Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(1): 311-314

Received: 15-11-2018
Accepted: 18-12-2018

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Evaluation of insecticides, biopesticides and clay for the management of fruit fly, *Bactrocera* spp. infesting bottle gourd

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Abstract
Fruit flies (Diptera: Tephritidae) are a major pest of agricultural commodities throughout the world, causing 30 to 100 per cent yield losses, therefore, field trials were conducted to evaluate some insecticides, biopesticides and clay for the management of fruit fly, *Bactrocera* spp. infesting bottle gourd. Among insecticides, ƛ-cyhalothrin with least fruit infestation (14.62%) and maximum avoidable loss value (47.93%) proved effective in managing fruit flies. Among biopesticides, spinosad (17.38% infestation) and azadirachtin though inferior over the synthetic pyrethroid, were found effective over neem and pongamia oil, *Beauveria bassiana*, clay and also over the recommended insecticide i.e malathion. Neem oil, *B. bassiana*, pongamia oil, clay and neemastra treatments were not found much effective though these were superior over control. The highest benefit cost ratio (BCR) was recorded in deltamethrin (20.54:1) and was followed by ƛ- cyhalothrin (15.39:1) treatment. The botanicals and microbials were not economically viable as the BCR computed was <1 except for *B. bassiana*, with a quite low BCR value (1.21:1).

Keywords: *Bactrocera* spp., bottle gourd, ƛ-cyhalothrin, spinosad, azadirachtin, biopesticides

Introduction
India stands second in the world next only to China as far as vegetable production in the country is concerned. Bottle gourd is grown in an area of 153 thousand hectares with a production of 2529 thousand metric tonnes [1]. Among summer vegetables, cucurbitaceous crops viz. bitter gourd, bottle gourd, cucumber and sponge gourd constitute a major group of host plants for the fruit flies. Being a direct pest with high multiplication rate and concealed nature, it becomes one of the most difficult pests to manage. Two species namely *Bactrocera tau* (Walker) and *B. cucurbitae* (Coquillett) infest these crops [2, 3, 4, 5, 6, 7] causing significant reduction in the yield and market value of the produce. Further, these persistent insecticides leave a toxic residue on the fruit which is a cause of concern for human health and also the environment, which suggest a need to find alternative methods for the suppression of this pest. Therefore, the present investigation was carried out to test some insecticides along with biopesticides and a non-chemical method (clay) against fruit fly, *Bactrocera* spp. in the mid hill region of Himachal Pradesh.

Materials and Methods
The field trial was conducted on bottle gourd (local), during 2016 at the experimental farm of the Department of Entomology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). The insecticides namely, ƛ-cyhalothrin and deltamethrin; biopesticides *viz.* spinosad, azadirachtin, neem oil, pongamia oil, *Beauveria bassiana* (used @ 1 % representing 1×10^9 CFU/gm) and neemastra were evaluated against fruit flies infesting bottle gourd. In addition, a non-chemical method i.e. use of clay was also evaluated. All the treatments were compared with the standard recommended insecticide Malathion and control. The trial was laid out in a randomized block design (RBD) where each treatment was replicated thrice. The first spray application was given after initiation of 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. In oil treatments, a sticker Indtron –AE (0.01%) was added for making proper emulsion.

The data on fruit infestation were converted into per cent infestation and analysis was done using OPSTAT programme.

Neemastra Preparation: Neemastra was prepared by using a mixture of neem leaves (5kg), water (100 lit.), cow dung (1 kg) and cow urine (50 lit.). These ingredients were mixed by stirring in clockwise direction and covered with gunny bag which was kept in the shade for 48 hours. This was further stirred for 1-2 minutes daily in clockwise direction and after 2 days it was sieved and kept in a container for testing its efficacy.

The avoidable loss was worked out in different treatments as per formula of Pradhan (1964) as follows [8]:

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

In order to know the effectiveness of 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 products (insecticides and biopesticides) used for the management of the pest, 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 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

After 10 days of first foliar application of insecticides, biopesticides and clay (Table–1) it was revealed that maximum fruit fly infestation was recorded in control (55.32%) and all the test treatments were found superior over control. ƛ-cyhalothrin (21.52% infestation), deltamethrin (24.63% infestation) and spinosad (22 .82% infestation) being at par were superior over rest of the test treatments. The biopesticides *viz.* neem oil, pongamia oil, *B. bassiana*, azadirachtin and neemastra treatments with 46.15, 46.76, 42.05, 31.56 and 49.51 per cent fruit infestation, respectively, though were found effective over control (55.32% infestation) but only azadirachtin (29.43% infestation) was at par with the recommended insecticide malathion (33.21% infestation). The clay treatment also was not much effective (44.04% infestation).

Similar results were obtained when the data were recorded after 10 days of the second spray (Table-1), where, ƛ-cyhalothrin, deltamethrin and spinosad with 13.62, 18.02 and 17.56 per cent infestation, respectively, being at par proved superior over other treatments. Among biopesticide treatments, azadirachtin (26.06% infestation) was at par with Malathion (29.95% infestation) treatment and statistically superior over neem oil (39.62% infestaion), *B. bassiana* (35.48% infestation), pongamia oil (43.44% infestation) and neemastra (47.86% infestation) treatments.

The clay treatment (40.56 % infestation) though superior over neemastra (47.86% infestation) and control (65.22% infestation) treatment, did not prove effective in suppressing the fruit fly infestation

After 10 days of third spray application the infestation increased to 70 per cent in control. ƛ-cyhalothrin (8.72% infestation) being at par with spinosad (11.76% infestation) and deltamethrin (13.42%) treatments. Azadirachtin (20.50% infestation) treatment was next in order of effectiveness and was superior over Malathion (28.76% infestation). Clay treatment (39.02% infestation) was at par with neem oil (34.67% infestation) and *B. bassiana* (33.68% infestation) and was superior over neemastra (44.5% infestation) and pongamia oil (41.5% infestation) treatment.

Table 1: Bioefficacy of insecticides, biopesticides and clay against fruit fly, *Bactrocera* spp. infesting bottle gourd

Treatment	Fruit infestation (%) 10 days after			Mean fruit infestation (%)
	Spray I	SprayII	Spray III	
ƛ-cyhalothrin (0.004%)	21.52 (27.63)	13.62(21.61)	8.72(17.16)	14.62(22.13)
Deltamethrin (0.0028%)	24.63(29.74)	18.02(24.99)	13.42(21.46)	18.69(25.40)
Spinosad (0.002%)	22.82(28.54)	17.56(24.61)	11.76(20.04)	17.38(24.40)
Neem oil (2.0%)	46.15(42.79)	39.62(38.98)	34.67(36.07)	40.15(39.28)
B.bassiana (1%)	42.05(40.42)	35.48(36.54)	33.68(35.44)	37.07(37.46)
Pongamia oil (2.0%)	46.76(43.14)	43.44(41.23)	41.5(40.10)	43.9(41.49)
Neemastra (5.0%)	49.51(44.72)	47.86(43.77)	44.5(41.84)	47.29(43.44)
Azadirachtin (0.01%)	31.56(34.16)	26.06(30.69)	20.5(26.88)	26.04(30.57)
Clay (10%)	44.04(41.57)	40.56(39.52)	39.02(38.63)	41.21(39.91)
Malathion (0.1%)	35.82(36.74)	29.95(33.16)	28.76(32.43)	31.51(34.11)
Control (Water)	55.32(48.06)	65.22(53.90)	70.00(56.80)	63.51(52.92)
Mean	38.20(37.95)	34.31(35.36)	31.27(33.21)	

Figures in the parentheses are arc sine transformed values

C D (0.05)

Treatment (T) (1.75)

Spray interval (I) (0.91)

T×I (3.04)

When overall means were compared, ƛ-cyhalothrin (14.62% infestation) was the most effective treatment (Table-1) and was superior to spinosad (17.38% infestation) and deltamethrin (18.69% infestation) treatments, however, the latter two treatments were statistically at par. Azadirachtin (26.04% infestation) was best among biopesticide treatments and was also found superior to Malathion (31.51% infestation). Neem oil, *B. bassiana*, pongamia oil, neemastra, and clay treatments were not found very effective though were statistically superior over control (63.51% infestation). The mean infestation at different spray intervals was significant.

In the present studies, the infestation in clay treatment recorded was comparatively more. Since locally available

clay powder was used by mixing it in water with addition of sticker (0.1%). However, the commercial formulation of clay, Surround 50 WP, which is so far not available in our country has given better results in the studies carried out in different countries. Hence, the kaolin particle film (Surround 50 WP) which act as repellent for landing and barrier to oviposition can prove economically viable and sound component of integrated approach in the management of fruit flies [9, 10].

Sood and Sharma (2004) reported significantly less fruit infestation in summer squash by *B. cucurbitae* with synthetic pyrethroid treatments namely deltamethrin (37.5 g ai ha^{-1}), cypermethrin (75 g ai ha^{-1}) and fenvalerate (75 g ai ha^{-1}) in comparison to malathion (375 g ai ha^{-1}) [11]. They also observed that neem derivatives, although were statistically superior over untreated control, were less effective than the synthetic insecticides in suppressing the infestation. Out of the seven insecticides and biopesticides evaluated for the management of *B. cucurbiate* in cucumber and bitter gourd, ƛ-cyhalothrin (0.004%) with 14.38 and 15.78 per cent infestation in cucumber and bitter gourd, respectively, was the most effective treatment and was superior to azadirachtin and malathion, thus corroborating the results obtained in the present study [12]. Similarly, Bhowmik *et al*. (2014) reported deltamethrin (15.72% infestation) and acephate (14.46% infestation) effective in checking the fruit fly infestation in bottle gourd. Neemazal and karanj oil resulted in 33.27 and 34.14 per cent infestation, respectively, and hence were not very effective though being superior over control (54.57% infestation), thus supporting the results obtained in the present study [13]. Sawai *et al*. (2014) reported synthetic pyrethroid, deltamethrin (0.016%) to be very effective (20.15% infestation) in checking fruit fly infestation in ridge gourd [14]. In a similar study, Khatun *et al*. (2016) 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 to 38.40 per cent in control, these results are in line with the findings of the present study [15].

Table 2: Avoidable loss due to application of insecticides, biopesticides and clay against fruit fly, *Bactrocera* spp. in bottle gourd

Treatment	Mean yield(kg/plant)	Increase in yield over control (kg)	Avoidable loss (%)
ƛ-cyhalothrin (0.004%)	10.5	5.0	47.93
Deltamethrin (0.0028%)	9.7	4.2	43.45
Spinosad (0.002%)	10.0	4.5	45.15
Neem oil (2.0%)	8.2	2.7	33.06
B.bassiana (1 %)	7.8	2.3	29.91
Pongamia oil (2.0%)	7.3	1.9	25.45
Neemastra (5.0%)	6.3	0.9	13.67
Azadirachtin (0.01%)	9.1	3.6	39.70
Clay (10%)	7.5	1.5	20.00
Malathion (0.1%)	8.7	3.2	37.16
Control (water)	5.5	-	-

The data presented in Table-2 revealed that the maximum losses were avoided with ƛ-cyhalothrin, deltamethrin and spinosad with the avoidable loss values of 47.93, 43.45 and 45.15 per cent respectively in comparison to 37.16 per cent loss in recommended insecticide i.e malathion (0.1%).The avoidable loss values of 39.70, 33.04, 29.91, 25.45, 22.67 and 13.67 per cent, were recorded in azadirachtin, neem oil, *B. bassiana*, pongamia oil, clay and neemastra treatments, respectively. Similar results were obtained by Kate *et al*. (2010) who estimated the avoidable loss value of 38.69 per cent in cucumber against *B. cucurbitae*, when fenthion (0.1%) and Malathion (0.1%) were applied alternatively starting from fruit formation to fruit maturity [16]. The results obtained are in accordance with the present study where, 37.16 per cent losses were avoided with Malathion (0.1 %).

Table 3: Benefit cost ratio of insecticides and biopesticides application against fruit fly, *Bactrocera spp* in bottle gourd

Treatment	Mean yield (kg/plant)	Increase in yield over control (kg)	Cost of Increased yield @ Rs20 /kg	Cost of the test treatment (Rs)	Net Monetary return (Rs)	Benefit Cost Ratio (BCR)
ƛ-cyhalothrin (0.004%)	10.5	5.0	100.66	6.14	94.52	15.39:1
Deltamethrin (0.0028%)	9.7	4.2	84	3.9	80.1	20.54:1
Spinosad (0.002%)	10.0	4.5	90	8.20	81.8	9.98:1
Neem oil (2.0%)	8.2	2.7	54	109.92	-55.92	*
B.bassiana (1%)	7.8	2.3	46.66	21.12	25.54	1.21:1
Pongamia oil (2.0%)	7.3	1.9	37.32	150	-112.68	*
Azadirachtin (0.01%)	9.1	3.6	72	75	-3.0	*
Malathion (0.1%)	8.7	3.2	64.66	4.8	59.86	12.47:1
Control (Water)	5.5	-	-	-	-	-

*Indicate value<1

As revealed from the data presented in Table 3, the increase in yield over control was maximum (5.0 kg/ plant) in ƛ-cyhalothrin treatment and was followed by spinosad (4.5 kg/plant) and deltamethrin (4.2 kg/plant). The recommended insecticide Malathion, registered 3.2 kg increase in yield over control. The increase in yield over control was 2.7, 2.3, 1.9 and 3.6 kg/ plant respectively, in neem oil, *B. bassiana*, Pongamia oil and azdirachtin treatments, respectively.

When the cost of the increased yield and cost of treatments were taken into consideration to calculate the BCR, maximum ratio (20.54:1) was recorded in deltamethrin treatment followed by ƛ-cyhalothrin (15.39:1) which was due to the less cost of the former. The biopesticides were not found economical as the net monetary returns obtained were less in comparison to the cost of test treatment, except for *B. bassiana* were a BC ratio of 1.21:1 was obtained. Since in the

study crude formulation of clay was used which did not give good results and hence was not considered to work out the BCR.

The net monetary return was maximum (Rs. 94.52/plant) in ƛ-cyhalothrin treatment followed by deltamethrin (Rs.80.1/plant) but the benefit cost ratio (BCR) was highest (20.54:1) in deltamethrin, due to the low cost of the test treatment.

Sunil *et al*. (2016) reported the maximum benefit cost ratio in deltamethrin + jaggery @ 0.0028 + 0.015 % (1:2.42), followed by deltamethrin @ 0.0028 per cent (1:2.23), malathion @ 0.1 per cent (1:2.20), dichlorvos @ 0.152 per cent (1:2.01), spinosad @ 0.014 per cent (1:1.96), azadirachtin @ 0.005 per cent (1:1.90), in managing the fruit fly in bitter gourd [17]. In the present studies also, the deltamethrin was found effective and also resulted in the high benefit cost ratio.

Conclusions

The results obtained in the present study reveal ƛ-cyhalothrin (0.004%), delatmethrin (0.0028%) and spinosad (0.002%) to be effective in checking fruit fly, *Bactrocera* spp. infestation in bottle gourd. Azadirachtin, among biopesticides was found better from the bioefficacy point of view. Hence, various modules can be evaluated further by using these pesticides in rotation in three spray schedule. Initially, biopesticide can be used followed by the other effective insecticides keeping in view the environmental and health concern. Clay treatment proved moderately efficacious but has an effect on the quality of the produce. Therefore, kaolin clay which is so far not available in India can be evaluated as it is very fine and easy to apply in comparison to coarse spray, further it may not affect the fruit quality also.

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