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Management of *Bactrocera* spp. infesting cucumber using new insecticide molecules

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Abstract
Dipteran fruit flies belonging to family Tephritidae are a major constraint in production of cucumber in India, causing 30 to 100 percent yield losses, therefore, field trials were conducted to evaluate bioefficacy and economics of some novel molecules of insecticides for the management of fruit fly, *Bactrocera* spp. infesting cucumber under mid hills of Himachal Pradesh during 2017 cropping season. ƛ-cyhalothrin @ 0.004% performed best among the insecticides (17.04% infestation) followed by emamectin benzoate @ 0.002% (24.02% infestation) significantly least mean fruit infestation than control. Also maximum avoidable loss (70.69%) were recorded in ƛ-cyhalothrin followed by emamectin benzoate (67.31%) treated plots which proved effective in managing fruit flies. The highest benefit cost ratio (BCR) was recorded in ƛ-cyhalothrin (29.48:1) and was followed by malathion (4.78:1) treatment. In rynaxypyr and diflubendiamide treatments the negative BCR ratios were obtained due to very high cost of application.

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

Introduction
Cucumber (*Cucumis sativus*) is warm season vegetable crop belonging to family cucurbitaceae cultivated in India [1, 2]. In Himachal Pradesh cucumber is majorly grown in low hill and mid hill agroclimatic zones during summer. The *Bactrocera* spp. Tephritid fruit flies are the most noxious and destructive insect pests infesting all cucurbit vegetables worldwide [3]. The unvarying occurrence of *B. tau, B. cucurbitae* and *B. scutellaris* in cucurbit vegetables and tomato have been reported by various workers [4-9] from mid-hills of Himachal Pradesh. Among these three species, *Bactrocera tau* was reported as the most serious pest of cucurbits in Himachal Pradesh [6, 10]. The cucurbit fruit fly *B. cucurbitae* can attack about 16 different types of cucurbit crops. Although the rate of attack varies among the crop, infestation reduced both the yield and quality of the cucurbit fruits. The total damage caused by these fruit flies has been estimated to be about 70 percent with 50 percent in sponge gourd, 60 percent in bitter gourd and 80 percent in bottle gourd [5, 11, 12]. To control the pest a cluster method has been developed and suggested, but among all these methods, the chemical control method is still popular to the Indian farmers because of its quick and visible results. So, evaluation of new insecticides molecules for control of fruit fly infestation in cucumber was conducted.

Materials and Methods
The field trial was conducted on cucumber (K-75), during 2017 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 was given after fruit setting, which was followed by two more foliar applications at an interval of 10 days. The spray was provided with the help of a knap sack sprayer till run off stage. In control, however, only water was sprayed on the plants. The data on fruit infestation was converted into percent infestation and analysed by OPSTAT programme.
The avoidable loss was worked out in different treatments as per 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, the benefit cost ratio was worked out by recording yield in different treatments as well as in control, 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 rate. The ratio between net monetary returns and expenditure incurred was calculated in order to find out the benefit cost ratio.

Results and Discussion

Bioefficacy studies

During 2017, when the data were recorded 10 days after the first spray application (Table 1), maximum fruit fly infestation was recorded in control (63.44% infestation). All the test treatments were found better than control. The minimum infestation (22.41% infestation) was recorded in lambda-cyhalothrin which proved to be the most effective treatment. Emamectin benzoate (31.21% infestation), rynaxypyr (34.44% infestation) and diflubendiamide (35.10% infestation) being statistically at par were also effective treatments. These were followed by spinosad (39.39% infestation), indoxacarb (41.16% infestation) and recommended insecticide malathion (45.68% infestation), all the three being statistically at par.

The fruit infestation in control increased to 72.62 percent when the data were recorded after 10 days of second foliar application, however the decreasing trend in all the test treatments was observed (Table 2). The infestation varied from 18.24 to 40.60 percent. Again, lambda-cyhalothrin (18.24% fruit infestation) was found superior in checking the fruit fly infestation in comparison to rest of the treatments. Emamectin benzoate, rynaxypyr and diflubendiamide with fruit infestations of 25.00, 29.09 and 31.11 percent, respectively, were statically at par and proved effective in checking fruit fly infestation after lambda-cyhalothrin. Spinosad (34.24% infestation) and indoxacarb (36.11% infestation) treatments being at par were also found superior to malathion (40.60%) in checking fruit fly infestation.

The data presented in Table 2 reveal that infestation escalated to 77.04 percent in control, whereas, in other treatments, a decreasing trend was observed, when the data were recorded after 10 days of third spray application. The infestation in lambda-cyhalothrin treatment decreased to 10.37 percent, which was statistically superior over the other treatments and again proved most effective. In emamectin benzoate and rynaxypyr treatments, 15.88 and 18.65 percent fruits were found infested, respectively, with fruit flies and these being at par were also found at par with diflubendiamide (19.58% infestation). Spinosad, indoxacarb, and malathion with fruit infestation of 20.50, 23.15 and 28.52 percent, respectively, were at par and found next in order of effectiveness.

Table 1: Bioefficacy of insecticides against fruit fly, *Bactrocera* spp. infesting cucumber at during 2017

Treatment	Fruit infestation (%) 10 days after			Mean fruit infestation (%)
	Spray I	SprayII	Spray III	
Lambda-cyhalothrin (0.004%)	22.41(28.22)	18.24(25.12)	10.37(18.77)	17.01(24.04)
Emamectin benzoate (0.002%)	31.21(33.91)	25.00(29.91)	15.88(23.46)	24.03(29.10)
Rynaxypyr (0.006%)	34.44(35.89)	29.09(32.62)	18.65(25.43)	27.40(31.31)
Diflubendiamide (0.01%)	35.10(36.24)	31.11(33.88)	19.58(26.14)	28.60(32.09)
Spinosad (0.002%)	39.39(38.84)	34.24(35.78)	20.50(26.77)	31.38(33.80)
Indoxacarb (0.007%)	41.16(39.88)	36.11(36.90)	23.15(28.74)	33.47(35.17)
Malathion (0.1%)	45.68(42.51)	40.60(39.55)	28.52(32.19)	38.27(38.08)
Control (water)	63.44(52.79)	72.62(58.44)	77.04(61.50)	71.03(57.57)
Mean	39.10(38.53)	35.88(36.53)	26.71(30.37)	-

Figures in parentheses are arc sine transformed values

CD $_{(0.05)}$

Treatment (T)	(2.70)
Spray Interval (I)	(1.66)
T×I	(4.68)

When the overall mean infestation was compared, lambda-cyhalothrin with 17.01 percent proved to be the most effective treatment in managing the fruit flies in cucumber. Emamectin benzoate with fruit infestation of 24.03 percent and rynaxypyr with fruit infestation of 27.40 percent were statistically at par and superior over diflubendiamide (28.60% fruit infestation), and spinosad (31.38% fruit infestation) which being at par were in turn superior to indoxacarb (33.47% fruit infestation) and malathion (38.27% fruit infestation. All the treatments were found superior over control (71.03% infestation).

The overall infestation differed significantly at different spray intervals, minimum being after third spray 26.71 percent followed by second and first spray, where the average fruit infestation recorded was 35.88 and 39.01 percent, respectively.

Table 2: Avoidable loss due to application of insecticides against fruit fly in cucumber during 2017

Treatment	Mean yield (kg/plant)	Increase in yield over control (kg)	Avoidable loss w.r.t control (%)	Avoidable loss in comparison to malathion (%)
Lambda-cyhalothrin (0.004%)	5.8	4.1	70.69	48.28
Emamectin benzoate (0.002%)	5.2	3.5	67.31	42.31
Rynaxypyr (0.006%)	4.8	3.1	64.58	37.50
Diflubendiamide (0.01%)	4.3	2.6	60.47	30.23
Spinosad (0.002%)	3.9	2.2	56.41	23.08
Indoxacarb (0.007%)	3.4	1.9	55.88	11.76
Malathion (0.1%)	3.0	1.3	43.33	-
Control (water)	1.7	-	-	-

As presented in the Table 2, the maximum loss can be avoided with the use of lambda-cyhalothrin (70.69%), followed by emamectin benzoate, rynaxypyr, and diflubendiamide where the avoidable loss values computed were 67.31, 64.58 and 60.47 percent, respectively. In rest of the treatments *viz*. spinosad, indoxacarb and malathion, the avoidable loss values were 56.41, 55.88 and 43.33 percent, respectively. When the avoidable losses were calculated in comparison to recommend insecticide malathion, again lambda-cyhalothrin (48.28%) was the best followed by emamectin benzoate (42.31%), rynaxypyr (37.50%), diflubendiamide (30.23%), spinosad (23.08%) and indoxacarb (11.76%).

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

Treatment	Mean yield (kg/tree)	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%)	5.8	4.1	82.0	2.69	79.3	29.48:1
Emamectin benzoate (0.002%)	5.2	3.5	70.0	24.24	45.8	1.89:1
Rynaxypyr (0.006%)	4.8	3.1	62.0	35.14	26.9	*
Diflubendiamide (0.01%)	4.3	2.6	52.0	31.50	20.5	*
Spinosad (0.002%)	3.9	2.2	44.0	8.21	35.8	4.36:1
Indoxacarb (0.007%)	3.4	1.9	38.0	10.44	27.6	2.64:1
Malathion (0.1%)	3.0	1.3	26.0	4.50	21.5	4.78:1
Control (water)	1.7	-	-	-	-	-

*Indicate value<1

As revealed from the data presented in Table 3, the increase in yield over control was maximum (4.1 kg/plant) in lambda-cyhalothrin treatment followed by emamectin benzoate, rynaxypyr, diflubendiamide, spinosad and indoxacarb with a yield of 3.5, 3.1, 2.6, 2.2 and 1.9 kg per plant, respectively. The recommended insecticide i.e. malathion registered 1.3 kg increase in yield over control.

The maximum benefit cost ratio (29.48:1) was computed in lambda-cyhalothrin treatment followed by malathion (4.78:1) and spinosad (4.36:1). In rest of the treatments *viz.* indoxacarb, emamectin benzoate, rynaxypyr and diflubendiamide, the net monetary return value though were positive and high but due to high cost of the test insecticides it resulted in low BCR ratios. In rynaxypyr and diflubendiamide treatments the negative BCR ratios were obtained due to very high cost of application.

Discussion

In a similar study conducted by Khatun *et al*. (2016) [14] lambda-cyhalothrin (0.005%) proved effective in checking *B. cucurbitae* infestation in bitter gourd with 17.23 percent infestation in comparison to 38.40 percent in control, these results are in line with the findings of the present study. Present finding corroborates with results obtained by Abrol (2017) [15] where they evaluated different insecticides for the management of fruit flies in bottle gourd and bitter gourd. Results reveal that lambda-cyhalothrin was most effective in checking fruit fly infestation followed by spinosad. Lambda-cyhalothrin (0.004%) was effective against fruit flies in peach, cucumber and tomato also reported by Thakur (2011) [16]. The results of Gyi *et al.* (2003) [17] and Sood and Sharma (2004) [18] support the results of present findings that lambda-cyhalothrin was effective against ber fruit fly and cucubit fruit flies, respectively. Results obtained by Sharma (2019) [19] were in line with the results of present study where they reported that lambda-cyhalothrin (0.008 and 0.004%) and spinosad (0.004%) reduced the fruit fly infestation in cucumber followed by recommended insecticide malathion (0.1%).

Results of present study are in line with Kate *et al.* (2010) [20] who estimated the avoidable loss value of 38.69 percent in cucumber against *B. cucurbitae*, when fenthion (0.1%) and malathion (0.1%) were applied alternatively starting from fruit formation to fruit maturity. The avoidable loss study result was in line with the study of Abrol (2017) [15] where the maximum losses were avoided by lambda-cyhalothin followed by spinosad which were more than malathion. Sharma (2018) [21] reported that maximum avoidable losses calculated for lambda-cyhalothrin followed by spinosad and deltamethrin which supports the results of present investigation.

The BC ratio calculated by Abrol (2017) [15] for lamda-cyhalothrin treatment corroborates with the BC ratio value of present investigation. The result in accordance with the results of Sharma (2018) where the maximum BC ratio obtained in synthetic pyrithroid (lambda-cyhalothin).

Conclusions

The results obtained in the present study reveal among all the test insecticides lambda-cyhalothrin (0.004) followed by emamectin benzoate (0.002%) were most effective insecticides. Rynaxypyr (0.006%), diflubendiamide (0.01%), spinosad (0.002%) and indoxacarb (0.007%) were next in row. Malathion (0.1%) was the least effective treatment

among all the test insecticides but performed better than control. As far as economics is concerned 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 by 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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