.004 per cent	2	0.938	y=0.3321-2.5099x	0.8992±0.1077	7.93	1.26 18.25	1.95	1	2	0.379	y=0.2126-2.2456x	0.8914±0.1181	7.78	1.29 19.52	2.09	1
Emamectin benzoate 0.001 per cent	2	0.719	y=-0.1863-2.1842x	0.8492±0.1176	7.06	1.22 16.87	1.74	2	2	0.785	y=0.2228-2.0792x	0.8507±0.1231	7.09	1.25 17.82	1.90	2

Conclusion

The overall results proved that chlorantraniliprole 0.004 per cent was the most effective insecticide against *H. armigera* infesting soybean followed by emamectin benzoate 0.001 per cent and indoxacarb 0.010 per cent. Similarly the higher residual toxicity was exhibited by these insecticides against larvae of *H. armigera* on soybean.

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