



Comparative study of insecticide resistance management strategies against brinjal shoot and fruit borer (*Leucinodes orbonalis*) (Lepidoptera: Crambidae)

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Received: 19 August 2020; Accepted: 12 February 2021

ABSTRACT

An experiment was conducted for *kharif* (2015–16 to 2017–18) in the field conditions to evaluate different insecticide usage tactics as resistance management strategies against *Leucinodes orbonalis* Guenee a serious shoot and fruit borer pest of brinjal (*Solanu melongena* L.). The results on bio-efficacy of insecticides revealed that in terms of shoot infestation, rotational strategy (chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emmamectin benzoate 5 SG @ 200 ml/ha, spinosad45 SC @ 125 ml/ha, chorpyrifos20EC @ 1000 ml/ha, cypermethrin 25 EC @ 250 ml/ha) was significantly effective and recorded least per cent shoot infestation as compared to other resistance management strategies. Rotational strategy was highly effective in reducing fruit infestation and it was followed by chlorantraniliprole 18.5 SC, emmamectin benzoate 5SG and Spinosad 45 SC which comes under sequential strategy. Fruit yield obtained highest i.e. 360 q/ha with rotational strategy, however due to higher cost of chemicals, benefit cost ratio was found to be low but net profit was highest and it was followed by sequential strategy and mixture strategy. Based on the overall mean population of natural enemy, i.e. coccinellids (*Cheilomenes sexmaculata* and *Coccinella septempunctata*) it was apparent that the majority of the newer molecules were safer to the predator. Hence, rotational strategy, i.e. spraying of chlorantraniliprole 18.5 SC, emmamectin benzoate 5 SG, spinosad45 SC, chorpyrifos 20 EC and cypermethrin25 EC at 15 days interval can be used as a new tool by farmers for effective management against *L. orbonalis*.

Keywords: Brinjal, Coccinellids, *Leucinodes orbonalis*, Resistance management strategy

Brinjal (*Solanu melongena* L.) is a most popular and economically important vegetable among small-scale farmers and low income consumers of the country (Bhushan *et al.* 2011). After potato, it ranks second highest consumed vegetable in India, along with tomato and onion. It is grown in about 668.72 thousand ha contributing 12399.90 metric tonnes production with an average national productivity of 18.54 mt/ha (NHB 2017). Brinjal, an economically important commercial crop, is reported variedly to be infested by more than 36 pests (Regupathy *et al.* 1997) from the time of its planting to harvest. Among them, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee (Crambidae:Lepidoptera) is considered to be the most key pest of brinjal and it has become a very serious production constraint in all brinjal growing countries (Alam *et al.* 2003). Damage can often be severe resultant the variable economic yield losses from 37–93% in various states of India

(Choudhary and Gaur 2009). Among the different vegetables, maximum pesticide usage is in brinjal with 4.60 kg a.i per ha after chilli (Kodandaram *et al.* 2013). Conventional insecticides, viz. organophosphates, synthetic pyrethroids and carbamates are generally used to control the pest but these reduce the beneficial arthropods and have ill effect on non-target organisms. Extensive use of pesticides has led to the development of high level of insecticide resistance to a number of conventional insecticides on *L. orbonalis* (Rahman and Rahman 2009). However, growing concerns about the harmful residues in food, effects on non-target organisms and development of insecticide resistance have necessitated the development of new and safer molecules (Kodandram *et al.* 2015). Thus, timely implementation of resistance management program may help in delaying the development of insecticide resistance and provide time for a comprehensive and effective pest management program. Therefore, the present study was conducted with sequential strategy, rotational strategy and mixture strategy which is a part of IRM (Insecticide Resistance Management) program at national level.

MATERIALS AND METHODS

Experimental site: The trials were conducted in randomized block design having plot size of 25 m² and

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spacing 75 cm × 75 cm at All India Co-ordinated Research Project on Vegetable Research Centre of Bihar Agricultural College, Sabour, Bhagalpur, Bihar (latitude 87° 2' 54"E, longitude 25° 14' 24"N, altitude 30 MSL.). The study was carried out during *kharif* 2015–16, 2016–17 and 2017–18. The seedlings of variety, Mukta Keshi were transplanted on 5th August 2015, 8th August 2016 and 14th August 2017 as per recommended package of practices except insect-pest management practices.

Test chemicals: The proprietary formulations of insecticides, viz. chlorantraniliprole 18.5 SC (Corazen) @ 150 ml/ha of DUPONT Pvt Ltd, emamectin benzoate 5 SG (Bioclaim) @ 200 ml/ha of BIOSTADT India, spinosad 45 SC (Tracer) @ 125 ml/ha of Dow Agro Pvt Ltd, chlorpyrifos 20 EC (Dursban) @ 1000 ml/ha of Dow Agro Pvt Ltd, cypermethrin 25 EC (Superkiller) @ 250 ml/ha of Dhanuka Agritech Pvt Ltd, Chlorpyrifos 50% + cypermethrin 5% EC (Naag 505) @ 1000 ml/ha of India Mart Pvt. Ltd, were obtained from their respective source of supply and used in the present investigation.

Field efficacy: There were seven treatments under three different strategies, i.e. sequential strategy, rotational strategy and mixture strategy and the treatment details were i-Sequential strategy: T₁ – chlorantraniliprole 18.5 SC @ 150 ml/ha, T₂ – emamectin benzoate 5SG @ 200 ml/ha, T₃ – spinosad 45 SC @ 125 ml/ha, T₄ – chlorpyrifos 20EC @ 1000 ml/ha, T₅ – cypermethrin 25 EC @ 250 ml/ha, ii. Rotational strategy: T₆ – chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emamectin benzoate 5 SG @ 200 ml/ha, spinosad 45 SC @ 125 ml/ha, chlorpyrifos 20 EC @ 1000 ml/ha, cypermethrin 25 EC @ 250 ml/ha, iii. Mixture strategy: T₇ – Chlorpyrifos 50% + cypermethrin 5% EC @ 1000 ml/ha (Combination Product/insecticide) and untreated control. All the treatments were applied under warm and sunny conditions with little or no winds using high volume knapsack sprayer fitted with hollow cone nozzle and using 375-500 l of spray fluid per ha. First spraying was done at 30 days after transplanting and sprays were given at an interval of 15 days. In sequential strategy, each insecticide has been sprayed once and rotated with the next insecticide, whereas in rotational strategy, each insecticide has been sprayed only twice and rotated in sequence with the next insecticide and at 15 days interval were maintained between each sprays. Observations on per cent shoot damage and per cent fruit borer damage on number and weight basis, cost economics and yield (kg) per plot after five harvests were recorded. The yield per plot was converted to yield q/ha. Natural enemy observations were also taken per plant basis.

Statistical analysis: The data on per cent shoot and fruit damage in field trials were subjected to one way analysis of variance (ANOVA) after transformation by using SPSS Version 16.0 software.

RESULTS AND DISCUSSION

Per cent shoot damage: Data on evaluation of different insecticide resistant strategies against per cent shoot damage by *L. orbonalis* (Table 1) indicates that all the treatments

were significantly superior over untreated control. However, among the different treatments, T₆, i.e. rotational strategy (chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emamectin benzoate 5 SG @ 200 ml/ha, spinosad 45 SC @ 125 ml/ha, chlorpyrifos 20 EC @ 1000 ml/ha, cypermethrin 25 EC @ 250 ml/ha) was found to be significantly effective (6.84% and 73.39%) in reduction of per cent shoot damage, per cent reduction of shoot over control and it was at par sequential strategy (chlorantraniliprole 18.5 SC @ 150 ml/ha (8.57% and 66.67%). The next best treatment was T₂, i.e. emamectin benzoate 5SG @ 200 ml/ha (11.62% and 54.80%) and it was followed by T₃, i.e. spinosad 45 SC @ 125 ml/ha (13.58% and 47.18%) and both comes under sequential strategy. While, maximum (19.44% and 24.39%) per cent shoot infestation was recorded with T₄, i.e. chlorpyrifos 20EC @ 1000 ml/ha (19.44% and 24.39%). Experimental results clearly stated that rotational strategy, i.e. chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emamectin benzoate 5 SG @ 200 ml/ha, spinosad 45 SC @ 125 ml/ha, chlorpyrifos 20 EC @ 1000 ml/ha, cypermethrin 25 EC @ 250 ml/ha was most effective in reduction of shoot damage by shoot and fruit borer. The present results are in conformity with Shah *et al.* (2012) who found that minimum per cent shoot damage was recorded in order of effectiveness was emamectin benzoate (Proclaim 5 WG) 0.0025% (89.56) > flubendiamide (Fame 480 SC) 0.01% (83.70) > rynaxypyr (Coragen 20 SC) 0.006% (81.04) > lufenuron (Match 5 EC) 0.005% (74.62) > novaluron (Remon 10 EC) 0.01% (69.03) > indoxacarb (Fego 15.5 SC) 0.007% (67.46) > thiodicarb (Larvin 75 WP) 0.075% (61.66) > spinosad (Spintor 45 SC) 0.0135% (59.55) > dichlorvos (Nuvan 76 EC) 0.076% (45.97) > fenvalerate (Tatafen 20 EC) 0.01% (36.63). Reshma and Behera (2018) reported that flubendiamide 480 SC @ 78.70 g a.i. /ha, rynaxypyr 20 SC @ 33.33 ml a.i/ha and spinosad 45 SC @ 10 ml a.i/ha proved highly effective in minimum per cent shoot damage by *L. orbonalis*.

Per cent fruit damage on number and weight basis: Regarding fruit infestation on number basis (Table 1) indicated that mean per cent fruit damage (number basis) varied from 8.47 to 32.12%. All the treatments were significantly superior over control. However, minimum per cent (8.47% and 73.63%) fruit infestation was noticed in the treatment T₆, i.e. rotational strategy and it was followed by T₁, i.e. chlorantraniliprole 18.5 SC (10.50% and 67.31%) which comes under sequential strategy. The next best treatments were T₂ and T₃, i.e. emamectin benzoate 5 SG @ 0.5 g/l (13.13% and 59.12%) and spinosad 45 SC @ 0.5 ml/l (14.05% and 56.25%) which were at par with each other's and they comes under sequential strategy. On the contrary, maximum (19.71% and 38.64%) per cent fruit infestation was recorded with T₄, i.e. chlorpyrifos 20EC @ 2 ml/l. However, per cent fruit infestation on weight basis is concerned (Table 1), mean value of three years result showed that least (11.56% and 70.25%) fruit damage was noticed in the treatment T₆, i.e. rotational strategy and it was followed by treatment T₁, T₂ and T₃, i.e. chlorantraniliprole 18.5 SC, emamectin benzoate 5 SG

Table 1 Evaluation of different resistance management strategies on shoot and fruit infestation by *L. orbonalis* during *kharif* 2015–16 to 2017–18

Treatment	Per cent shoot damage (mean value of three years)	Per cent reduction in shoot infestation over control	Per cent fruit damage (Number basis) (mean value of three years)	Per cent reduction in fruit infestation over control	Per cent fruit damage (Weight basis) (mean value of three years)	Per cent reduction in fruit infestation over control	Coccinellids population/plant (mean value of three years)
<i>Sequential strategy</i>							
T ₁ Chlorantraniliprole 18.5 SC (0.006 %)	8.57 (16.99 ^{d*})	66.77	10.50 (18.85 ^{bcd*})	67.31	14.35 (22.24 ^{bcd*})	62.87	0.92 (1.19 ^{b**})
T ₂ Emamectin benzoate 5 WG (0.0025 %)	11.62 (19.89 ^{bcd})	54.80	13.13 (21.21 ^{bc})	59.12	16.48 (23.93 ^{bc})	57.36	0.92 (1.19 ^b)
T ₃ Spinosad 45 SC (0.0135 %)	13.58 (21.53 ^{bc})	47.18	14.05 (21.99 ^{bc})	56.25	17.75 (24.90 ^{bc})	54.07	0.88 (1.17 ^b)
T ₄ Chloropyrifos 20 EC (0.5 %)	19.44 (26.14 ^b)	24.39	19.71 (26.31 ^b)	38.64	22.18 (28.08 ^b)	42.61	0.65 (1.06 ^b)
T ₅ Cypermethrin 20EC (0.04 %)	17.69 (24.85 ^b)	31.19	18.20 (25.20 ^b)	43.34	20.46 (26.88 ^b)	47.06	0.60 (1.05 ^b)
<i>Rotational strategy</i>							
T ₆ Ryn+Ema+Spin+ Chloro+Cyper	6.84 (15.12 ^d)	73.39	8.47 (16.83 ^{b-c})	73.63	11.56 (19.83 ^{b-c})	70.25	0.82 (1.14 ^b)
<i>Mixture strategy</i>							
T ₇ Chlorpyrifos 50 % + cypermethrin 5 % EC	16.10 (23.63 ^b)	37.38	15.59 (23.23 ^b)	51.46	18.44 (25.42 ^b)	52.29	0.62 (1.06 ^b)
T ₈ Untreated control	25.71 (30.46 ^a)		32.12 (34.51 ^a)		38.65 (38.43 ^a)		1.73 (1.48 ^a)
SEm (±)	0.89		1.01		1.01		0.06
CD (P=0.05)	2.68		3.08		3.06		0.19

*Figures in parentheses are arcsine transformed values; **Figures in parentheses are square root transformation; Means followed by a common letter are not significantly different at the 5 % level by DMRT.

and spinosad 45 SC (14.35%, 16.48% and 17.75%) which comes under rotational strategy. The present study clearly stated that rotational strategy, i.e. chlorantraniliprole 18.5 SC @ 150 ml/ha followed by emamectin benzoate 5 SG @ 200 ml/ha, spinosad 45 SC @ 125 ml/ha, chlorpyrifos 20 EC @ 1000 ml/ha, cypermethrin 25 EC @ 250 ml/ha was significantly superior in reduction of fruit damage (both number and weight basis) than other resistance management strategies. The present observations on the effectiveness of chlorantraniliprole, emamectin benzoate and spinosad are in conformity with Reshma and Behers (2018) who reported that the fruit infestation was recorded least in flubendiamide 480 SC @ 78.70 g a.i./ha, rynaxypyr 20 SC @ 33.33 ml a.i./ha and spinosad 45 SC @ 10 ml a.i./ha. Shah *et al.* (2012) reported that minimum per cent fruit damage was recorded in order of effectiveness was emamectin benzoate (75.06%) > flubendiamide (63.02%) > rynaxypyr (61.55%) > lufenuron (49.93%) > novaluron (47.69%) > indoxacarb (45.34%) > thiodicarb (41.08%) > spinosad (37.27%) > dichlorvos (25.58%) > fenvalerate (24.51%). The present findings are also supported by Mainali *et al.* (2015) who found that the fruit infestation per cent on number and weight basis was significantly lowest in Chlorantraniliprole (6.57 and 6.31%)

and Spinosad (12.08 and 11.15%) treated plots as compared to other treatments.

Natural enemy: The safeness of treatments to predatory coccinellids was a necessary factor to take into account (Table 1). Based on three years observation on the mean population of coccinellids, it indicates that most of the treatments were safer to coccinellids. Maximum population of coccinellids was recorded with untreated control (1.73/plant). However, chlorantraniliprole, emamectin benzoate and spinosad were also found safer (0.92, 0.92 and 0.88/plant) to coccinellids. The present study clearly indicated that all the newer molecules were safer to predator. Saha *et al.* (2014) reported that the control invariably gave higher count of coccinellids than others. Flubendiamide, chlorantraniliprole and spinosad were safer for coccinellids and spiders. Sudarshan and Sarkar (2011) revealed that flubendiamide and chlorantraniliprole were also safer for coccinellids and spiders.

Yield and cost economics: The marketable fruit yield (q/ha) was significantly more in all the treatments as compared to untreated control (Table 2). The highest (360.11 q/ha and 49.15%) yield obtained in plots treated with rotational strategy (T₆), i.e. chlorantraniliprole 18.5

Table 2 Yield and cost economics of different treatments in brinjal during *khariif* 2015–16 to 2017–18 (Mean value of three years)

Treatment	Yield (q/ha)	Per cent increase in yield over control	Gain in yield over control	Value of additional yield	Total Cost (Treatment + labour cost)	Net gain (₹)	Benefit: cost
<i>Sequential strategy</i>							
Chlorantraniliprole 18.5 SC (0.006%)	343.85 ^a	46.75	160.75	343850	8734	335116	39.37
Emamectin benzoate 5 WG (0.0025%)	334.19 ^{ab}	45.21	151.09	334190	9134	325056	36.59
Spinosad 45 SC (0.0135%)	329.06 ^{ab}	44.35	145.96	329060	8034	321026	40.96
Chloropyrifos 20 EC (0.5%)	286.55 ^c	36.10	103.45	286550	7634	278916	37.54
Cypermethrin 20EC (0.04%)	282.45 ^c	35.17	99.35	282450	7334	275116	38.51
<i>Rotational strategy</i>							
Ryn+Ema+Spin + Chloro+Cyper	360.11 ^a	49.15	177.01	360110	10234	349876	35.19
<i>Mixture strategy</i>							
Chlorpyrifos 50% + cypermethrin 5% EC	301.13 ^c	39.19	118.03	301130	4984	296146	60.42
Untreated control	183.10 ^d						
SEm (±)	8.05						
CD (P=0.05)	24.41						

Market price of fruit yield: 1000 q; Means followed by a common letter are not significantly different at the 5% level by DMRT.

SC followed by emamectin benzoate 5 SG, spinosad 45 SC, chlorpyrifos 20 EC, cypermethrin 25 EC. This treatment was at par with chlorantraniliprole 18.5 SC (T₁) (343.85 q/ha and 46.75%) and it was followed by emamectin benzoate 5SG@ (T₂) (334.19 q/ha and 45.21 %) and spinosad 45 SC (T₃) (329.06 q/ha and 44.35%). All this three treatments comes under sequential strategy. As far as cost of economics is concerned (Table 2), the treatment T₆, i.e. rotational strategy obtained maximum (349876) net gain than other resistance management strategies and it was followed by treatment T₁ (chlorantraniliprole 18.5 SC), T₂ (emamectin benzoate 5 SG) and T₃ (spinosad 45 SC) (335116, 325056 and 321026). The benefit cost ratio calculated on the basis of cost of protection for different insecticidal treatments indicated in chronological order was chlorpyrifos+cypermethrin>spinosad 45 SC >chlorantraniliprole 18.5 SC >Cypermethrin 20EC >Chloropyrifos 20 EC >Emamectin benzoate 5 WG >Ryn+Ema+Spin+Chloro+Cyper. In spite of lower effectiveness, yield and net gain, chlorpyrifos+cypermethrin and Chloropyrifos 20 EC was recorded higher benefit cost ratio because of lower price of these insecticides. The present findings clearly depicted that rotational strategy recorded significantly higher yield and net profit in all the three years than other strategies. The present results are in conformity with Saha *et al.* (2014) who reported that maximum yield was obtained with rynaxpyre 20 SC followed by flubendiamide 480 SC, spinosad 2.5 SC and emamectin benzoate 5SG. Mainali *et al.* (2015) recorded that chlorantraniliprole treated plot recorded the maximum marketable yield (32.03 mt/ha) followed by spinosad (30.93 mt/ha) with 34.39% and 29.77% increase in marketable fruit yield over untreated check, respectively.

Thus, the present study suggested that rotational strategy (chlorantraniliprole 18.5 SC followed by emamectin benzoate 5 SG, spinosad 45 SC, chlorpyrifos 20 EC, cypermethrin 25 EC) was superior than other resistance management strategies in terms of significant reduction of shoot as well as fruit infestation by *L. orbinalis*, however, on the basis of cost benefit ratio, chlorpyrifos 50% + cypermethrin 5% EC, spinosad 45 SC and chlorantraniliprole 18.5 SC were superior.

ACKNOWLEDGEMENTS

The authors are grateful to All India Coordinated Research Project (AICRP), Varanasi for providing financial grant to carry out the research work.

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