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Evaluation of some new insecticides molecules for the management of fruit fly, *Bactrocera* spp. infesting cucumber

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Abstract
The Tephritidae fruit flies are a major limitation in the cultivation of cucumber in the mid-hill region of Himachal Pradesh State of India. To manage the menace of fruit flies the experiment was laid to study the efficacy and monetary returns of different new insecticides against fruit flies during cropping season 2018. The results of the bioefficacy study revealed lambda-cyhalothrin @ 0.004% with least fruit infestation (17.13%) as the most effective insecticide in checking the fruit fly population which was followed by emamectin benzoate @ 0.002% (24.64% infestation). Also, the maximum avoidable loss (65.57%) was recorded in λ-cyhalothrin followed by emamectin benzoate (61.11%) treated plots which proved their efficiency in managing fruit flies. The highest benefit cost ratio (BCR) was recorded in λ-cyhalothrin (28.74:1) and was followed by malathion (5.67:1) treatment. In rynaxypyr and diflubendiamide treatments the negative BCR ratios were obtained due to very high cost of the test treatment.

Keywords: *Bactrocera* spp., cucumber, emamectin benzoate, λ-cyhalothrin

Introduction
Cucumber (*Cucumis sativus*), a vegetable crop belonging to family cucurbitacae is extensively grown all over the tropical and sub-tropical countries and the family includes the largest number of summer and rainy season vegetables in India [1, 2]. Tephritid fruit flies, *Bactrocera* spp. are the most serious and destructive insect pests infesting all cucurbit vegetables worldwide except in Arctic and Antarctic regions [3]. Attack is severe after rainy season when humidity is high. In mid-hills of Himachal Pradesh regular occurrence of *B. tau*, *B. cucurbitae* and *B. scutellaris* in cucurbit vegetables and tomato have been reported by various workers [4, 5, 6, 7, 8, 9]. *Bactrocera tau*, in particular, was reported as the most serious pest of cucurbits in Himachal Pradesh [6, 10]. The total damage caused by these fruit flies has been estimated to be about 70 per cent with 50 per cent in sponge gourd, 60 per cent in bitter gourd and 80 per cent in bottle gourd [5, 11, 12]. Their attack not only reduce yield but also affects fruit quality hence making it unfit for consumption. Mostly, cucumber is eaten as raw due to which more persistence insecticides cannot apply on this crop. The management strategies have been mostly conducted with organophosphate insecticides. The present study provides information on the use of insecticides with different mode of action and the benefit that can be earned by managing the pest with the help of these insecticides.

Materials and Methods
The field trial was conducted on cucumber (K-75), during 2018 at the experimental farm of the Department of Entomology, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The six insecticides namely lambda-cyhalothrin, emamectin benzoate, diflubendiamide, rynaxypyr, indoxacarb and spinosad were evaluated against fruit flies infesting cucumber. All treatments were compared with the recommended insecticide malathion and control. The experiment was laid out in a randomized block design (RBD) where each treatment was replicated thrice. The first spray application of insecticides was given after fruit set, which was followed by two more foliar applications at 10 days interval. The spray was provided with the help of a knapsack sprayer till run off stage. In control, however, only water was sprayed on the plants. The data on fruit infestation was converted into per cent infestation and analysed by OPSTAT programme.

The avoidable loss was worked out in different treatments as per the formula of Pradhan (1964) [13] as follows:

$$\text{Avoidable loss (\%)} = \frac{\text{Yield in treatment - yield in control}}{\text{Yield in treatment}} \times 100$$

In order to know the effectiveness of test treatments in monetary terms, yield in different treatments as well as in control was recorded and with the help of this benefit cost ratio was worked out, also taking into account the cost of test insecticides used for the management of the pests, keeping rest of the factors constant. The increase in yield in different treatments over control was calculated as follows:

Increase in yield over control (kg) = Yield in treatment (kg) – yield in control (kg)

Thereafter, the monetary value of increased yield was worked out at the selling price. To calculate the benefit cost ratio (BCR), ratio between net monetary return and expenditure incurred during the spray of insecticides, was calculated.

Results

Bioefficacy studies

In the year 2018, after 10 days of first foliar application of insecticides (Table 1), maximum fruit fly infestation was recorded in control (64.65%) and all the test treatments were found superior over control. Lambda-cyhalothrin with 22.42 per cent fruit infestation was found superior than rest of the test treatments. Emamectin benzoate with 32.12 per cent fruit infestation, rynaxypyr and diflubendiamide with 34.54 and 35.55 per cent fruit infestations, respectively, being at par also proved effective in checking fruit fly infestation. Spinosad, indoxacarb, and malathion with 40.00, 41.67 and 45.92 per cent fruit infestation, respectively, were at par and were not found much effective.

After 10 days of second spray application, lambda-cyhalothrin (18.94% infestation) again was the most effective treatment and was found superior to all the other test treatments. Emamectin benzoate, rynaxypyr and diflubendiamide with 25.59, 30.20 and 32.12 per cent fruit infestation, respectively, all the three being at par, were the next best treatments after lambda-cyhalothrin. Spinosad and indoxacarb with 35.35 and 37.12 per cent fruit infestation, being at par with recommended insecticide malathion (40.56% fruit infestation) were less effective, though superior over control (73.33%).

When fruit infestation data were recorded ten days after the third spray application, the infestation in control further escalated to 77.78 per cent, whereas a decrease in infestation was recorded in all the other treatments. Minimum infestation (10.00%) was recorded in plants treated with lambda-cyhalothrin. Emamectin benzoate, rynaxypyr and diflubendiamide with fruit infestation of 16.20, 19.05 and 19.58 per cent, respectively, being at par were also found effective. Spinosad and indoxacarb with 20.64 and 24.07 per cent fruit infestation were at par with recommended insecticide malathion (29.44% infestation). All the test treatments were, however, found superior over control.

Table 1: Bioefficacy of insecticides against fruit fly, *Bactrocera* spp. infesting cucumber

Treatment	Fruit infestation (%) 10 days after			Mean fruit infestation (%)
	Spray I	SprayII	Spray III	
Lambda-cyhalothrin (0.004%)	22.42(28.19)	18.98(25.64)	10.00(18.43)	17.13(24.09)
Emamectin benzoate (0.002%)	32.12(34.49)	25.59(30.35)	16.20(23.38)	24.64(29.41)
Rynaxypyr (0.006%)	34.54(35.92)	30.20(33.30)	19.05(25.57)	27.93(31.60)
Diflubendiamide (0.01%)	35.55(36.57)	32.12(34.49)	19.58(26.14)	29.08(32.40)
Spinosad (0.002%)	40.00(39.22)	35.35(36.46)	20.64(26.82)	32.00(34.17)
Indoxacarb (0.007%)	41.67(40.19)	37.12(37.50)	24.07(29.36)	34.29(35.69)
Malathion (0.1%)	45.92(42.64)	40.56(39.54)	29.44(32.81)	38.64(38.33)
Control (water)	64.65(53.50)	73.33(58.91)	77.78(61.85)	71.92(58.09)
Mean	39.61(38.84)	36.66(37.02)	27.10(30.55)	-

Figures in parentheses are arc sine transformed values

CD $_{(0.05)}$

Treatment (T): (2.70)

Spray Interval (I): (1.65)

T×I: (4.67)

The overall means when compared revealed minimum fruit infestation in lambda-cyhalothrin (17.13%) treatment. Emamectin benzoate and rynaxypyr, where the fruit infestation recorded was 24.64 and 27.93 per cent, respectively, were at par and next best treatments. Diflubendiamide and spinosad with 29.08 and 32.00 per cent fruit infestation, respectively, were at par and superior over indoxacarb (34.29% infestation) and recommended insecticide malathion (38.64% infestation). All the test treatments were found superior over control (71.92% infestation).

While comparing overall infestation at different spray intervals, it was observed that minimum infestation was recorded after third spray (27.10%) in comparison to 36.66 and 39.61 per cent infestation after the second and first spray, respectively.

Table 2: Avoidable loss due to application of insecticides against fruit fly in cucumber

Treatment	Mean yield (kg/plant)	Increase in yield over control (kg)	Avoidable loss in comparison to control (%)	Avoidable loss in comparison to malathion (%)
Lambda-cyhalothrin (0.004%)	6.10	4.00	65.57	40.98
Emamectin benzoate (0.002%)	5.40	3.30	61.11	33.33
Rynaxypyr (0.006%)	5.20	3.10	59.62	30.77
Diflubendiamide (0.01%)	4.80	2.70	56.25	25.00

Spinosad (0.002%)	4.70	2.60	55.32	23.40
Indoxacarb (0.007%)	3.90	1.80	46.15	7.69
Malathion (0.1%)	3.60	1.50	41.67	-
Control (water)	2.10	-	-	-

A perusal of the data presented in the Table 2 reveal lambda-cyhalothrin, emamectin benzoate, rynaxypyr, diflubendiamide, spinosad, and indoxacarb treatments resulted in avoidable loss values of 65.57, 61.11, 59.62, 56.25, 55.32 and 46.16 per cent. However, for the recommended insecticide malathion, the avoidable loss value was 41.67 per cent.

Avoidable losses in comparison to recommended insecticide malathion ranged between 7.69 and 40.98 per cent, being maximum in lambda-cyhalothrin (40.98%) followed by emamectin benzoate (33.33%), rynaxypyr (30.77%), diflubendiamide (25.00%) and spinosad (23.40%). Minimum losses are avoided by indoxacarb with a value of 7.69 per cent.

Table 3: Benefit cost ratio of insecticide application against fruit fly, *Bactrocera* spp. in cucumber during 2018

Treatment	Mean yield (kg/plant)	Increase in yield over control (kg)	Cost of increased yield @ Rs 20/kg	Cost of the test treatment (Rs)	Net monetary return (Rs)	Benefit Cost Ratio (BCR)
Lambda-cyhalothrin (0.004%)	6.10	4.0	80.0	2.69	77.3	28.74:1
Emamectin benzoate (0.002%)	5.40	3.3	66.0	24.24	41.8	1.72:1
Rynaxypyr (0.006%)	5.20	3.1	62.0	35.14	26.9	*
Diflubendiamide (0.01%)	4.80	2.7	54.0	31.50	22.5	*
Spinosad (0.002%)	4.70	2.6	52.0	8.21	43.8	5.33:1
Indoxacarb (0.007%)	3.90	1.8	36.0	10.44	25.6	2.45:1
Malathion (0.1%)	3.60	1.5	30.0	4.50	25.5	5.67:1
Control (water)	2.10	-	-	-	-	-

*Indicate value<1

The data presented in Table 3 reveal that during 2018, the increase in yield over control was maximum (4.0 kg/plant) in lambda-cyhalothrin treatment. The increase in yield over control was 3.3, 3.1, 2.7, 2.6 and 1.8 kg per plant, in emamectin benzoate, rynaxypyr, diflubendiamide, spinosad, and indoxacarb, respectively. The recommended insecticide malathion registered 1.5 kg increase in yield over control.

The BCR ratio was maximum (28.74:1) in lambda-cyhalothrin treatment with maximum net monetary return (Rs. 77.30 per plant). Though the net monitory return value of spinosad (Rs. 43.80) was more in comparison to malathion (Rs. 25.50) but BCR ratio of malathion (5.67:1) was higher over spinosad (5.33:1) due to higher cost of treatment of the latter. Among rest of the test treatments *viz.* indoxacarb, emamectin benzoate, rynaxypyr and diflubendiamide though the net monetary returns were positive and high but the benefit cost ratio was low due to higher cost of treatments than the net monetary returns. In indoxacarb, emamectin benzoate, rynaxypyr and diflubendiamide treatments the negative BCR ratios were obtained due to very high cost of application.

Discussion

The results in the present study are in accordance with Sharma (2019) [14] where lambda-cyhalothrin (0.008 and 0.004%) and spinosad (0.004%) were found effective and reduced the fruit fly infestation in cucumber followed by malathion (0.1%). In a similar study, Khatun *et al.* (2016) [15] reported lambda-cyhalothrin (0.005%) effective in checking *B. cucurbitae* infestation in bitter gourd with 17.23 per cent infestation in comparison to 38.40 per cent in control, these results are in line with the findings of the present study. In cucumber, Khursheed and Raj (2012) [16] evaluated different insecticides against fruit fly and the results obtained were in accordance with the present study. The results of Gyi *et al.* (2003) and Sood and Sharma (2004) [17, 18] are in accordance with the findings of the present study where synthetic pyrethroid, lambda-cyhalothrin was effective against ber fruit fly and cucurbit fruit flies, respectively.

Results of present investigation are in accordance with Thakur (2011) [19] where the maximum yield of cucumber and tomato was obtained in lambda-cyhalothrin treated plots wherein the lowest infestation was recorded.

Results of avoidable loss study are in line with the study conducted by Abrol (2017) [20] where the maximum losses were avoided in lambda-cyhalothrin followed by spinosad which was more than the recommended insecticide malathion. Sharma (2018) [21] also reported that maximum avoidable loss value was obtained for lambda-cyhalothrin followed by spinosad and deltamethrin in mango. The BC ratio calculated by Abrol (2017) [20] corroborates the results of present finding where the highest BC ratio was calculated for lambda cyhalothin (28.74:1).

Conclusion

The results obtained in the present study revealed that out of all the test insecticides lambda-cyhalothrin (0.004%) followed by emamectin benzoate (0.002%) were the most effective insecticides. Rynaxypyr (0.006%), diflubendiamide (0.01%), spinosad (0.002%) and indoxacarb (0.007%) were next in row of effectiveness. Malathion (0.1%) was less effective in comparison to the rest of the test insecticides but performed better than control. From the economics point of view, maximum BC ratio was obtained for lambda-cyhalothrin (29.48:1) followed by malathion (4.78:1) and spinosad (4.36:1). Hence, various modules can evaluated further by using these insecticides in rotation in three spray schedule against fruit fly *Bactrocera* spp. in cucumber to minimize resistance and maximize profit.

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