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RESEARCH ARTICLE

Evaluation of New Insecticides Against Tomato Fruit Borer, *Helicoverpa armigera* Hubner

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ABSTRACT

The survey was conducted to assess the pesticide use pattern tomato and two field experiments were conducted to assess the efficacy of new insecticide molecules against tomato fruit borer. The results revealed that farmers used eighteen different insecticides for the management of fruit borer in tomato and quinalphos, chlorantraniliprole, flubendamide, chlorpyriphos, lambda cyhalothrin and indoxacarb were found to be frequent used insecticide in tomato. Among the insecticides tested, flubendiamide 480 SC registered percent damage reduction of about 86.37 and 96.41 per cent & cent percent and 99.6 per cent reduction of larval population over untreated control in first and second experiment, respectively followed by chlorantraniliprole 18.5 SC at 30 g a.i.ha^{-1}, lambda cyhalothrin 5 EC @ 15 g a.i. ha^{-1}, indoxacarb 14.5 SC at 75 g a.i. ha^{-1}, chlorpyriphos 20 EC at 200 g a.i. ha^{-1} and quinolphos 25 EC at 250 g a.i. ha^{-1}. The harvest time residues of flubendiamide 480 SC at 48 g a.i. ha^{-1} were at a below detectable levels in tomato fruit and soil samples collected during the first harvest. Hence, flubendiamide 480 SC @ 48 g.ai. ha^{-1} is included as a best fit component in the integrated pest management of fruit borers in tomato.

Keywords: *Tomato, Flubendiamide, Survey, Bioefficacy, Residue, Fruit borer*

INTRODUCTION

Tomato (*Solanum lycopersicum* Linnaeus = *Lycopersicon esculentum* Mill) is one of the most important and widely grown vegetable crops of both the tropics and subtropics. It is originally a native of tropical America from Peruvian and Mexican regions. This crop is cultivated over an area of 0.84 million ha with an annual production of 20.33 million tonnes and productivity of 24.2 tonnes per ha in India (Anonymous, 2022). The crop was encountered by many insect pests, of which tomato fruit borer, *Helicoverpa armigera* Hubner, was recorded as a major pest causing huge economic loss to tomatoes. Annual loss from this pest alone in various agricultural and horticultural crops, is estimated as 2 billion US dollars (Hayden and Brambila, 2015). This pest alone can cause up to 70 percent yield loss in tomatoes (Wakil *et al.,* 2018). The annual crop loss due to *H. armigera* in India has been estimated at around Rs. 2,000 crores (Pawar *et al*., 1999). The larva of fruit borer feed on foliage, floral buds and flowers and bores into fruits, thus making them unfit for human consumption. Chemical insecticides are used as the frontline defense sources against this pest. Most of the insecticides used on agricultural crops belong to a limited number of chemically different classes. At present the usage of broad spectrum insecticides like organophosphates, carbamates and synthetic pyrethroids were more to manage the pests of tomato. Indiscriminate use of pesticides leads to the development of resistance in pests against pesticides, pest resurgence and bioconcentrations of pesticide residues in consumable produce at harvest (Armes *et al*., 1994). However, chemical pesticides continue to be the mainstay of most of the economically important insect pest control programme. At the same time,

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to overcome the above mentioned problems, the identification of new chemical molecules with higher insecticidal properties, lower mammalian toxicity and lower dosage application with the selective mode of action fits well in the integrated pest management concept. Hence, in the management of pests with chemical insecticides, resistance has often been a problem or a potential problem and one of the most essential reasons why insecticides with a new mode of action have been desired. With the above background, research work was carried out to study the efficacy of new insecticide molecules against tomato fruit borer *H. armigera* and the harvest time residue of effective insecticide used in tomato.

MATERIAL AND METHODS

A detailed survey on pesticide usage pattern in tomato was undertaken at Coimbatore district of Tamil Nadu. The information on pesticide use pattern was gathered from 25 progressive farmers from Thondamuthur block. An interview schedule was prepared and used for the collection of data. The objectives and scope of the study were first explained to farmers for their fair cooperation. Even though the farmers of the study area did not maintain any records, they were able to furnish necessary information by memory recall and virtue of their experience.

Two field experiments were conducted to evaluate the bioefficacy of commonly used insecticides against fruit borer in tomato in two different places *viz.,* Naraseepuram (Experiment I) and Mathambatti (Experiment II) near Thondamuthur, Coimbatore district in randomized block design (RBD). The experiment was carried out with seven treatments *viz.,* quinolphos 25 EC @ 250 g.ai. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g.ai. ha^{-1}, flubendiamide 480 SC @ 48 g.ai. ha^{-1}, chlorpyriphos 20 EC @ 200 g.ai. ha^{-1}, lambdacyhathrin 5 EC @ 15 g.ai. ha^{-1}, indoxacarp 14.5 SC @ 75 g.ai. ha^{-1} and untreated check. All the treatments were replicated three times with a plot size of 25 m^2. Two rounds of spray were given in 15 days interval starting from the fruit initiation stage. The observations on fruit borer damage and larval population were recorded as pretreatment counts before spraying and post treatment count at 7 and 14 days after each spraying. The number of larvae was recorded on five randomly selected plants per plot, and the fruit damage was assessed based on a number of fruits with boreholes and total number of fruits in five randomly selected plants per plot and expressed as percent fruit damage.

Sampling of tomato (2 kg) was done from the plots treated with flubendiamide 480 SC @ 48 g a.i. ha^{-1} and untreated control plots during the first harvest and samples were transported to the laboratory and processed immediately. The time interval between last spraying and first harvest was 18 days in the first trial and 22 days in the second trial. The samples were processed by adopting modified QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) method (Anastassiades *et al.,* 2003). The reference standards of flubendiamide (99.6 % purity) were purchased from M/S Sigma Aldrich, Bangalore, India. Stock solutions (1000 µg mL^{-1}) of flubendiamide standard was prepared by dissolving 24.30 mg of analyte in 25 mL acetonitrile (v/v) in separate volumetric flasks. An intermediate stock solution of 100 and 10 µg mL^{-1} and working standard solutions (0.05 to 1 µg mL^{-1}) were prepared by serial dilution method. These working standards were used to determine the retention time of these compounds and for the quantitative determination of residues in samples. Recovery studies were carried out in order to establish the reliability of the method. The estimation of flubendiamide residues were performed by LCMS (Shimadzu, series 2020) equipped with diode array detector (SPD-M20A), degasser (DGU-20 A5R) and an autosampler (SIL-30AC). Chromatographic separation was achieved with reverse phase C18 column, 250 mm x 4.6 id x 5 µ particle size in a column oven, at 40°C. The isocratic elution condition employed a mobile phase of acetonitrile and 5 mM ammonium acetate (50:50) with a flow rate of 1 mL min^{-1} and the injection volume was 10 µL. Nitrogen gas was used as both nebulizer and collision gas. The drying gas flow rate was 15 L min^{-1} and nebulizing gas flow rate was 1.5 L min^{-1}. The Desolvation Line (DL) temperature was 250°C and heat block temperature was 400°C. The ions were monitored at positive SIM (Single Ion Monitoring) mode with an ESI (Electrospray Ionization) interface. The instrument parameters were controlled by LC Solutions software. The target ion mass, wavelength of maximum absorbance (ʎ max) and retention time for flubendiamide were 223 g mol^{-1}, 215 nm and 1.52 minutes, respectively. The amount of residue was determined by comparing the sample response with the response of standard by using the formula, Residues (ppm) = As/Astd x Wstd/Ws x Vs/Asj, where, A_s - Peak area of the sample; A_{std} - Peak area of the standard; W_{std} - Weight of the standard in ng; W_s - Weight of the sample in g; V_s - Volume of the sample (final extract in mL); A_{sj} - Aliquot of the sample injected in mL.

RESULTS AND DISCUSSION

The results of survey conducted to assess the pesticide use pattern tomato revealed that cent per cent of the farmers were used power operated sprayer for insecticide application. Nearly 76 percent farmers spray 7 to 10 rounds of pesticides to control the fruit borer alone. Regarding the spraying interval, sixty eight per cent of the farmers, followed 5 to 10 days of spraying interval (Table 1). Totally eighteen different insecticides were used by farmers for the management of fruit borer in tomato. It includes quinalphos (92 %), chlorantraniliprole (88 %), flubendamide (88 %), chlorpyriphos (84 %), lambda cyhalothrin (84 %), indoxacarb (80 %), emamectin benzoate (72 %), triazophos (72 %), fipronil (68 %), bifenthrin (68 %), spinosad (60 %), thiodicarb (56 %), dimethoate (52 %), profenofos (48 %), thiacloprid (36 %), cyantraniprole (36 %), noraluron (36 %) and carbaryl (24 %). Among these, quinalphos, chlorantraniliprole, flubendamide, chlorpyriphos, lambda cyhalothrin and indoxacarb usage was found to be maximum (Table 1). Current finding is in accordance with the results of Rauf *et al*., (2004), Sandur, (2004) and Mazlan and Mumford, (2005) who reported that, farmers in Malaysia, India and Indonesia often sprayed up to eleven types of insecticides per season, with spray intervals of 2 to 3 days on *Brassica* vegetables. The surveys in Kenya and Zimbabwe (Oruku and Ndungu, 2001; Sithole, 2005) revealed that there was an overwhelming reliance on broad-spectrum insecticides (pyrethroids, organophosphates, and carbamates), often applied weekly or biweekly.

Table 1. Survey on pesticide use pattern to control fruit borer in tomato at Coimbatore

Details (Collected from 25 Farmers)		Coimbatore	
		Number	Percentage
Number of Spraying	> 10 Nos.	-	-
	7-10 Nos.	19	76.0
	5 - 7 Nos.	5	20.0
	< 5 Nos.	1	04.0
Sprayer used	Power sprayer	25	100.0
	Hand sprayer	-	0.0
Frequency of spraying	3 to 5 days	8	32.0
	5 to 10 days	17	68.0
Insecticides used	Quinalphos	23	92.0
	Chlorantraniliprole	22	88.0
	Flubendamide	22	88.0
	Chlorpyriphos	21	84.0
	Lambda cyhalothrin	21	84.0
	Indoxacarb	20	80.0
	Emamectin benzoate	18	72.0
	Triazophos	18	72.0
	Fipronil	17	68.0
	Bifenthrin	17	68.0
	Spinosad	15	60.0
	Thiodicarb	14	56.0
	Dimethoate	13	52.0
	Profenofos	12	48.0
	Thiacloprid	9	36.0
	Cyantraniprole	9	36.0
	Noraluron	9	36.0
	Carbaryl	6	24.0

Table 2. Effect of insecticides on fruit damage in tomato (Experiment 1)

S. No	Treatments	Percent damage								
		I spray					II spray			
		PTC	7 DAT	14 DAT	Mean	% ROC	7 DAT	14 DAT	Mean	% ROC
1	Quinolphos 25 EC @ 250 g a.i.ha^{-1}	18.26	10.48 (18.89)^{c}	8.57 (17.02)^{d}	9.53	51.38	7.15 (5.51)^{c}	4.96 (12.87)^{c}	6.06	72.99
2	Chlorantraniliprole18.5 SC @ 30 g a.i.ha^{-1}	18.63	7.28 (15.65)^{a}	6.15 (14.36)^{a}	6.72	65.72	4.25 (11.90)^{a}	1.93 (7.99)^{a}	3.09	86.21
3	Flubendiamide 480 SC @ 48 g a.i.ha^{-1}	19.35	6.98 (15.32)^{a}	5.87 (14.02)^{a}	6.43	67.20	3.85 (11.32)^{a}	2.26 (8.65)^{a}	3.06	86.37
4	Chlorpyriphos 20 EC @ 200 g a.i.ha^{-1}	19.45	10.87 (19.25)^{c}	8.15 (16.59)^{cd}	9.51	51.45	7.56 (15.96)^{c}	5.08 (13.03)^{c}	6.32	71.80
5	Lambdacyhalothrin 5 EC @ 15 g a.i.ha^{-1}	19.12	8.18 (16.62)^{b}	7.57 (15.97)^{b}	7.88	59.80	5.16 (13.13)^{b}	4.22 (11.85)^{b}	4.69	79.08
6	Indoxacarb 14.5 SC @ 75 g a.i.ha^{-1}	18.45	8.45 (16.90)^{b}	7.80 (16.22)^{bc}	8.13	58.52	5.55 (13.60)^{b}	4.18 (11.80)^{b}	4.87	78.30
7	Untreated check	18.63	19.15 (25.95)^{d}	20.03 (26.59)^{e}	19.59	-	21.65 (27.73)^{d}	23.18 (28.78)^{d}	22.42	-

*Mean of four replications; ROC- Reduction over control; PTC- Pretreatment count; DAT - Days after Treatment; Figures in parentheses are arc sin transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

The results of the field experiment (Experiment 1) showed the damage per cent due to bollworm complex before imposing treatments ranged from 18.26 to 19.45 (Table 2). After first round of application the highest mean per cent reduction was recorded in plots treated with flubendiamide 480 SC at 48 g a.i. ha^{-1} (67.20%) over untreated check followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1} (65.72%) and lowest was recorded in quinolphos 25 EC @ 250 g a.i. ha^{-1} (51.38 %) treated plots. After second round of application, flubendiamide 480 SC at 48 g a.i. ha^{-1} registered a mean reduction of 86.37 per cent damage over untreated check followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1} (86.21%), lambda cyhalothrin 5 EC @ 15 g a.i. ha^{-1} (79.08%), indoxacarb 14.5 SC at 75 g a.i. ha^{-1} (78.30%), chlorpyriphos 20 EC at 200 g a.i. ha^{-1} (71.80%) and quinolphos 25 EC at 250 g a.i. ha^{-1} (72.99 %) (Table 2). The larval population of *H. armigera* before imposing treatments ranged from 8.61 to 9.67 larvae per five plants (Table 3). There was a significant reduction in the larval population after spraying flubendiamide 480 SC. On the seventh day after treatment (DAT), the lowest larval population was recorded in plots sprayed with flubendiamide 480 SC at 4860 g a.i. ha^{-1} (1.13 larvae/ five plants) followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1} (1.39 larvae/ five plants), indoxacarb 14.5 SC at 75 g a.i. ha^{-1} (2.09 larvae/ five plants) and lambda cyhalothrin 5 EC @ 15 g a.i. ha^{-1} (2.42 larvae/ five plants) and the highest larval population was observed in the plots treated with quinolphos 25 EC at 250 g a.i. ha^{-1} (4.11 larvae/ five plants) and chlorpyriphos 20 EC at 200 g a.i. ha^{-1} (4.37 larvae/ five plants) found to be on par with each other among each other, whereas, untreated check recorded 11.33 larvae per five plants. After 14 DAT, flubendiamide 480 SC at 48 and chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1} recorded 82.90 and 80.40 percent reduction in larval population when compared to the untreated check. After the second round of application, at 7 DAT, flubendiamide 480 SC at 48 g a.i. ha^{-1} and chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1} were found be more effective than other treatments recording 0.00 and 0.08 larvae per five plants, respectively, whereas, untreated check recorded the highest of 12.81 larvae per five plants. After two rounds of spray,

Table 3. Effect of test chemicals on fruit borer larvae in tomato (Experiment 1)

S. No	Treatments	Population (Number per 5 plants)								
			I spray				II spray			
		PTC	7 DAT	14 DAT	Mean	% ROC	7 DAT	14 DAT	Mean	% ROC
1	Quinolphos 25 EC @ 250 g a.i.ha^{-1}	8.98	4.11 (2.15)^{e}	5.25 (2.40)^{d}	4.68	60.37	3.34 (1.96)^{c}	4.85 (2.31)^{f}	4.10	64.44
2	Chlorantraniliprole18.5 SC @ 30 g a.i.ha^{-1}	8.61	1.39 (1.37)^{a}	3.24 (1.93)^{a}	2.32	80.40	0.08 (0.76)^{a}	0.12 (0.79)^{a}	0.10	99.13
3	Flubendiamide 480 SC @ 48 g a.i.ha^{-1}	8.91	1.13 (1.28)^{b}	2.91 (1.85)^{a}	2.02	82.90	0.00 (0.71)^{a}	0.00 (0.71)^{b}	0.00	100.00
4	Chlorpyriphos 20 EC @ 200 g a.i.ha^{-1}	9.52	4.34 (2.20)^{e}	5.40 (2.43)^{cd}	4.87	58.76	3.08 (1.89)^{c}	4.51 (2.24)^{e}	3.80	67.04
5	Lambdacyhalothrin 5 EC @ 15 g a.i.ha^{-1}	9.67	2.42 (1.71)^{d}	3.31 (1.95)^{b}	2.87	75.74	0.96 (1.21)^{b}	1.91 (1.55)^{d}	1.44	87.54
6	Indoxacarb 14.5 SC @ 75 g a.i.ha^{-1}	9.09	2.09 (1.61)^{c}	3.29 (1.95)^{bc}	2.69	77.22	1.09 (1.26)^{b}	1.62 (1.46)^{c}	1.36	88.23
7	Untreated check	9.33	11.33 (3.44)^{f}	12.29 (3.58)^{e}	11.81	0.00	12.81 (3.65)^{d}	10.22 (3.27)^{g}	11.52	0.00

*Mean of four replications; ROC- Reduction over control; PTC- Pretreatment count; DAT - Days after Treatment; Figures in parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

flubendiamide 480 SC at 48 g a.i. ha^{-1} recorded a cent percent reduction of the larval population of *H. armigera* over the untreated check (Table 3).

The results of field experiment 2 revealed that, the pretreatment damage was in the range of 10.23 to 12.92 per cent (Table 4). Among the chemicals tested, flubendiamide 480 SC at 48 g a.i. ha^{-1} was found to be the most effective treatment recording a mean per cent damage reduction of 52.15 and 96.42 per cent after first and second rounds of spraying, respectively followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1}, lambda cyhalothrin 5 EC @ 15 g a.i. ha^{-1}, indoxacarb 14.5 SC at 75 g a.i. ha^{-1} registered a mean per cent reduction of 95.12, 91.30 and 90.87 per cent damage after two applications over untreated check, respectively. The pretreatment population of *H. armigera* varied from 6.32 to 7.53 larvae per five plants (Table 5). After first round of spray, among the insecticidal treatments, the highest reduction was recorded by flubendiamide 480 SC at 48 g a.i. ha^{-1} (83.49%) treated plots followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha^{-1}, indoxacarb 14.5 SC at 75 g a.i. ha^{-1} and lambda cyhalothrin 5 EC @ 15 g a.i. ha^{-1} recorded a mean per cent population reduction of 82.87, 78.50 and 76.82 per cent over untreated check, respectively. The build up of *H. armigera* population at 14 DAT necessitated the second spray. After two rounds of spray, flubendiamide 480 SC at 48 g a.i. ha^{-1} registered 99.60 mean per cent reduction over control and the lowest per cent reduction was observed in the plots treated with quinolphos 25 EC at 250 g a.i. ha^{-1} (72.07 %). Flubendiamide 480 SC at 48 g a.i. ha^{-1} was registered statistically superior compared to other insecticidal treatments (Table 5).

The results of the field experiments on tomato revealed that flubendiamide 480 SC effected marked reduction in the per cent damage caused by fruit borer as well as the reduction of population of *H. armigera* larvae over untreated check. Narayana and Rajasri (2006), Kuttalam *et al.,* (2008) and Kubendran *et. al.,* (2008) reported that flubendiamide at 50 and 100 g a.i. ha^{-1} was found to be effective against *H. armigera* compared to standard checks of spinosad and indoxacarb. Effectiveness of flubendiamide 480 SC in checking the population and damage of diamond back

Table 4. Effect of insecticides on fruit damage in tomato (Experiment 2)

S. No	Treatments	Percent damage								
		I spray					II spray			
		PTC	7 DAT	14 DAT	Mean	% ROC	7 DAT	14 DAT	Mean	% ROC
1	Quinolphos 25 EC @ 250 g a.i.ha-1	10.48	8.98 (17.43)c	6.42 (14.67)b	7.70	45.25	4.19 (11.81)f	3.35 (10.54)f	3.77	78.21
2	Chlorantraniliprole18.5 SC @ 30 g a.i.ha-1	11.48	7.23 (15.59)a	6.45 (14.71)ab	6.84	51.37	1.28 (6.49)b	0.41 (3.67)b	0.85	95.12
3	Flubendiamide 480 SC @ 48 g a.i.ha-1	10.23	7.45 (15.83)a	6.01 (14.19)a	6.73	52.15	1.01 (5.76)a	0.23 (2.74)a	0.62	96.42
4	Chlorpyriphos 20 EC @ 200 g a.i.ha-1	10.25	8.23 (16.67)b	6.86 (15.18)bc	7.55	46.36	3.23 (10.35)e	2.86 (9.73)e	3.05	82.40
5	Lambdacyhalothrin 5 EC @ 15 g a.i.ha-1	12.36	7.21 (15.57)a	7.06 (15.40)bc	7.14	49.27	2.03 (8.19)c	0.98 (5.68)d	1.51	91.30
6	Indoxacarb 14.5 SC @ 75 g a.i.ha-1	11.90	6.98 (15.31)a	7.38 (15.76)c	7.18	48.95	2.35 (8.81)d	0.81 (5.16)c	1.58	90.87
7	Untreated check	12.92	13.85 (21.84)d	14.28 (22.02)d	14.07	0.00	16.78 (24.18)g	17.82 (24.96)g	17.30	-

*Mean of four replications; ROC- Reduction over control; PTC- Pretreatment count; DAT - Days after Treatment; Figures in parentheses are arc sin transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

Table 5. Effect of test chemicals on fruit borer larvae in tomato (Experiment 2)

S. No	Treatments	Population (Number per 5 plants)								
		I spray					II spray			
		PTC	7 DAT	14 DAT	Mean	% ROC	7 DAT	14 DAT	Mean	% ROC
1	Quinolphos 25 EC @ 250 g a.i.ha-1	7.21	3.29 (1.95)c	3.42 (1.98)d	3.36	58.19	2.01 (1.58)f	2.23 (1.65)f	2.12	72.07
2	Chlorantraniliprole18.5 SC @ 30 g a.i.ha-1	6.75	1.19 (1.30)a	1.56 (1.44)a	1.38	82.87	0.05 (0.74)b	0.19 (0.83)b	0.12	98.42
3	Flubendiamide 480 SC @ 48 g a.i.ha-1	6.32	1.29 (1.34)a	1.36 (1.36)b	1.33	83.49	0.02 (0.72)a	0.04 (0.73)a	0.03	99.60
4	Chlorpyriphos 20 EC @ 200 g a.i.ha-1	7.46	3.52 (2.00)c	3.85 (2.09)e	3.69	54.08	1.87 (1.54)e	1.98 (1.57)e	1.93	74.64
5	Lambdacyhalothrin 5 EC @ 15 g a.i.ha-1	6.79	1.49 (1.41)b	2.23 (1.65)c	1.86	76.82	0.41 (0.95)c	0.72 (1.10)c	0.57	92.56
6	Indoxacarb 14.5 SC @ 75 g a.i.ha-1	7.53	1.59 (1.45)b	1.86 (1.54)d	1.73	78.50	0.68 (1.09)d	0.82 (1.15)d	0.75	90.12
7	Untreated check	6.86	7.56 (2.84)d	8.49 (3.00)f	8.03	0.00	8.26 (2.96)g	6.92 (2.72)g	7.59	0.00

*Mean of four replications; ROC- Reduction over control; PTC- Pretreatment count; DAT - Days after Treatment; Figures in parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

Table 6. Harvest time residues of flubendiamide 480 SC in tomato fruits

Treatments	Residues of flubendiamide 480 SC (in mg g^{-1})			
	Fruits		Soil	
	I picking	II picking	I picking	II picking
Experiment 1				
Flubendiamide 480 SC @ 48 g a.i.ha^{-1}	BDL	BDL	BDL	BDL
Control	BDL	BDL	BDL	BDL
Experiment 2				
Flubendiamide 480 SC @ 48 g a.i.ha-1	BDL	BDL	BDL	BDL
Control	BDL	BDL	BDL	BDL

BDL - Below detectable level

moth in cabbage was confirmed by Vinothkumar *et al.,* (2007). Vinothkumar *et al.,* (2010) reported that, ready mixture formulation of flubendiamide + thiacloprid 480 SC @ 50 g a.i. ha^{-1} was effectively checking the population of *H. armigera* in cotton. This shows that newer insecticides are effective even at lower doses.

The study on harvest time residues of flubendiamide 480 SC at 48 g a.i. ha^{-1} in tomato revealed that the minimum detection limit of the instrument was 0.01 µg g^{-1}. The limit of detection (LOD) for the tomato fruit and soil samples was 0.015 µg g^{-1} and the limit of quantification was 0.05 µg g^{-1} considering the weight of the sample as 10 g for tomato fruit and soil samples, and final volume of the extract was 1 mL. The standard chromatogram of flubendiamide is presented in Fig.1. The mean recovery was 92.15 percent from samples fortified at 0.05, 0.25 and 0.5 µg g^{-1} levels. The harvest time residues of flubendiamide 480 SC at 48 g a.i. ha^{-1} were at below detectable level in tomato fruit and soil samples collected during first harvest (Table 6). Present result is in accordance with the finding of Thilagam (2005), who reported the residues of flubendiamide 480 SC in cotton lint, seed, oil and soil at below detectable levels at the time of harvest similarly flubendiamide 480 SC applied at 30 and 60 g a.i. ha^{-1} left residues at BDL in rice grains, husk, and straw and soil samples (Thilagam 2005).

CONCLUSION

Tomato fruit borer is the major pest of tomato, farmers use eighteen different insecticides to check the population and damage caused by *H. armigera*. Quinalphos, chlorantraniliprole, flubendamide, chlorpyriphos, lambda cyhalothrin and indoxacarb were found to be maximum use in tomato ecosystem. Among all, flubendiamide 480 SC effected a marked reduction in the percent damage caused by fruit borer as well as the reduction of the population of *H. armigera* larvae over an untreated check without leaving any residue in the harvested product. Hence, flubendiamide 480 SC @ 48 g.ai. ha^{-1} is included as best fit component in the integrated pest management of fruit borers in tomato.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

The authors assure that the contents were written by us and were not plagiarized.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail.-

Author contributions

Idea conceptualization – BVK; Experiments – BVK and VM; Guidance - BVK, Writing original draft - VM; Writing - reviewing & editing – BVK, VM.

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