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Evaluation of different combinations of insecticides and biopesticides for the management of fruit flies infesting bitter gourd

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Abstract
Fruit flies have been a constant threat to agricultural commodities from the distant past and the management of the pest is very difficult. To reduce the pesticide pressure and slow down the development of resistance, different combinations of insecticides and biopesticides were evaluated against the fruit flies. When biopesticides were rotated with insecticides in a three spray schedule (applied at an interval of 10 days) in 12 combinations for their efficacy as well as economic viability for the management of fruit flies in bitter gourd, combination C_2 [azadirachtin (0.01%) - spinosad (0.002%) - λ-cyhalothrin (0.004%)] with minimum fruit infestation (17.39% infestation), maximum yield (12.03 kg/plant) and maximum avoidable loss value (58.10%) was found most efficacious but the Incremental Benefit Cost Ratio (IBCR) computed was quite low (2.17:1). The combination C_7 [*B. bassiana* (1×10^{10} CFU/gm) - λ-cyhalothrin (0.004%) - spinosad (0.002%)] was next in order of effectiveness and was also economically viable with higher IBCR value (13.25:1). The combinations (C_1 - C_5) in which azadirachtin formulation was applied as the first spray, the IBCR computed was quite low, due to the high price of the biopesticide. All the test combinations were found superior to control (C_{12}), wherein only water was sprayed.

Keywords: Fruit flies, bitter gourd, biopesticides, spinosad, λ-cyhalothrin, azadirachtin

1. Introduction
India is a country where more than 60 percent of the farmers are dependent on agriculture for a livelihood, of which horticulture account for one of the major components due to the higher economic returns per unit area (Ravichandra, 2014) [17].
In vegetable production, India with 10,259 thousand-hectare areas and 1, 84,394 thousand metric tonnes production, stands next only to China (Anonymous 2018) [3]. Cucurbits constitute one of the largest groups of summer vegetables, which play an important role in the human diet and also helps in building-up farmers' economy. Cucurbits are generally eaten as raw in the form of salads, pickles and vegetables and considered as food of low calorific value but with sufficient vitamins, proteins and fibers. Bitter gourd, with a production of 1,137 thousand metric tonnes, grown in an area of 97 thousand hectares, is one of the major cucurbitaceous vegetable crop in India and is known to lower the blood sugar level in diabetic patients due to presence of a compound *Charantin* (Dhillon *et al*. 2005) [7].
Fruit flies (Diptera: Tephritidae) due to their faster reproduction rate and polyphagous nature are known to be invasive pest of various horticultural commodities (Sarwar, 2015) [18]. The two major species namely *Bactrocera cucurbitae* (Coquillett) and *B. tau* (Walker) cause much of the damage (Rabindranath and Pillai 1986; Gupta and Verma 1992; Sood and Nath 1999; Nath *et al*. 2007; Prabhakar *et al*. 2007; Thakur and Gupta 2013; Sunil *et al*. 2016) [16, 8, 25, 12, 14, 27, 26]. These flies being direct pest not only reduce the yield but also prove bottleneck in quality fruit production. The pest is reported to cause 50 percent infestation in cucurbits and under favourable conditions the infestation may even reach 100 percent (Dhillon *et al*. 2005; Philippe *et al*. 2010) [7, 13]. The management of fruit flies becomes even more difficult as the three immature stages i.e. egg, larva and pupa are hidden. Generally, the conventional organophosphate insecticides were used for the management of the fruit flies (Agarwal *et al*. 1987; Bhatnagar and Yadava 1992; Dashad *et al*. 1999; Vargas *et al*. 2003; Kate *et al*. 2010) [2, 4, 6, 28, 9], but due to their persistent nature and deposition of toxic residue on fruits, they are a cause of concern to health and also to the environment, suggesting thereby the need to explore alternate approaches. The choice of the insecticides to be used for the management of pest

further becomes more important when the food commodity is to be eaten as raw. The novel insecticides with different mode of action like spinosad and lambda cyhalothrin have been found effective against the fruit flies infesting cucumber and bottle gourd crops (Abrol 2017) [1], however, the repeated use of the same insecticide must not be advocated under the philosophy of pest management. Hence, it was envisaged to use various combinations comprising insecticides and biopesticides for the management of fruit flies infesting bitter gourd.

2. Materials and Methods

The insecticides namely lambda-cyhalothrin, deltamethrin and cyantraniliprole, and biopesticides *viz*. spinosad, azadirachtin and *Beauveria bassiana* based formulations were evaluated in different combinations for fruit fly management. The field trial was conducted at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) situated at 77°11″ East longitude, 32°5″ North latitude and at an elevation of around 1300 m above mean sea level (amsl), in bitter gourd crop.

The seeds of the bitter gourd variety Solan Hara, developed by the University were sown during mid-May, 2019, in polybags filled with sieved virgin forest soil, and well decomposed farm yard manure in the ratio of 1:1. The plants so generated were transplanted in a plot 3×2m at a distance of 1×1m. All the recommended practices except the insecticide application, as recommended in 'Package of Practices for Vegetable Crops' of Dr. Y.S. Parmar University of Horticulture and Forestry, were followed.

The bioefficacy of the different combinations was compared with each other as well as with the recommended insecticide Malathion (0.1%) and control (water). The trial was laid out in randomized block design (RBD) where each treatment was replicated thrice. In total 12 combinations including recommendation (Malathion 50EC) and control (spray of water only) were evaluated. The first spray was given after fruit set, which was followed by two more foliar applications as per the combination at an interval of 10 days. The spray was provided with the help of a knap sack sprayer till run off stage. The data obtained were subjected to analysis of variance by using OP Stat and the means found significantly different were separated by least significant difference (LSD) at p= 0.05 (Sheoran *et al*. 1998) [22]. The observations were recorded after 10 days of each spray by counting infested fruits out of the total fruits and later it was converted into percent fruit infestation.

The fruit yield in all the combinations was also recorded at each harvest and the average yield for each combination was worked out in the test crop bitter gourd. The data recorded were compared with the recommended insecticide i.e. Malathion (0.1%) and control (spray of water only).

2.1 Economics of different combinations

The loss avoided in yield for different combinations was worked out as per formula of Pradhan (1964) [15] 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 combinations in monetary terms, the incremental benefit cost ratio was worked out by recording yield and the cost of test products (Insecticides and biopesticides) in different combinations, keeping rest of the factors constant.

2.2 Phytotoxicity Study

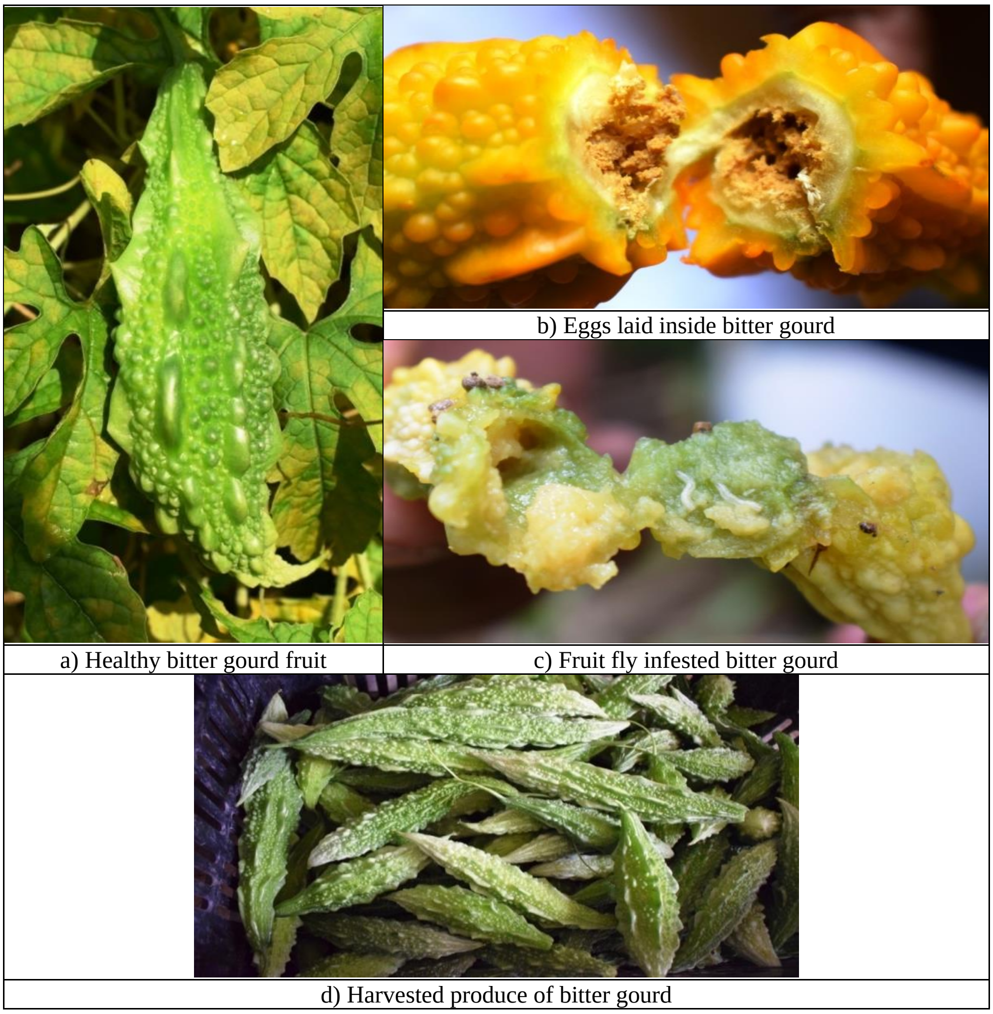
The phytotoxic effects for all the test combinations in the form of burning, vein clearing, epinasty/hyponasty etc. were observed regularly, throughout the experimental period.

3. Results and Discussion

3.1 Bioefficacy studies

The data pertaining to the percent fruit infestation (Fig. 1) recorded after 10 days of each spray application are presented in Table 1. When the data on fruit infestation were recorded after 10 days of the first spray application, all the test combinations were found superior to control (47.94% infestation). The fruit infestation in azadirachtin based combinations (C_1 to C_5) being on par with each other ranged between 27.22 and 29.65 percent. These were also found at par with combination C_{11} (recommended insecticide, Malathion) where 30.65 percent infestation was recorded. The azadirachtin (C_1 to C_5) and Malathion (C_{11}) based combinations were superior to combinations, C_6, C_7, C_8, C_9 and C_{10} (initiated with *B. bassiana* spray) where fruit infestation recorded was 39.38, 38.37, 38.70, 38.31 and 39.29 percent, respectively.

After 10 days of the second spray application, the highest fruit infestation (58.99%) was recorded in combination C_{12} (control). The combination C_7 (*B. bassiana*- λ-cyhalothrin) with numerical minimum infestation was at par with combinations C_1 to C_5 (azadirachtin-spinosad based) with fruit infestation ranging between 18.86 and 21.98 percent. These were followed by the combinations C_{11} (Malathion-Malathion), C_9 (*B. bassiana*- spinosad), C_8 (*B. bassiana-deltamethrin*) and C_6 (*B. bassiana*- cyantraniliprole) being on par with fruit infestation of 24.72, 26.13, 27.43 and 29.03 percent, respectively. The combination C_{10} (*B. bassiana*-Malathion) with 32.50 percent infestation was the least effective test combination. When the data were recorded 10 days after the third spray application, the combinations C_2 (azadirachtin-spinosad- λ-cyhalothrin) and C_7 (*B. bassiana*- λ-cyhalothrin-spinosad), both being on par with fruit infestation of 6.07 and 8.53 percent, respectively, proved effective in the management of fruit flies.



a) Healthy bitter gourd fruit
b) Eggs laid inside bitter gourd
c) Fruit fly infested bitter gourd
d) Harvested produce of bitter gourd

Fig 1: Fruit fly infestation in bitter gourd (a, b, c, d)

The combinations C_4 (azadirachtin- spinosad- spinosad), C_3 (azadirachtin- spinosad- deltamethrin), C_9 (*B. bassiana*- spinosad- spinosad), C_1 (azadirachtin- spinosad- cyantraniliprole), C_8 (*B. bassiana*- deltamethrin- spinosad) and C_5 (azadirachtin- spinosad- malathion) with fruit infestation levels of 15.36, 16.11, 18.24, 19.27, 20.05 and 20.20 percent, respectively, being statistically at par with each other were next in the order of effectiveness. Combination C_{10} (*B. bassiana*- malathion- spinosad) registered the highest infestation of 28.28 percent amongst test combinations, whereas all the test combinations were found superior to control (65.99% infestation).

When the overall means of the three spray applications was taken into consideration, combination M_2 (azadirachtin- spinosad- λ-cyhalothrin) with a minimum fruit infestation (17.39%) was the most effective. It was followed by C_7 (*B. bassiana*- λ-cyhalothrin- spinosad), C_4 (azadirachtin- spinosad- spinosad), C_3 (azadirachtin- spinosad- deltamethrin) and C_1 (azadirachtin- spinosad- cyantraniliprole) being on par with fruit infestation of 21.45, 21.61, 21.85 and 23.57 percent, respectively. The combinations C_1, C_5, C_9, and C_8 with fruit infestation of 23.57, 23.76, 27.56 and 28.73 percent, respectively, were at par with each other and also with combination C_{11} (25.74% infestation) consisting the recommended insecticide (malathion). Among the solely biopesticide based combinations, C_4 (azadirachtin-spinosad- spinosad) recorded the lowest infestation (21.61%) and was at par with combinations C_1, C_3, C_5 and C_7 where insecticides were rotated with biopesticides. All the test combinations were found superior over control when an infestation of 57.64 percent was recorded.

The Table 2 pertains to the data of the avoidable loss in yield in various test combinations. The highest avoidable loss value over control (58.10%) was recorded in combination C_2 (azadirachtin- spinosad- λ-cyhalothrin) and was followed by combinations C_7 (*B. bassiana*- λ- cyhalothrin- spinosad), C_4 (azadirachtin- spinosad- spinosad), C_3 (azadirachtin- spinosad- deltamethrin), C_1 (azadirachtin- spinosad- cyantraniliprole) and C_5 (azadirachtin- spinosad- malathion) where avoidable loss values were 53.72, 53.59, 53.42, 50.93 and 50.30 percent, respectively, whereas the avoidable loss value of 46.72 percent was recorded in malathion based combination (C_{11}). When the avoidable loss over the recommended insecticide Malathion were considered, the combinations C_2 (azadirachtin-spinosad- λ-cyhalothrin), C_7 (*B. bassiana*- λ-cyhalothrin- spinosad), C_4 (azadirachtin- spinosad- spinosad), C_3 (azadirachtin- spinosad- deltamethrin), C_1 (azadirachtin- spinosad- cyantraniliprole) and C_5 (azadirachtin- spinosad- Malathion) were found to be viable over Malathion. In the remaining combinations, negative values were obtained.

The data presented in Table 3 reveal the value of the Incremental Benefit Cost Ratio (IBCR) recorded for the various test combinations. The highest increase in yield over control (6.99 kg) was recorded in combination C_2 (azadirachtin- spinosad- λ-cyhalothrin), but due to higher cost of the test combination (Rs. 55.20/ plant), the IBCR calculated was less (2.17:1). This was followed by combination C_7 (*B. bassiana*- λ- cyhalothrin- spinosad) with increase in yield over control and net monetary returns of 5.85 kg and Rupees 135.99 per plant, respectively, however with lower cost of test combination (Rs. 10.26/ plant) the IBCR recorded was higher (13.25:1). Overall the maximum IBCR (22.02:1) was recorded in the recommended insecticide based combination (C_{11}). The combination C_1 was not economically viable as the IBCR computed was less than 1.

Table 1: Bioefficacy of insecticides and biopesticides based combinations against fruit fly, *Bactrocera* spp. infesting bitter gourd

Combination	Fruit infestation (%) 10 days after spray						Mean fruit infestation (%)
	SPRAY 1		SPRAY 2		SPRAY 3		
C_1	Azadirachtin (0.01%)	29.47(32.82)	Spinosad (0.002%)	21.98(27.83)	Cyantraniliprole (0.0075%)	19.27(25.91)	23.57(28.85)
C_2	Azadirachtin (0.01%)	27.22(31.40)	Spinosad (0.002%)	18.86(25.71)	λ -cyhalothrin (0.004%)	6.07(14.14)	17.39(23.75)
C_3	Azadirachtin (0.01%)	28.67(32.33)	Spinosad (0.002%)	20.77(27.08)	Deltamethrin (0.0028%)	16.11(23.59)	21.85(27.67)
C_4	Azadirachtin (0.01%)	28.85(32.45)	Spinosad (0.002%)	20.61(26.91)	Spinosad (0.002%)	15.36(23.01)	21.61(27.46)
C_5	Azadirachtin (0.01%)	29.65(32.94)	Spinosad (0.002%)	21.43(27.45)	Malathion (0.1%)	20.20(26.62)	23.76(29.00)
C_6	*B. bassiana* (1×10^{10} CFU/gm)	39.38(38.84)	Cyantraniliprole (0.0075%)	29.03(32.57)	Spinosad (0.002%)	22.16(28.03)	30.19(33.15)
C_7	*B. bassiana* (1×10^{10} CFU/gm)	38.37(38.25)	λ -cyhalothrin (0.004%)	17.45(24.63)	Spinosad (0.002%)	8.53(16.76)	21.45(26.55)
C_8	*B. bassiana* (1×10^{10} CFU/gm)	38.70(38.45)	Deltamethrin (0.0028%)	27.43(31.54)	Spinosad (0.002%)	20.05(26.50)	28.73(32.16)
C_9	*B. bassiana* (1×10^{10} CFU/gm)	38.31(38.22)	Spinosad (0.002%)	26.13(30.69)	Spinosad (0.002%)	18.24(25.15)	27.56(31.35)
C_{10}	*B. bassiana* (1×10^{10} CFU/gm)	39.29(38.79)	Malathion (0.1%)	32.25(34.58)	Spinosad (0.002%)	28.28(32.09)	33.27(35.15)
C_{11}	Malathion (0.1%)	30.65(33.59)	Malathion (0.1%)	24.72(29.76)	Malathion (0.1%)	21.84(27.77)	25.74(30.37)
C_{12}	Control (water)	47.94(43.80)	Control (water)	58.99(50.17)	Control (water)	65.99(54.33)	57.64(49.43)
	Mean	34.71(35.99)		26.64(30.74)		21.84(26.99)	

Figures in the parentheses are arc sine transformed values
CD $_{(0.05)}$
Treatment (T): (2.42)
Spray interval (I): (1.21)
T×I: (4.20)

Table 2: Avoidable loss in yield due to application of insecticides and biopesticides based combinations against fruit fly, *Bactrocera* spp. in bitter gourd

Combination No.	SPRAY 1	SPRAY 2	SPRAY 3	Mean yield (kg/plant)	Increase in yield over control (kg)	Avoidable loss (%) over control	Avoidable loss (%) over recommended insecticide**
C_1	Azadirachtin (0.01%)	Spinosad (0.002%)	Cyantraniliprole (0.0075%)	10.27	5.23	50.93	7.89
C_2	Azadirachtin (0.01%)	Spinosad (0.002%)	λ -cyhalothrin (0.004%)	12.03	6.99	58.10	21.36
C_3	Azadirachtin (0.01%)	Spinosad (0.002%)	Deltamethrin (0.0028%)	10.82	5.78	53.42	12.57
C_4	Azadirachtin (0.01%)	Spinosad (0.002%)	Spinosad (0.002%)	10.86	5.82	53.59	12.89
C_5	Azadirachtin (0.01%)	Spinosad (0.002%)	Malathion (0.1%)	10.14	5.10	50.30	6.71
C_6	*B. bassiana* (1×10^{10} CFU/gm)	Cyantraniliprole (0.0075%)	Spinosad (0.002%)	7.89	2.85	36.12	*
C_7	*B. bassiana* (1×10^{10} CFU/gm)	λ -cyhalothrin (0.004%)	Spinosad (0.002%)	10.89	5.85	53.72	13.13
C_8	*B. bassiana* (1×10^{10} CFU/gm)	Deltamethrin (0.0028%)	Spinosad (0.002%)	8.72	3.68	42.20	*
C_9	*B. bassiana* (1×10^{10} CFU/gm)	Spinosad (0.002%)	Spinosad (0.002%)	8.89	3.85	43.31	*
C_{10}	*B. bassiana* (1×10^{10} CFU/gm)	Malathion (0.1%)	Spinosad (0.002%)	6.94	1.90	27.38	*
C_{11}	Malathion (0.1%)	Malathion (0.1%)	Malathion (0.1%)	9.46	4.42	46.72	-
C_{12}	Control (water)	Control (water)	Control (water)	5.04	-	-	-

*- means negative values were obtained

Table 3: Incremental Benefit Cost Ratio of insecticides and biopesticides based combinations evaluated against fruit fly, *Bactrocera* spp. in bitter gourd

Combination No.	Spray 1	Spray 2	Spray 3	Mean yield (kg/plant)	Increase in yield over control (kg)	Cost of increased yield @ Rs 25/kg	Cost of the test treatment (Rs)	Net monetary return (Rs)	Incremental Benefit Cost Ratio (IBCR)
C_1	Azadirachtin (0.01%)	Spinosad (0.002%)	Cyantraniliprole (0.0075%)	10.27	5.23	130.75	68.07	62.68	*
C_2	Azadirachtin (0.01%)	Spinosad (0.002%)	λ -cyhalothrin (0.004%)	12.03	6.99	174.75	55.20	119.55	2.17:1
C_3	Azadirachtin (0.01%)	Spinosad (0.002%)	Deltamethrin (0.0028%)	10.82	5.78	144.50	55.00	89.50	1.63:1
C_4	Azadirachtin (0.01%)	Spinosad (0.002%)	Spinosad (0.002%)	10.86	5.82	145.50	56.82	88.68	1.56:1
C_5	Azadirachtin (0.01%)	Spinosad (0.002%)	Malathion (0.1%)	10.14	5.10	127.50	55.68	71.82	1.29:1
C_6	*B. bassiana* (1×10^{10} CFU/gm)	Cyantraniliprole (0.0075%)	Spinosad (0.002%)	7.89	2.85	71.25	23.13	48.12	2.08:1
C_7	*B. bassiana* (1×10^{10} CFU/gm)	λ -cyhalothrin (0.004%)	Spinosad (0.002%)	10.89	5.85	146.25	10.26	135.99	13.25:1
C_8	*B. bassiana* (1×10^{10} CFU/gm)	Deltamethrin (0.0028%)	Spinosad (0.002%)	8.72	3.68	92.00	10.06	81.94	8.15:1
C_9	*B. bassiana* (1×10^{10} CFU/gm)	Spinosad (0.002%)	Spinosad (0.002%)	8.89	3.85	96.25	11.88	84.37	7.10:1
C_{10}	*B. bassiana* (1×10^{10} CFU/gm)	Malathion (0.1%)	Spinosad (0.002%)	6.94	1.90	47.50	10.74	36.76	3.42:1
C_{11}	Malathion (0.1%)	Malathion (0.1%)	Malathion (0.1%)	9.46	4.42	110.50	4.80	105.70	22.02:1
C_{12}	Control (water)	Control (water)	Control (water)	5.04	-	-	-	-	-

*- The combination was economically non-viable because computed IBCR was less than 1

The Fig. 2 clearly represents the inverse relationship between infestation and yield. In combinations where the infestation was low (C_2) the yield recorded was high and in combinations where the infestation was high (C_{12}) the yield recorded was low.

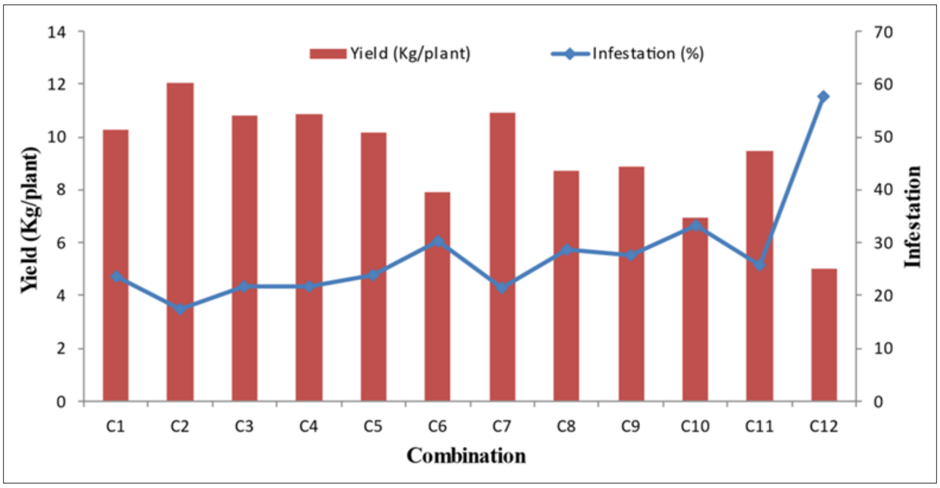


Fig 2: Relationship between infestation and yield in different Insecticide Bio-pesticide combinations

3.2 Discussion

In the present study, the fruit fly infestation in control (C_{12}) increased from 47.94 to 65.99 percent, whereas, in all the test treatment a decreasing trend in infestation was observed. Similar results have been reported by Abrol (2017) [1], where the infestation in control increased from 54.26 to 64.22 percent in bitter gourd crop. The management of these fruit flies is of prime importance because if the crop remains unchecked the infestation increases drastically, some workers even reported the infestation to reach upto 100 percent in various crops under favourable circumstances (Dhillon *et al*. 2005; Philippe *et al*. 2010) [7, 13].

The results presented in Table 1 reveal that after the first spray application, the infestation recorded in azadirachtin based combinations (C_1 to C_5) was at par with malathion based combination (C_{11}), both of which were superior to the *B. bassiana* based combinations. In earlier studies carried out for fruit fly management azadirachtin has been found superior to *B. bassiana* for the management of fruit flies (Abrol 2017; Sharma 2018; Sharma 2019) [1, 21, 20].

Further when data were recorded 10 days after the second spray application, numerical minimum infestation was recorded in combinations C_7 (*B. bassiana*- λ-cyhalothrin) being at par with combinations C_1 to C_5 (azadirachtin-spinosad), however the infestation recorded in combinations C_6 to C_{10} (except C_7) was higher than C_1 to C_5. This clearly indicates that even though the infestation recorded after the first spray application in combination C_7 was higher, the application of λ-cyhalothrin during the second spray successfully reduced the fruit fly infestation bringing it at par with combinations C_1 to C_5, where spinosad succeeded azadirachtin in second spray application. Similar results were reported 10 days after the third spray application, where the combinations C_2 and C_7 comprising of the insecticide λ-cyhalothrin were at par and the most effective combinations in fruit fly management. The present study finds support from the work carried out by Khursheed and Raj (2012) [11], where out of the seven insecticides evaluated for fruit fly management, λ-cyhalothrin proved to be most effective (15.78%). Khatun *et al*. (2016) [10] reported that λ -cyhalothrin with 17.23 percent infestation was most effective in managing fruit fly, *B. cucurbitae* in bitter gourd, in comparison to 38.40 percent in control. Abrol (2017) [1] also reported the effectiveness of λ-cyhalothrin in the management of fruit fly infesting bitter gourd crop.

In the combination based study carried out by Shivangi *et al*. (2017) [23], the combination T_2 comprising three sprays application of spinosad 45SC (200 ml/ha) was most effective in checking fruit fly infestation in cucumber. Sharma (2018)[21] also reported the effectiveness of spinosad over azadirachtin for the management of fruit flies in mango. Thus supporting the results in the present study, where the test combination M_4 (azadirachtin- spinosad- spinosad) ranked third in terms of effectiveness.

Sood and Sharma (2004) [24] reported significantly less infestation in summer squash with deltamethrin (37.5 g ai/ ha) in comparison to malathion (375 g ai/ ha), which is in accordance with the results obtained in the present study, where deltamethrin based combinations (C_3 and C_8) were found superior to malathion based combination (C_{11}). The present study also finds support from the work carried out by Bhowmik *et al.* (2014) [5], who reported the effectiveness of deltamethrin (15.72%) in fruit fly management in bottle gourd, however in the present study since deltamethrin was used in rotation, the values observed vary. Sawai *et al.* (2014)[19] reported deltamethrin was followed by spinosad for the management of fruit flies in ridge gourd, which is in partial agreement with the present study, where the infestation recorded in spinosad and deltamethrin based combination (C_4 and C_3) were found equally effective (15.36 and 16.11% infestation).

In the present study, the highest avoidable loss over yield value (58.10%) was obtained in test combination C_2 followed by test combinations C_7, C_4 and C_3 with avoidable loss values of 53.72, 53.59 and 53.42 percent, respectively, as compared with recommended insecticide malathion where 46.72 percent avoidable loss was obtained in bitter gourd. The study finds support from the work of Abrol (2017) [1] where the maximum avoidable loss value was recorded in lambda cyhalothrin (48.72%) treatment, followed by spinosad (44.44%) and deltamethrin (41.75%) in comparison to malathion (35.48%) in bitter gourd.

Abrol (2017) [1] recorded that the BCR computed for the treatment comprising azadirachtin was very less due to the higher cost of the biopesticide and the treatment was considered non-viable, which is partially in agreement with the present study, where the combinations in which azadirachtin was used as the first spray application the BCR computed was quite less. Among all the test combinations, the highest value of BCR was recorded in combination C_{11} (Malathion based), where biopesticides were rotated with insecticides, the combination C_7 recorded the highest BCR. The present study is in line with the work carried out by Sharma (2018) [21], where among all the treatments the maximum BCR was recorded for the recommended insecticide malathion (19.83:1), followed by spinosad (16.79:1), whereas, the BCR recorded in the treatment comprising azadirachtin was negative as the cost of the test treatment incurred was higher.

4. Conclusions

Among all test combinations, C_2 [azadirachtin (0.01%), spinosad (0.002%) and λ-cyhalothrin (0.004%)] was found most effective in checking fruit fly, *Bactrocera* spp. infestation in terms of bioefficacy in bitter gourd (17.39%), but incremental BC ratio of all combinations (C_1 to C_5) was very low, due to high input cost of the biopesticide azadirachtin (Rs 2567/litre). Whereas, combination C_7 (1^{st} spray of *B. bassiana*, 2^{nd} spray of λ-cyhalothrin and 3^{rd} spray of spinosad) has maximum IBCR value among the test combinations, due to less cost of test product. Though three spray based combination of recommended insecticide i.e. malathion-malathion-malathion performed well in managing fruit flies and also showed highest incremental BC ratio due to its low cost and high efficacy but the repeated use of the same insecticide is generally not advocated as it may result in development of insect resistance but in addition to harmful effect on environment.

Hence, based on the results obtained in the present study, the combination C_7 [*B. bassiana* (1×10^{10} CFU/gm), λ-cyhalothrin (0.004%), and spinosad (0.002%)] with better efficacy and economic viability can be used for the management of fruit flies in an effective and ecologically sound manner.

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