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Bio-efficacy of insecticides against aphids (*Chaetosiphon fragaefolii*) on strawberry

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Abstract
Field experiments were carried out at Entomology Farm, SKUAST-J, Chatha for two consecutive years (2018 and 2019) to evaluate the bio-efficacy of selective insecticides against aphids on strawberry. The results of study revealed that during both the years, lowest mean aphid population was observed in Imidacloprid 17.8SL treated plots followed by Fipronil 5SC. Chlorpyriphos 20EC, Quinalphos 25EC and Dichlorvos 76EC offered moderate aphid control on strawberry wherein Chlorpyriphos 20EC and Quinalphos 25EC were at par with each other in reducing the aphid population. Neem oil behaved as least effective treatment in reducing aphid population and was found at par with control. Moreover, cost-benefit ratios were worked out to determine the most effective and economical treatment. The highest cost-benefit ratio was obtained in plots treated with Imidacloprid (1:19.67) and was closely followed by Fipronil (1:19.37) and Dichlorvos (1:18.69) treatments. The least cost benefit ratio was obtained with Neem oil (1:14.84) treated plots.

Keywords: *C. fragaefolii*, strawberry, insecticides, bio-efficacy, imidacloprid, neem oil

1. Introduction
Berry fruits like strawberry are now gaining momentum in our country as they constitute the important sources of bioactive compounds which enhance the nutritional values of human diet and improve the human health (Diamanti *et al*., 2012) [4]. Strawberries are one of the most popular, soft and luscious fruits cultivated throughout the world (Biswas *et al*., 2007) [1]. The cultivated strawberry (*Fragaria x ananassa* Duch.) are valued for its flavour, fragrance and richness in natural bioactive compounds, especially anthocyanins (Karaagac *et al*., 2019) [8]. It occupies a unique place among fruits and is most important soft fruit after grapes. As per Department of Horticulture, 174 hectares of land is under the cultivation of strawberries in J&K which gives a yearly produce of 388 metric tons fruit (Anonymous, 2013). In Jammu and Kashmir state, strawberry fruit production in general has made very rapid progress. It has recently come up as one of the most favoured and profitable fruits to be grown in Jammu region of Jammu and Kashmir state. However, strawberry yield and fruit quality is influenced by several factors such as soil, environmental factors, insects, pathogens, etc. Of the several factors which limit strawberry production, attack by a large number of insect-pests, particularly strawberry aphids, at different growth stages of the crop (Sridhar *et al*., 2001) [13] is of particular concern in its cultivation. The infestation by strawberry aphid, *C. fragaefolii* is a common phenomenon in strawberry cultivation and its continuous desapping leads to the development of sooty mould (*Capnodium* sp.) resulting into reduced photosynthesis, production, and fruit quality (Krczal, 1982; Rondon *et al*., 2005; Cedola and Greco, 2010) [9, 11, 2]. The strawberry aphid also causes indirect damage by transmitting viruses such as the *strawberry mild yellow edge virus*, *strawberry crinkle virus* and *strawberry mottle virus* (Krczal, 1982) [9]. Shankar and Abrol (2019) [12] highlighted the importance of strawberry crop and the management practices utilizing IPM methods to combat these important and major insect pests of strawberry. Keeping the importance of this fruit in view and the problem posed by strawberry aphids, the present study was conducted to evaluate the efficacy of selected insecticides against aphids on strawberry.

2. Materials and Methods
Field experiments were conducted for two consecutive years (2018 and 2019) at Entomology Farm, SKUAST-J, Chatha, J&K in randomized block design with seven treatments and three replications to determine the efficacy of insecticide against insect-pests infesting strawberry. The insecticides *viz*., Neem oil 1500ppm (3ml/l), Fipronil 5SC (1ml/l), Dichlorvos (1.5ml/l),

Chlorpyriphos (2ml/l), Imidacloprid 17.8SL (0.3 ml/l), Quinalphos 25EC (2ml/l) were sprayed as and when insect-pests population reached peak or ETL level. Observations on the number of insect-pests were recorded one day prior to the spray and three and ten days after the spray. Pre-treatment and post treatment counts on 5 randomly selected plants were taken. Number of fruits damaged by the total number of fruits were recorded from 100 fruits randomly selected from each plant after ten days of second spray and then fruit damage (%) were calculated. The yield was recorded on the net plot area basis which were converted to kg/ha for statistical analysis. The monetary returns and incremental cost-benefit ratios of treatments were assessed based on the yield and cost of plant protection.

2.1 Preparation of insecticidal solution

The spray solution for field application was put together by the following methods. In case of liquid formulations, the required quantity of insecticides was added in little quantity of water and stirred thoroughly. The remaining quantity of water was then put on slowly with constant stirring, to get the desired concentration of spray fluid. The amount of insecticides needed (ml or g) per litre of water was calculated by the following formula-

$$\text{Amount of insecticide (ml or g) per litre of water} = \frac{\text{Concentration required (\%)}}{\text{Percentactive ingredient}} \times 1000$$

2.2 Method of insecticidal solution application and timing

Two foliar sprays were included in the experiments. The first spray was done near the ETL level of the insect pest and the second spray of the insecticides was done at 15 days interval. Knapsack sprayer was used for the insecticidal solution spray. The spraying of the solution was done till the gentle run-off of droplets started from the leaves of the citrus trees, to ensure to complete covering of the foliage. The sprayer was cleaned well after spray of each insecticidal solution. The spray was done at evening time to ensure the minimum loss to the bee fauna of the place, with using the protective mask to avoid accidental inhaling of the insecticides.

2.3 Observation of data

Total two insecticidal applications were done during the year 2018 and 2019 after insect-pests reached ETL level. Pre count of the pest population was recorded one day prior to the spray. The population count after insecticidal spray was taken at 5 and 10 days in case of strawberry aphid. Percent reduction after single day was calculated using formula.

$$\text{Percent reduction} = \frac{\text{(Pre spray count-post spray count)}}{\text{(Pre spray count)}} \text{ x } 100$$

Final Insecticidal bio-efficacy was calculated using Henderson and Tilton formula.

$$\text{Corrected \%} = (1 -) \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}} \times 100$$

Where,
n = Insect population, T = treated, Co = control

The data collected was then subjected to the test of normal distribution (Kolmogorov-Smirnov test for normality). Then the values were subjected to the square root transformation and were statistically analyzed to obtain the value of the critical difference, so that Bio-efficacy of different insecticidal treatments can be accurately compared against targeted insect pest. Following ANOVA, differences between data sets were determined using least significant difference at P = 0.05 in all instances.

3. Result and Discussion

The data obtained on the bio-efficacy of insecticides against strawberry aphids during 2018 and 2019 has been presented in Table 1 and Table 2, respectively. The perusal of the data revealed that the lowest mean population of aphid (3.64 aphids/3 leaves/3 plants) was observed in Imidacloprid 17.8 SL @ 0.3 ml/L treated plots after both the sprays during 2018 experiments. It was followed by Fipronil 5 SC@ 1.0 ml/L (4.94 aphids/3leaves/3 plants). While rest of the treatments like Chlorpyriphos 20 EC @2.0 ml/L (6.22 aphids/3leaves/3 plants), Quinalphos 25 EC @2.0 ml/L (6.51 aphids/3leaves/3 plants) and Dichlorvos 76 EC @1.5 ml/L (9.90 aphids/3leaves/3 plants) offered moderate control of aphids on strawberry. Chlorpyriphos 20 EC and Quinalphos 25 EC was found at par with each other in terms of bio-efficacy in reducing the aphid population/3leaves/3 plants. Neem oil 1500 ppm @3.0 ml/L behaved as the least effective treatment in reducing the aphid populations (20.84 mean population of aphids) and was found at par with the control. Further, the data was subjected to Tukey HSD test for more precise result revealed that the per cent reduction of aphids by different treatments after two sprays was found to be superior in Imidacloprid 17.8 SL @ 0.3 ml/L treated plots (87.16 %) which was followed by Fipronil 5 SC@ 1.0 ml/L (83.02 %). The treatment Imidacloprid 17.8 SL was found significantly different from all other treatments in reducing the percentage aphid population over control. Again during 2019, the lowest mean population of aphids (5.44/3 leaves/3 plants) was observed in Imidacloprid 17.8 SL @ 0.3 ml/L treated plots after both the sprays. It was followed by Fipronil 5 SC@ 1.0 ml/L (6.18 aphids/3leaves/3 plants). While rest of the treatments like Quinalphos 25 EC @2.0 ml/L (8.04 aphids/3leaves/3 plants), Chlorpyriphos 20 EC @2.0 ml/L (8.70 aphids/3leaves/3 plants) and Dichlorvos 76 EC @1.5 ml/L (9.95 aphids/3leaves/3 plants) offered moderate control of aphids on strawberry. Chlorpyriphos 20 EC and Quinalphos 25 EC was found at par with each other in terms of reducing the aphid population/3leaves/3 plants. Neem oil 1500 ppm @3.0 ml/L behaved as the least effective treatment in reducing the aphid populations (28.42 mean population of aphids) and was found at par with the control. Further, Tukey HSD test revealed that the per cent reduction of aphids by different treatment after two sprays was found to be superior in Imidacloprid 17.8 SL @ 0.3 ml/L treated plots (88.26 %) which was followed by Fipronil 5 SC@ 1.0 ml/L (85.22 %). The treatment Imidacloprid 17.8 SL was found significantly different from all other treatments in reducing the percentage aphid population over control. Overall examination of the data showed that insecticides can provide immediate relief resulting in suppression of the insect pest population but simultaneously the activity of beneficial fauna along with natural enemies could be promising and an effective tool to manage the pest naturally. Kacharmazov (1976) [7] reported that systemic insecticides such as dimethoate (Bi-58), thiometon (Intration), pirimicarb (pirimor), or Endosulfan (thionex) should be sprayed on the plants 10-15 days after

transplanting to save the mother plants against the attack of aphid (*Chaetosiphon fragaefolii*) which is widespread in Bulgaria. Lowery *et al*. (1993) [10] reported that the sprays of Neem seed oil and Neem seed extracts to intact plants in the laboratory resulted in significant reductions in numbers of *C. fragaefolii*. Hughes *et al*. (1969) [6] reported that runners must be sprayed at least three sprays in mid to late May, June and early July for adequate protection from winged aphids which might be infected with virus. Graichen *et al*. (1980) [5] in Germany reported that the preventive measures are necessary to protect the crop from aphids by spraying the systemic insecticides like Bi 58EC (dimethoate) @ 0.075 once from mid-April to the beginning of May, again after harvest and finally from the end of September to mid-October. Moreover, Dara (2019) [3] focused on ecological aspects of pest management which includes the human, environmental, social, and economic factors. The adoption of pest management on berry fruits leads not only to the influence of the safer food production but also conserve the nutritional aspects of the luscious and delicious strawberry fruits.

Table 1: Evaluation of efficacy of selected insecticides against strawberry aphids during 2018

Tr. No.	Treatments	Dosage	Pre count (numbers per /3leaves/3 plants)	Post-treatment population of aphids (numbers per /3leaves/3 plants)				Mean	% Reduction over control
				Days after spraying					
				First spray*		Second spray*			
				5	10	5	10		
1	**Untreated (Control)**	-	24.00(4.90)	24.37(5.41)	28.25(2.58)	13.40(5.10)	18.76(5.50)	20.84	0.00
2	Neem oil 1500 ppm	3.0 ml/L	28.67(5.35)	24.37(4.94)	26.81(5.18)	13.40(3.66)	18.76(4.33)	20.84	28.90f
3	Fipronil 5SC	1.0 ml/L	26.55(5.15)	2.66(1.63)	4.75(2.18)	4.28(2.07)	8.08(2.84)	4.94	83.02b
4	Dichlorvos 76 EC	1.5 ml/L	27.88(5.28)	5.58(2.36)	9.48(3.08)	9.47(3.08)	15.07(3.88)	9.90	65.93e
5	Chlorpyriphos 20 EC	2.0 ml/L	28.56(5.34)	3.71(1.93)	5.57(2.36)	9.47(1.81)	6.13(2.48)	6.22	78.22c
6	Imidacloprid 17.8 SL	0.3 ml/L	25.99(5.10)	1.82(1.35)	3.64(1.91)	3.27(2.44)	5.82(2.41)	3.64	87.16a
7	Quinalphos 25 EC	2.0 ml/L	26.85(5.18)	3.49(1.87)	6.63(2.58)	5.97(5.10)	9.95(3.15)	6.51	78.02cd
SEm ±			0.26	0.18	0.24	0.26	0.26	0.19	-
CD at 5 %			NS	0.53	0.74	0.79	0.77	0.58	-

*Mean of three replications,
Figures in parentheses are square root of √ x+ 0.5

Table 2: Evaluation of efficacy of selected insecticides against strawberry aphids during 2019

Tr. No.	Treatments	Dosage	Pre count (numbers /3leaves/3 plants)	Post-treatment population of aphids (numbers per /3leaves/3 plants)				Mean	% Reduction over control
				Days after spraying					
				First spray*		Second spray*			
				5	10	5	10		
1	**Untreated (Control)**	-	23.0(4.80)	29.25 (5.41)	28.25(5.32)	26.00(5.10)	30.20(5.50)	28.42	0.00
2	Neem oil 1500 ppm	3.0 ml/L	24.60(4.95)	12.28(3.50)	23.32(4.83)	27.99(5.29)	27.75(5.27)	22.84	29.22f
3	Fipronil 5SC	1.0 ml/L	25.70(5.07)	3.85(1.96)	4.97(2.23)	5.96(2.44)	9.93(3.15)	6.18	85.22b
4	Dichlorvos 76 EC	1.5 ml/L	23.70(4.86)	4.73(2.17)	8.99(3.00)	8.09(2.84)	17.97(4.24)	9.95	63.28e
5	Chlorpyriphos 20 EC	2.0 ml/L	24.30(4.93)	4.87(2.21)	7.30(2.70)	8.76(2.96)	13.87(3.72)	8.70	77.58c
6	Imidacloprid 17.8 SL	0.3 ml/L	25.70(5.07)	3.85(1.96)	5.77(2.40)	3.46(1.86)	8.66(2.94)	5.44	88.26a
7	Quinalphos 25 EC	2.0 ml/L	22.10(4.70)	4.42(2.10)	8.41)(2.90)	5.88(2.43)	13.45(3.67)	8.04	76.15cd
SEm ±			0.25	0.20	0.27	0.25	0.28	0.22	-
CD at 5 %			NS	0.62	0.83	0.75	0.85	0.66	-

*Mean of three replications ,
Figures in parentheses are square root of √ x+ 0.5
Table 3: Cost- Benefit ration and Net Income of different treatments on strawberry during 2018

Treatments	Dosage	Fruit yields (q/ha)	Cost of insecticidal sprays/ha+labour charges (Rs. /ha)	Amount realized from the market rate of strawberry fruits (Rs.)	Net Profit (Rs. /ha)	Cost-Benefit Ratio
Neem oil 1500 ppm	3.0 ml/L	21.54	1480.00	25848.00	24268.00	1:14.84
Fipronil 5SC	1.0 ml/L	23.65	2520.00	28384.00	25864.00	1:19.37
Dichlorvos 76 EC	1.5 ml/L	22.86	2100.00	27428.00	25328.00	1:18.69
Chlorpyriphos 20 EC	2.0 ml/L	23.17	2400.00	27808.00	25408.00	1:17.93
Imidacloprid 17.8 SL	0.3 ml/L	24.18	2800.00	29012.00	26212.00	1:19.67
Quinalphos 25 EC	2.0 ml/L	22.38	2250.00	26856.00	24806.00	1:16.35
Control	-	19.59	-	23504.00	23504.00	-

Table 4: Cost- Benefit ration and Net Income of different treatments on strawberry during 2019

Treatments	Dosage	Fruit yields (q/ha)	Cost of insecticidal sprays/ha+labour charges (Rs. /ha)	Amount realized from the market rate of strawberry fruits (Rs.)	Net Income (Rs. /ha)	Cost-Benefit Ratio
Neem oil 1500 ppm	3.0 ml/L	20.75	1550.00	24896.00	23346.00	1:11.30
Fipronil 5SC	1.0 ml/L	23.23	2520.00	27872.00	25352.00	1:18.76
Dichlorvos 76 EC	1.5 ml/L	22.23	2100.00	26680.00	24580.00	1:16.84
Chlorpyriphos 20 EC	2.0 ml/L	22.32	2400.00	26780.00	24380.00	1:15.15
Imidacloprid 17.8 SL	0.3 ml/L	23.97	2750.00	28768.00	26018.00	1:20.45

Quinalphos 25 EC	2.0 ml/L	21.80	2250.00	26164.00	23914.00	1:13.42
Control	-	19.29	-	23144.00	23144.00	-

3.1 Estimation of Cost-Benefit Ratio

Table 3 and Table 4 represents the comparative economics of different insecticidal treatments used for Strawberry aphid control during 2018 to 2019. For determining the most effective and economical treatment the cost-benefit ratios were worked out. The data presented in Table 3 revealed that the maximum net profit of Rs. 26212.00 per hectare was obtained in plots receiving Imidacloprid 17.8 SL treatment and was followed by Fipronil 5SC, Chlorpyriphos 20 EC and Dichlorvos 76 EC which gave net profit of Rs. 25864.00, 25408.00 and 25408.00 per hectare, respectively during 2018. The treatment of Neem oil 1500 ppm (Rs. 24268.00/ha) was found to be lowest economical in respect of net profit returns. The highest cost-benefit ratio was obtained in plots receiving with Imidacloprid (1:19.67) and was closely followed by Fipronil (1:19.37) and Dichlorvos (1:18.69) treatments. The cost benefit ratio was least with Neem oil (1:14.84) treated plots due to their efficacy in terms of mortality as compared to safer insecticides. With Chlorpyriphos (1:17.93) and Quinalphos (1:16.35) the cost-benefit ratios were observed to be moderate. Similar results in terms of net profit and cost-benefit ratios were also observed with the test insecticides on strawberry during 2019 (Table 4). The respective net profit in terms of rupees per hectare during 2019 was maximum with Imidacloprid (Rs. 26018.00) followed by Fipronil (Rs. 25352.00), and Dichlorvos (Rs. 24580.00). The cost-benefit ratios among various insecticidal treatments varied between 1:20.45 and 1:11.30 during 2019, maximum being observed with Imidacloprid which was followed by Fipronil treatment. Again, high cost-benefit ratio with Imidacloprid and low ratio with Neem oil treatments observed.

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