Pest Management in Horticultural Ecosystems
Vol. 30, No.2 pp 320-325 (2024)
DOI Number : 10.5958/0974-4541.2024.00053.9

IPM modules against litchi fruit and shoot borer, *Conopomorpha sinensis* Bradley using safer and newer insecticides

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ABSTRACT: A field trial was conducted at ICAR-National Research Centre on Litchi, Mushahari, Muzaffarpur; Bihar to develop optimal combination of IPM modules for managing the litchi fruit and shoot borer (*Conopomorpha sinensis*; Lepidoptera: Gracillariidae) a major pest of litchi. At harvest stage, most of the treatments showed more than 85% efficacy on reduction in borer infestation over control. The highest reduction in borer infestation was found in flubendiamide (19.92%) + thiacloprid 19.92 % 480 SC(94.56%) followed by lambda cyhalothrin 5 EC(90.09%). The least infested fruit (1.50 kg/tree) and highest healthy fruit (24.99 kg/tree) was recorded with flubendiamide 19.92% + thiacloprid 19.92 % 480 SC followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (23.44 kg/tree), lambda cyhalothrin 5 EC (18.34 kg/tree) and chlorantranilprole 18.5 SC (16.67 kg/tree) against lowest (1.67 kg/tree) in control. Additionally, minimum yield loss (5.66%) was recorded with flubendiamide 19.92% + thiacloprid 19.92 % 480 SC followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (10.23%), lambda cyhalothrin 5 EC (14.09%) and chlorantranilprole 18.5 SC (16.67%) against maximum (90.46%) in control. Similarly, reduction in fruit infestation over control calculated on weight basis was also highest in flubendiamide 19.92% + thiacloprid 19.92 % 480 SC (90.53%) followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (83.14%), lambda cyhalothrin 5 EC (81.00%) and chlorantranilprole 18.5 SC (79.73%). Neonicotinoid based combination products containing flubendiamide, spirotetramat and/ or beta-cyfluthrin are recommended to manage the litchi shoot and fruit borer management in an effective way to achieve the maximum yield.

Keywords: Litchi fruit and shoot borer, *Conopomorpha sinensis*, insecticides, pest management

INTRODUCTION

Litchi, *Litchi chinensis* Sonn. belongs to family Sapindaceae, is one of the most important subtropical evergreen fruit crop. It is considered as queen of the subtropical fruits due to its attractive deep pink/red colours and flavoured juicy aril. The fruit has high nutritive value and excellent pulp (aril) quality known for its characteristics flavor and taste. India is the second largest producer of litchi in the world next to China. It is now an important commercial fruit crop in India due to its high market demand and export potential. Cultivation of litchi is widely spread in eastern India (Bihar, Jharkhand, West Bengal, and NE region) which provides livelihood opportunities to millions of people in the region (Kumar *et al.* 2014). This crop is also gaining momentum in Uttarakhand, UP, Himachal Pradesh, Jammu, Punjab, Orissa and non-traditional areas of southern states (Kerala, Karnataka and Maharashtra), owing to its high economic returns and ever increasing demand in the domestic markets. Insect-pests *viz*., fruit and shoot borer, litchi mite, bark eating borer, leaf folder, litchi looper, litchi weevils etc, which causes severe loss resulting in poor yield (Srivastava *et al*., 2015; Reddy *et al*., 2016; Srivastava *et al*., 2018)**.** Among insect-pests, litchi fruit and shoot borer, *Conopomorpha sinensis* (Lepidoptera: Gracillariidae)is one of the major threat to litchi growers, causing severe losses to fruit as well as young shoots, to the tune of 24-48% and 7-70%, respectively (Srivastava *et al*., 2017). The insects (larvae) damage the newly emerged shoot during September- October resulting in failure of shoot to bloom. Further, it punctures the peduncle of fruits (both developing as well as mature) during April-May resulting to severe loss through early fruit drop and appearance of excreta/larvae, when fruit is cut/opened after ripening. Like other crops, insecticides are most powerful and widely accepted for the control of pests in litchi and therefore, newer molecules with selective action, safer to non target organisms and environmentally sound may be explored to protect this precious crop (Srivastava *et al., 2004*; Srivastava *et al.,* 2005; Srivastava *et al.,* 2007; Kumar *et al*., 2014). Eco-friendly insect pest management is crucial for achieving sustainable food production. Several environmentally conscious and sustainable approaches to pest control should be prioritized to protect crops while minimizing negative impacts on pollinator bees and beneficial organisms. These methods include the use of botanicals (Divekar *et al*., 2022; Divekar *et al*., 2024), host plant resistance (HPR) (Divekar et al. 2019), plant secondary metabolites (Divekar *et al*., 2022), bio-control agents (Divekar P., 2023; Shinde *et al*., 2021), defense proteins (Divekar *et al*., 2023), and safer chemical control options (Kodandaram *et al*., 2024).

Insecticidal combinations are effective alternative to address the problem and to mitigate insecticide resistance. Combining insecticides with different properties such as nature action can be advantageous for containing both chewing and sucking pests simultaneously. Mixtures may enhance the overall target spectra allowing the control of a wide range of pests when they are present on the crop at the same time (Reddy *et al.*, 2018). Therefore, keeping in view the importance of litchi fruit and shoot borer, a field trial was conducted to evaluate the different optimal combination IPM modules against this key pest.

MATERIALS AND METHODS

Present study was conducted at experimental farm of ICAR-National Research Center on Litchi, Muzaffarpur, Bihar (latitude and longitude of 26^{o}5'87''N and 85^{o}26'64'' E, respectively at altitude of 210m asl) during 2017-2018. Experiment was laid out in RBD with 6 treatments replicated 4 times (Table 1) in cv. Shahi. Good agronomical practices were followed as per recommended package of practices (Kumar *et al.,* 2015).

One foliar spray of neem based formulations was given at the time of panicle emergence before flowering to avoid egg laying by the moth. Three sprays of all the chemicals were applied at different interval during April-May. First spray was given at clove size fruit, second spray at cardamom size fruit (after fifteen days of first spray) while third spray was given at 10 days after second spray (about 15 days before harvest). Spraying was done on outer as well as inner canopy in all the direction on the tree with the help of power sprayer having hollow cone nozzles.

Observations were recorded on the basis of damaged fruit at early stage, mid stage and harvesting stage. To observe the borer infestation at early stage (clove size fruit) and mid stage (cardamom size fruit), the fallen fruits were collected from each treatments and cut/open with the help of sharp knife. At fruit maturity, 100 fruits from each treatment were plucked randomly for recording observation. The peduncle of harvested fruit was removed and presence of larva or their excreta was considered as infested fruits. The damage was assessed based on the weight of total number of fruits and damaged fruits in the different treatments and the percent damage was worked out. The yield of litchi fruits was recorded from each plant on weight basis. Statistical analysis was carried out using SPSS software programme 24.0.

RESULTS AND DISCUSSION

All the treatments significantly reduced the fruit borer infestation in comparison to control during the period of experimentation. During 2017, no borer was observed at early stage in any treatment except spirotetramat 11.01% + imidacloprid 11.01% (1.33%) against 3.00 in control, that may be due to unfavorable environmental conditions (Table-1). At mid stage also, 0.00 borer infestation was observed in treatment with flubendiamide 19.92% + thiacloprid 19.92 which is closely followed by spirotetramat 11.01% + imidacloprid 11.01% (2.67%). Similar trend was observed at harvest stage too. During 2018, again no borer population was observed at early stage including control. At mid stage no population were recorded in two treatments namely, flubendiamide 19.92% + thiacloprid 19.92 % spirotetramat 11.01% + imidacloprid 11.01% followed by beta-Cyfluthrin 8.49 %+ imidacloprid 19.81 % (5.88%) against 47.78 % in control. At harvest stage again minimum infestation (3.88%) was observed in flubendiamide 19.92% + thiacloprid 19.92 % followed by lambda cyhalothrin (7.00%); chlorantraniliprole (9.33%) against 95.14% in control (Table 1).

Effect of different combination IPM modules on reduction of fruit borer infestation over control on litchi ecosystem are presented in Table 2. Data revealed that combined application of mixture insecticides with neem oil were found most effective in reducing borer population. During 2017, 100 per cent reduction over control of litchi fruit borer was recorded in flubendiamide 19.92% + thiacloprid 19.92 % followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (83.98%), chlorantranilprole 18.5 SC (65.99) at mid stage. At harvest stage, flubendiamide 19.92% + thiacloprid 19.92 % gave the maximum reduction over control (92.39 spirotetramat 11.01% + imidacloprid 11.01% (90.13%) and lambda cyhalothrin (86.04%). During 2018, again100 per cent reduction over control of litchi fruit borer was recorded in flubendiamide 19.92% + thiacloprid 19.92

Table 1. Efficacy of combination insecticides against litchi fruit and shoot borer infestation (%)

Treatments	Conc.	Early stage			Mid stage			Harvest stage		
		2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1-Lambda cyhalothrin 5 EC	0.003%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.33 (14.56)	6.67 (14.95)	6.50 (14.76)	8.33 (16.77)	7.00 (15.31)	7.67 (16.06)
T_2-Chlorantranilprole 18.5 SC	0.007%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.67 (13.75)	6.00 (14.14)	5.83 (13.95)	8.67 (17.11)	9.33 (17.75)	9.00 (17.44)
T_3-Beta-Cyfluthrin 8.49 %+ Imidacloprid 19.81 %	0.011%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.33 (14.56)	5.88 (14.00)	6.11 (14.29)	10.33 (18.71)	11.23 (19.56)	10.78 (19.15)
T_4-Flubendiamide 19.92% + Thiacloprid 19.92 % 480 SC	0.48%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.54 (12.29)	3.88 (11.27)	4.21 (11.81)
T_5-Spirotetramat 11.01% + Imidacloprid 11.01% 240 SC	0.36%	1.33 (6.53)	0.00 (0.00)	0.67 (4.61)	2.67 (9.36)	0.00 (0.00)	1.33 (6.60)	5.89 (14.01)	9.67 (18.07)	7.78 (16.19)
T_6-Control		3.00 (9.88)	0.00 (0.00)	1.50 (6.97)	16.67 (24.07)	47.78 (43.71)	32.22 (34.57)	59.67 (50.56)	95.14 (77.38)	77.40 (61.61)
SEm (±)		0.27	-	0.14	0.43	0.72	0.36	0.60	0.62	0.40
CD (P=0.05)		0.87	-	0.43	1.37	2.30	1.13	1.92	1.98	1.26

*values in parenthesis are angular transformed

% along with spirotetramat 11.01% + imidacloprid 11.01% 240 SC followed by beta-Cyfluthrin 8.49 % + imidacloprid 19.81 % (87.69%) chlorantranilprole 18.5 SC (87.44%) at mid stage. Similar trend was also observed at harvest stage. The maximum reduction of borer over control (95.92%) was noticed in flubendiamide 19.92% + thiacloprid 19.92 % followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (89.84%) and chlorantranilprole 18.5 SC (90.19%) at harvest stage. Pooled data also revealed that at mid stage100 percent reduction of borer infestation over control was noticed in flubendiamide 19.92% + thiacloprid 19.92 % followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (95.87%), chlorantranilprole 18.5 SC (81.91%). However, at harvest stage, all the treatments showed more than 86 % efficacy on reduction in borer infestation over control. The highest reduction in borer infestation was found in flubendiamide 19.92% + thiacloprid 19.92% (94.56%) followed by lambda cyhalothrin (90.09%), spirotetramat 11.01% + imidacloprid 11.01% 240 SC (89.95%), chlorantranilprole 18.5 SC (88.37%) and beta-cyfluthrin 8.49 % + imidacloprid 19.81 % (86.07%).

All mixture as well as solo insecticides significantly influenced the borer infestation and fruit yield of litchi (Table 3). Weight of infested litchi fruits showed that application of these molecules reduced the damage of litchi fruits done by borer that contributed towards more marketable fruit yield as compared to control. Highest healthy fruit (24.99 kg/tree) was recorded with flubendiamide 19.92% + thiacloprid 19.92 % 480 SC followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (23.44 kg/tree), lambda cyhalothrin 5 EC (18.34 kg/tree), chlorantraniliprole 18.5 SC (16.67 kg/tree) and beta-cyfluthrin 8.49 % + imidacloprid 19.81 % (15.30 kg/tree against lowest (1.67 kg/tree) in control.

Additionally, minimum yield loss also (5.66%) was recorded with flubendiamide 19.92% + thiacloprid 19.92 % 480 SC followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (10.23%), lambda

Table 2. Efficacy of combination insecticides on reduction of litchi fruit and shoot borer infestation over control (%)

Treatments	Conc.	Early stage			Mid stage			Harvest stage		
		2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1-Lambda cyhalothrin 5 EC	0.003%	100.00	0.00	100.00	62.03	86.04	79.83	86.04	92.64	90.09
T_2-Chlorantranilprole 18.5 SC	0.007%	100.00	0.00	100.00	65.99	87.44	81.91	85.47	90.19	88.37
T_3-Beta-Cyfluthrin 8.49 %+ Imidacloprid 19.81 %	0.011%	100.00	0.00	100.00	62.03	87.69	81.04	82.69	88.20	86.07
T_4-Flubendiamide 19.92% + Thiacloprid 19.92 % 480 SC	0.48%	100.00	0.00	100.00	100.00	100.00	100.00	92.39	95.92	94.56
T_5-Spirotetramat 11.01% + Imidacloprid 11.01% 240 SC	0.36%	55.67	0.00	55.33	83.98	100.00	95.87	90.13	89.84	89.95
T_6-Control	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

cyhalothrin 5 EC (14.09%) and chlorantranilprole 18.5 SC (16.67%) against maximum (90.46%) in control. Similarly, reduction in fruit infestation over control calculated on weight basis was also highest in flubendiamide 19.92% + thiacloprid 19.92 % 480 SC (90.53%) followed by spirotetramat 11.01% + imidacloprid 11.01% 240 SC (83.14%), lambda cyhalothrin 5 EC (81.00%) and chlorantranilprole 18.5 SC (79.73%).

Highest reduction of litchi fruit borer infestation with combination insecticides, might be due to different properties. such as selective action as well as ovicidal action of these chemicals.

Further, combinations may enhance the overall target spectra allowing the control of a wide range of pests when they are present on the crop at the same time (Reddy *et al.*, 2018). Chlorantraniliprole is a new insecticide belonging to the anthranilic diamide class of chemistry and is intended for the control of Lepidopteran, Coleopteran, and some Dipteran pests. Chlorantraniliprole exhibits excellent differential selectivity for insect ryanodine receptors over mammalian ryanodine receptors (Bentley *et al*., 2010). Flubendiamide, a benzene dicarboxamide, is a new class of insecticide having a new biochemical mode of action, affecting ryanodine receptors in insects and is highly effective at very low dose against a broad spectrum of lepidopteran pests including resistance strains (Tohnishi *et al*., 2005; Sreedhar, 2019). From the study, it can be concluded that combination insecticides aremost effective against litchi borer and shoot borer. More infestation of litchi fruit andshoot borer noticed during harvest stage perhaps due to occurrence of intermittent rains during fruit growth and development, which might have created the congenial environment for borer survival (Srivastava *et al*., 2017).

Reddy *et al.* (2018) also reported that combination insecticides are more effective than solo once against variety of insect pests. Similarly, Srivastava *et al.* (2015) also observed flubendiamide, chlorantraniliprole, neonicotinoids and pyrethroids are highly effective against litchi pests. The results are also in line with the findings of Srivastava *et al.* (2016) who reported that the three spraying of flubendiamide and/or thiacloprid or chlorantraniliprole at recommended dose kept the litchi fruit borer infestation below threshold level and also care other insect pests with same spraying.

The finding of present investigation holds a good promise in litchi fruit borer management. However, further studies on effect of these combinations on natural enemies need to be undertaken so that such combination

Table 3. Efficacy of combination insecticides on fruit borer infestation and their impact on fruit yield of litchi

Treatments	Conc.	Weight of infested fruits in terms of unmarketable yield (kg/tree)			Weight of healthy fruits in terms of marketable yield (kg/tree)			Yield loss (%)			Reduction in fruit infestation over control on weight basis (%)		
		2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1-Lambda cyhalothrin 5 EC	0.003%	3.10 (10.13)	2.91 (9.81)	3.01 (9.98)	18.56 (25.51)	18.11 (25.18)	18.34 (25.34)	14.31	13.84	14.09	76.15	84.41	81.00
T_2-Chlorantranilprole 18.5 SC	0.007%	3.10 (10.14)	3.32 (10.49)	3.21 (10.31)	17.11 (24.42)	16.23 (23.75)	16.67 (24.09)	15.34	16.98	16.15	76.15	82.22	79.73
T_3-Beta-Cyfluthrin 8.49 %+ Imidacloprid 19.81 %	0.011%	4.68 (12.49)	5.00 (12.91)	4.84 (12.71)	15.67 (23.31)	14.92 (22.71)	15.30 (23.01)	22.99	25.10	24.03	64.00	73.22	69.44
T_4-Flubendiamide 19.92% + Thiacloprid 19.92 % 480 SC	0.48%	1.67 (7.41)	1.33 (6.62)	1.50 (7.04)	24.31 (29.53)	25.66 (30.42)	24.99 (29.98)	6.43	4.93	5.66	87.15	92.88	90.53
T_5-Spirotetramat 11.01% + Imidacloprid 11.01% 240 SC	0.36%	2.00 (8.12)	3.33 (10.51)	2.67 (9.39)	25.21 (30.13)	21.66 (27.72)	23.44 (28.94)	7.35	13.33	10.23	84.62	82.16	83.14
T_6-Control	-	13.00 (21.13)	18.67 (25.59)	15.84 (23.44)	2.11 (8.34)	1.23 (6.36)	1.67 (7.42)	86.04	93.81	90.46	0.00	0.00	0.00
SEm (±)		0.10	0.15	0.10	0.30	0.15	0.14	-	-	-	-	-	-
CD (0.05)		0.33	0.49	0.31	0.96	0.48	0.45	-	-	-	-	-	-

can be more effectively utilized in future. Neonicotinoid based combination products having flubendiamide, spirotetramat and/ or beta-cyfluthrin are recommended to manage the litchi shoot and fruit borer management in a effective way with maximum yield.

ACKNOWLEDGEMENT

The authors would like to acknowledge the help of Director, ICAR-NRC Litchi, Muzaffarpur, for providing the necessary facilities required for the present investigation.

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MS Received: 25 September 2024
MS Acceptance: 15 November 2024