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Bioefficacy of insecticides and biopesticides against fruit flies (*Bactrocera* spp) infesting tomato (*Solanum lycopersicum* L.)

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Abstract
The present study was carried out to evaluate the bioefficacy of insecticides and biopesticides against fruit flies (*Bactrocera* spp) infesting Tomato (*Solanum lycopersicum* L.) was studied in Department of Entomology at Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan 173230 Himachal Pradesh, India. Results revealed lambda cyhalothrin (0.008%) as the most effective insecticide with infestation of 18.88 and 19.75 percent followed by the same insecticide at lower concentration (0.004%) where fruit fly infestation recorded was 20.49 and 22.00 percent and spinosad (0.004%) with infestation of 22.53 and 24.66 percent during 2014 and 2015 respectively. None of the treatments showed any phytotoxicity symptoms on tomato foliage and fruits. Azadirachtin at higher concentration (0.02%) with a fruit infestation of 30.56 and 31.75 percent was superior over Malathion (0.1 and 0.2%) concentration whereas, the least effective treatment was *B. bassiana* (1.0%) with 49.75 and 52.96 percent fruit infestation during 2014 and 2015, respectively.

Keywords: *Bactrocera*, biopesticides, bioefficacy, insecticides, tomato

Introduction
Tomato *Solanum lycopersicum* L. (Solanaceae) is emerging as one of the major off-season cash crops in lower and mid-hills of Himachal Pradesh. Solan, Sirmaur and Kullu districts harvests 86 percent of the state's overall production. Off-seasonal tomato cultivation peaks during monsoon in the hills when the crop is not harvesting in plains of north India. As it is short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day. Cash Crops cultivation plays an important role in the agricultural economy of India.

In tomato, pests are the main limiting factor in production. Fruit flies (Diptera: Tephritidae) reduce tomato quality and cause abortion of infested fruit (Gupta *et al*. 1990; Boopathi *et al*. 2013a) [8, 4]. Losses caused by fruit flies vary between 30 and 100% depending on the season (Hasyim *et al*., 2004; Dhillon *et al*., 2005; Boopathi 2013; Boopathi *et al*., 2013b) [9, 3, 5, 7]. The infestation level was highest as fruit matured, and little or no infestation occurred in the earlier fruit stages. Most fruits became increasingly susceptible to fruit fly damage close to harvest. Matwla *et al*., (2006) [13] also reported that fruit flies cause more severe damage to mature tomato fruit than to young fruit. Preventing fruit fly oviposition during fruit maturation is difficult because excessive insecticide residues on the fruit make them illegal to sell. Unfortunately, none of the cultivars were free from fruit fly infestation. *Zeugodacus tau* was the most common species in the complex in all cultivars, and is now considered a major insect pest of tomato in India because of its prevalence, rapid spread, and destructive nature (Boopathi *et al*. 2013a) [4]. Fruit flies can significant to total crop failure on tomato (Jose *et al*. 2013) [11]. In all geographical regions of Mizoram occurrence of *Z. tau* at high population densities was associated with high levels of damage and could lead to high economic losses in tomato fruit production (Boopati 2017) [2].

Most of the control measures against fruit flies are generally insecticide-oriented mainly the organophosphates. The increasing use of chemical insecticides has led to a number of problems like development of resistance to insecticides, high insecticide residues in market produce, resurgence and increase in infestation of insect species due to destruction of predators and parasitoids and ecological imbalance. Therefore the present study was conducted in subtropical area of Himachal Pradesh during 2014 and 2015 and two pyrethroids (Lambda cyhalothrin and deltamethrin) and biopesticides namely spinosad, *Beauveria bassiana* and azadirachtin were evaluated against the fruit flies.

Materials and Methods

Study was conducted to access the bioefficacy of insecticides and biopesticides against fruit flies (*Bactrocera* spp) infesting tomato (*Solanum lycopersicum* L.) in the experimental farm of department of Entomology at Dr. Y. S. Parmar University of Horticulture and forestry, Nauni, Solan (H.P.) during the year 2014 and 2015. The experimental farm is located at 30˚ 51' N latitude and 76˚ 11' E longitude with an elevation of 1200m above mean sea level and slope of 7-8 percent which falls in subtropical sub-humid temperate agro-climatic zone of Himachal Pradesh. The area receives an annual rainfall varying from 1000 mm to 1600 mm and 75 percent of its receive during monsoon season(July-September). Tomato (var. 2000+) seedlings were sown in nursery beds. The planting was done at spacing of 90 × 30 cm distance in a Randomized Block Design (RBD), where each treatment was replicated thrice. The first spray was applied near the ripening stage, 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. Treatments namely, lambda-cyhalothrin (0.004 and 0.008%), deltamethrin (0.0028 and 0.0056%), spinosad (0.002 and 0.004%), malathion (0.1 and 0.2%), azadirachtin (0.01 and 0.02%) and *Beauveria bassiana* (1.0 and 2.0%), were used in the present study. In control, however only water was sprayed on the plants. The data generated in the study was analysed for analysis of variance (ANOVA) by using OPSTAT statistical software programme. Comparison of treatment means was carried out using the critical difference (CD) at 5%.

Result and Discussion

The perusal of the data presented in Table 1 revealed that after 10 days of first foliar application, numerically minimum infestation was recorded in lambda-cyhalothrin (0.008%) with 27.74 and 28.03 percent infestation and was statistically at par with lower concentration (0.004%) of lambda-cyhalothrin (29.47 and 30.17% infestation), during 2014 and 2015 respectively, whereas during, 2014. Lambda-cyhalothrin at both the concentrations (0.004 and 0.008%) were at par with spinosad (0.002 and 0.004%) with infestation level of 35.73 and 33.73 percent and during 2015 both the concentrations (0.002 and 0.004%) of spinosad with infestation levels of 36.38 and 35.20 percent were at par with deltamethrin (0.0028% and 0.0056%). During 2014, deltamethrin (0.0028%), azadirachtin (0.01 and 0.02%) and malathion (0.1%) treatments, were at par and during 2015, azadirachtin (0.01 and 0.02%) with percent infestation of 41.64 and 44.99 respectively, was superior to malathion (0.1 and 0.2%). The present results are in agreement with the study conducted by Thakur (2011) [16], who reported that lambda-cyhalothrin (0.004%) was the most effective insecticide in checking fruit fly infestation in tomato, cucumber and peach crops and the Spinosad (0.002%) was the next best treatment in managing fruit fly infestation in fruit and vegetables crops. Abrol (2017) [1] also reported the efficacy of lambda-cyhalothrin (0.004%) in managing fruit fly, *Bactrocera* spp. in bottlegourd and bittergourd, which was followed by spinosad (0.002%) and deltamethrin (0.0028%) and supports the results obtained in the present study where lambda-cyhalothrin (0.004 and 0.008%) was the most effective treatment.

After 10 days of the second spray application, lambda-cyhalothrin at both the concentrations (0.004 and 0.008%) proved effective in fruit fly infestation. The fruit infestation recorded was 20.06 and 21.16 percent at higher concentration (0.008%) and 22.90 and 24.14 percent at lower concentration (0.004%) of lambda-cyhalothrin during both the years (Table 1). Whereas, the percent fruit infestation with lower and higher dose of lambda-cyhalothrin during both the years were at par with both the concentration of spinosad (0.002 and 0.004%), during 2014 and during, 2015, at par with higher concentration of (0.004%). During 2014, azadirachtin was found moderately efficacious with 36.38 and 30.72 percent infestation at 0.01 and 0.02 percent concentrations, respectively and was superior to malathion (0.1 and 0.2%) and during 2015, %) deltamethrin (0.0028 and 0.0056%), lower concentration (0.002%) of spinosad and higher concentration (0.02%) of azadirachtin were at par and proved to be next effective treatments. Khatun *et al*. (2016) [12] reported lambda cyhalothrin (0.005%) to be effective in managing *B. cucurbitae* infestation (17.23%) in bitter gourd. The results also find support from the study conducted by Sharma (2018) [14] evaluated biopesticides and for the management of fruit flies in mango and peach and reported spinosad (0.002%) to be most effective treatment. Similarly, Shivangi *et al.* (2017) [15] reported the module comprising of three spray application of spinosad to be most effective in checking fruit fly infestation in cucumber. These findings are in agreement with the study where the percent infestation recorded in spinosad (0.002 and 0.004%) was less in comparison to azadirachtin (0.01 and 0.02%). Hirekurubar *et al.* (2018) [10] evaluated insecticides and biopesticides against fruit fly *B. cucurbitae* infesting ridge gourd and reported spinosad and deltamethrin to be effective in checking fruit fly infestation.

The data were recorded 10 days after third spray application, a decreasing trend was recorded in fruit infestation in all the treatments. Lambda- cyhalothrin (0.008%) with 8.85 and 10.07 percent infestation during both the years, was most effective and at par with lower concentration (0.004%) of lambda-cyhalothrin with 9.11 and 11.71 percent fruit infestation during 2014 and 2015, respectively. Both the concentrations of lambda-cyhalothrin were at par with deltamethrin (0.0028 and 0.0056%) and spinosad (0.004%) concentrations during 2014 and during 2015, Lambda-cyhalothrin (0.008 and 0.004%) and spinosad (0.004%), treatments with 10.07, 11.71 and 13.74 per cent, infestation were at par and effective in managing fruit fly population. (Table 1). The trend also remained more or less the same in all the treatments. *B. bassiana* (1.0%) with fruit infestation 38.21 and 42.58 percent during 2014 and 2015, respectively was the least effective treatment, through being superior to control (78.08 and 79.44%) during both the years, respectively. Overall means were taken into consideration, lambda- cyhalothrin (0.008%) with 18.88 and 19.75 percent infestation during both the years, respectively was numerically the most effective treatment and was statistically at par with lower concentration (0.004%) of lambda-cyhalothrin with 20.49 and 22.00 percent infestation. Both the concentrations lambda- cyhalothrin were at par with spinosad (0.004%) with 22.53 percent fruit infestation during 2014.

Although during 2015, both the concentrations of spinosad (0.002 and 0.004%) with infestation 26.40 and 24.66 percent and deltamethrin (0.0028 and 0.0056%) with fruit infestation of 28.91 and 27.87 percent were statistically at par. Azadirachtin at higher concentration (0.02%) with a fruit infestation of 30.56 and 31.75 per cent, was superior over malathion (0.1 and 0.2%) concentration, in both the years 2014 and 2015 respectively. *B. bassiana* (1.0%) with 49.75

and 52.96 percent fruit infestation during 2014 and 2015, respectively was the least effective treatment. All the test treatments were superior to control (73.13 and 74.10%) during both the years. The results obtained are in line with present findings where, spinosad and deltamethrin were found effective in checking fruit fly infestation in tomato. Thakur and Gupta (2016) [17] conducted an experiment where different concentrations of azadirachtin (0.005%, 0.01% and 0.015%) and *B. bassiana* (Daman 1% WP 0.1%, 0.5% and 1%) were evaluated for oviposition deterrence against fruit fly, *B. tau* on cucumber. The results revealed, azadirachtin (0.015%) to be effective than *B. bassiana* (1%) and control, which is in line with the results obtained in the present study.

Table 1: Bio efficacy of insecticides and biopesticides against fruit fly, *Bactrocera* sp. infesting tomato during the year 2014 and 2015.

Treatment	Year 2014				Year 2015			
	Fruit Infestation (%) 10 days after			Mean	Fruit Infestation (%) 10 days after			Mean
	Spray 1	Spray2	Spray 3		Spray 1	Spray 2	Spray 3	
Lambda–cyhalothrin (0.004%)	30.17 (33.30)	24.1 (29.40)	11.71 (19.89)	22.00 (27.53)	30.17 (33.30)	24.14 (29.40)	11.71 (19.89)	22.00 (27.53)
Lambda–cyhalothrin (0.008%)	28.03 (31.85)	21.16 (27.35)	10.07 (18.48)	19.75 (25.89)	28.03 (31.85)	21.16 (27.35)	10.07 (18.48)	19.75 (25.89)
Deltamethrin (0.0028%)	38.72 (38.46)	30.34 (33.39)	17.68 (24.80)	28.91 (32.22)	38.72 (38.46)	30.34 (33.39)	17.68 (24.80)	28.91 (32.22)
Deltamethrin (0.0056%)	37.28 (37.61)	29.58 (32.93)	16.74 (24.13)	27.87 (31.56)	37.28 (37.61)	29.58 (32.93)	16.74 (24.13)	27.87 (31.56)
Spinosad (0.002%)	36.38 (37.08)	27.22 (31.42)	15.60 (23.15)	26.40 (30.55)	36.38 (37.08)	27.22 (31.42)	15.60 (23.15)	26.40 (30.55)
Spinosad (0.004%)	35.20 (36.32)	25.06 (30.00)	13.74 (21.73)	24.66 (29.35)	35.20 (36.32)	25.06 (30.00)	13.74 (21.73)	24.66 (29.35)
Malathion (0.1%)	51.49 (45.84)	43.68 (41.35)	31.40 (34.03)	42.19 (40.41)	51.49 (45.84)	43.68 (41.35)	31.40 (34.03)	42.19 (40.41)
Malathion (0.2%)	48.89 (44.35)	41.17 (39.88)	29.35 (32.78)	39.80 (39.00)	48.89 (44.35)	41.17 (39.88)	29.35 (32.78)	39.80 (39.00)
Azadirachtin (0.01%)	44.99 (42.11)	37.54 (37.77)	25.26 (30.15)	35.93 (63.68)	44.99 (42.11)	37.54 (37.77)	25.26 (30.15)	35.93 (63.68)
Azadirachtin (0.02%)	41.64 (40.17)	31.36 (34.04)	22.24 (28.12)	31.75 (34.11)	41.64 (40.17)	31.36 (34.04)	22.24 (28.12)	31.75 (34.11)
Beauveria bassiana (1.0%)	62.69 (52.45)	53.60 (47.05)	42.58 (40.71)	52.96 (46.74)	62.69 (52.45)	53.60 (47.05)	42.58 (40.71)	52.96 (46.74)
B. bassiana (2.0%)	60.17 (50.94)	48.04 (43.86)	41.39 (40.02)	49.87 (44.94)	60.17 (50.94)	48.04 (43.86)	41.39 (40.02)	49.87 (44.94)
Control (water)	68.55 (55.89)	74.30 (59.53)	79.44 (63.09)	74.10 (59.50)	68.55 (55.89)	74.30 (59.53)	79.44 (63.09)	74.10 (59.50)
Mean	44.94 (42.03)	37.48 (37.54)	27.48 (30.85)		44.94 (42.03)	37.48 (37.54)	27.48 (30.85)	
CD (0.05)	T=3.16 I= 1.52 TXI=5.47				T=2.31 I= 1.11 X=4.01			

*Figures in parentheses are arc sine transformed values; T: Treatment; I: Spray Interval; TXI: Interaction between Treatment and Spray Interval

Conclusion

Findings of the present study concluded that the foliar spray of lambda cyhalothrin (0.008%) resulted in minimum fruit fly infestation in tomato field followed by lower concentration of lambda cyhalothrin (0.004%) and spinosad (0.004%). Azadirachtin was found moderately effective in checking the infestation during both the years.

Therefore; various modules comprising of rotation of synthetic pyrethroids with Spinosad and azadirachtin can be evaluated further to achieve effective and ecologically sound fruit fly control.

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