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Hormoligosis Evaluation and Efficacy of Fenoxycarb on the Cotton Mealybug (*Phenacoccus solenopsis*)

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HIGHLIGHTS

- This manuscript highlights the application of fenoxycarb for the effective control of cotton mealybug.
- Use of sub-lethal dosage to evaluate the resistance development of insecticide.
- These results can be helpful for the dose selection during control in the fields, so that resistance can be reduced against pesticides.

Abstract: Sublethal dilutions exhibited hormoligosis when they were exposed to the different levels of pesticides. The present study was designed to check the efficacy and hormoligosis of fenoxycarb on four generations of cotton mealybug. The experiment was performed in the laboratory conditions at department of Entomology, University of Agriculture, Faisalabad. After 3 days, treatments showed statistically considerable differences ($P < 0.05$) and maximum mortality was recorded at the highest dose level of fenoxycarb. After 7 days, the treatments had significant differences ($P < 0.05$). The greater mortality (89.02%), fecundity (143.66%) and longevity (39.62%) was recorded at a concentration of fenoxycarb 2.4%. Laboratory bioassay showed that after 3 days of experiment, fenoxycarb was less effective at concentration LC_{10} (0.17 ppm) (0.03-0.36), while after 7-days result was LC_{10} (0.08 ppm) (0.05-0.12). The 1st instar showed maximum mortality at the concentration (LC_{50} = 10.02%). The maximum fecundity and longevity were found in control. The sex ratio was higher in control while the minimum at (LC_{10} = 0.17%). At 3 days, hormoligosis was observed in fecundity at LC_{10} (0.17%) in G1 (52.28) and in G4 (58.27) while LC_{50} (10.02%) in G1 (37.84) and G4 (42.73). At 7 days PAI of LC_{10} (0.01%) in G1 (58.61) and in G4 (63.50) while LC_{50} (0.39%) in G1

(37.67) and in G4 (44.89). The management of the insect pest in the cotton crop depends mainly on how we are using these chemicals.

Keywords: Insecticide; Impact; Cotton; Pest; Management.

INTRODUCTION

Cotton harvest is harmed by many sucking and bollworms insects, and inappropriate administration of these pests has increased their population. *Phenacoccus solenopsis* (Cotton mealybug) is found all over the world, first time reported in Pakistan in the year 2005 [1] from China in 2004 [2], and from India in 2007 [3], on the cotton crop that damaged different crops and plants. Cotton mealybug was confirmed in Pakistan to trigger 12 to 35% losses [1] and in North India's (10 to 60%) [4]. The mealybug of cotton is destructive pest of cotton, vegetables and ornamental plants worldwide. *P. solenopsis* has the capability of resistance development against several chemical classes of insecticides [5]. If preventive measures are not taken, then a lot of cotton yield loss occurs. In ancient times several insecticides were used to control the invasion of cotton mealybug but now resistance has developed against many insecticides [6]. Because there is no established integrated pest control strategy, new insecticidal classes are used haphazardly. In general, the development of pesticide resistance in a region is dependent on the widespread use of insecticides [7]. As a result of the application of conventional pesticides in agro ecosystem for the control of sucking pest complexity, their respective predators and parasitoids are also suppressed [8].

This pest is present in hidden spots like galls and grass sheaths and damaged crop plants by secreting meal secretions [9]. The cell sap is sucked from numerous plant areas, such as the leaves, roots, main stems, and fruiting bodies, both by adults and nymphs. Plants exhibit inhibition after swallowing sap and a get bushy look on their shooting tips which trigger huge losses for farmers. A major decrease in cotton yield is caused by cotton mealybug infestation ultimately huge loss occurs in terms of economic [3]. Cotton is essential non-nutritional crops and a big source of external professional income. *Gossypium hirsutum* characterizes 7.5% of the worth of horticulture and around 1.6% to grand domestic power. The crop was planted in the region of 3054 thousand hectares, 0.6% exactly a year ago (3072 thousand hectares). The generation is assessed at 11.7 million bunches for 2007-08, fewer with 9.3 percent in the course of the most recent day's creation of 12.9 million bundles [10].

Insecticides from various classes has been used for the management of several cotton pests such as *H. armigera*, *B. tabaci*, *S. litura*, and *T. tabaci* [11–13] and cotton mealy bug (*P. solenopsis*) [14] in cotton growing areas of Pakistan. Due to the repeated use of Insecticides, resistance has been developed against many insecticides. Therefore, the resulting susceptibility is attributed with respect to frequent doses of insecticides which is known as hormoligosis. It is a dose-reaction relationship divided into minor and major insecticide dose selection [15,16]. The group of insecticides considered bio-rational and efficient at lethal and sublethal levels are called insect growth regulators. Aspects of their action as biorational pesticides include disruption of hormonal regulation in certain insects that eventually results in improper molting, growth, and development. They are employed to manage a wide range of insect species by acting as juvenile hormone mimics, ecdysone agonists, and chitin formation inhibitors, among other things [8]. All these pesticides are used on physiological parameters of exposed treatments for reasonable results [17]. These fluctuations are egg size and hatching [18], pupil and larval weight [19], pupal ratio and adult development [18], developmental time and fecundity [20], adult endurance [21,22], and other parameters of insects biology [23]. Fenoxycarb is used for rice moth reproductive and metamorphosis [24], lacewing stages [25], physiological or behavioral moth activity [22] and various life stages of cotton mealybug [26]. Keeping in view the infestation of cotton mealybug and their chemical control measurements, this experiment was carried out to evaluate sublethal doses and hormoligosis of fenoxycarb on *P. solenopsis* under laboratory conditions. This study reveals the experimentation and findings which are baseline for the control strategies of cotton pest using the sub-lethal doses, which can be helpful in the over exposure of chemicals to nature and resistance control of cotton mealybug.

MATERIALS AND METHODS

Insecticide

A commercial formulation of insecticides has been used during the experiment. The pesticide's hormoligosis was assessed against *P. solenopsis* using different dosage levels of fenoxycarb for analysis.

Rearing of cotton mealybug

Before the collection of the of insects, pest populations were checked two times a week to observe the status of pest in the crop [27]. Cotton mealybug along with infected branches were sampled from the non-sprayed cotton plant. These insects were placed in jars under laboratory conditions for mass production, containing pumpkins as food. Mature mealybugs were taken and transformed into other jars containing healthy food [10].

Solutions preparation of insecticide

The solutions of the recommended dose of insecticide were prepared in acetone according to the recommendation of WHO [28]. Five concentrations of insecticide fenoxycarb were prepared. These five solutions (Table 1) were prepared with a stock solution of desired concentration. Successive solutions shall be made by this method.

Table 1. Concentrations of insecticides test in the present experiment.

Trade Name	Active Ingredient	Formulation	Company	Concentrations
Swift	Fenoxycarb	6.9 EW	Orange protection Pvt. Ltd 23-A, Wahdat road, Muslim Town, Lahore Pakistan.	0.15%,0.3%, 0.6%, 1.2%, 2.4%

Layout of Experiment-I

Pumpkin was taken into the laboratory, rinsed with water, and kept for full water evaporation. This was done to free the pumpkin from all contaminants. The insecticides test dilutions were sprayed onto the contamination-free pumpkin and stored on filter paper for drying. An experimental unit was developed and treated one pumpkin with their respective insecticide solutions. Twenty individuals were taken from culture of adult *P. solenopsis* and shifted for insecticides treatment with camel's hairbrush. The insects were fed with the pumpkin exposed to Fenoxycarb.

The *P. solenopsis* adults that were treated with insecticide were placed in petri-plates and closely monitored under light microscope. The individuals showed no reaction with their slight touch were considered dead. The experiment was performed up to the four generations of Data on the mortality rate of *P. solenopsis* females were obtained at 3 and 7 days. Each treatment was carried out three times. Data obtained on dead insects has translated into the Abbott formula for percentage corrected mortality. The mortality results were analyzed for the sublethal doses by Probit analysis [29] (LC_{10}, LC_{20}, LC_{30}, LC_{40}, and LC_{50}).

Layout of Experiment-II

In the second trial, all nymphs and adult females were collected from susceptible cotton mealybug production and treated with sublethal doses ($LC_{10,}$ $LC_{20,}$ $LC_{30,}$ $LC_{40,}$ and LC_{50}) of each insecticide for three days. These were reared on untreated pumpkins. Data were obtained on various parameters, including longevity, fecundity, mortality, and sex ratio. This approach has treated each insecticide's sublethal dose for four consecutive generations of the insecticide-exposed population of surviving *P. solenopsis*. Data was also be collected from similar parameters.

Statistical Analysis

The collected data were analyzed statistically using one-way ANOVA. The pairwise comparison was made using HSD (Tuckey’s test). The Minitab version 17 was used to analyze data at the probability (α = 0.05).

RESULTS

Experiment 01

Percent mortality of adult female of cotton mealybug at different dilution of fenoxycarb after 3 and 7 days of post-treatments

The cotton mealy bug after 3 days, treatments showed statistically considerable with differences (df = 4; F value = 5572; P value = 0.001) at probability level of 0.05% (Table 2). Higher mortality was recorded at highest dose level of fenoxycarb 2.4% (35.13%) followed by 1.2% (30.09%), 0.6% (21.06%), 0.3% (17.65%), 0.15% (11.35%) respectively (Table 3). After 7 days, data exposed that treatments had statistically considerable with differences (df = 4; F value = 312502; P value = 0.001) at probability level of 0.05% (Table 2). The greater mortality was recorded at maximum level of fenoxycarb 2.4% (89.02%) followed by 1.2% (73.74%), 0.6% (61.69%), 0.3% (56.62%), 0.15% (45.81%) respectively (Table 3).

Table 2. Analysis of Variance parameters of percent mortality at different fenoxycarb concentrations after 3 and 7 days.

	SOV	DF	SS	MSS	F	P
3 days	**Treatment**	4	1811.03	362.205	5572	0.001
	Error	12	0.78	0.065		
	Total	16	1811.81			
7 days	**Treatment**	4	11284.8	2256.96	312502	0.001
	Error	12	0.1	0.01		
	Total	16	11284.9			

Table 3. Means mortality of cotton mealybug at different concentrations of fenoxycarb after 3 and 7 days

Concentration (%)	3 days	7 days
	Mean ± S. E	
0.15	11.35 ± 0.20^{E}	45.81 ± 0.06^{E}
0.3	17.65 ± 0.38^{D}	56.62 ± 0.19^{D}
0.6	21.06 ± 0.59^{C}	61.69 ± 0.37^{C}
1.2	30.09 ± 0.34^{B}	73.74 ± 0.25^{B}
2.4	35.13 ± 0.61^{A}	89.02 ± 0.49^{A}
Control	6.15 ± 0.70^{F}	8.88 ± 0.57^{F}

All means are significantly different from one another.

Fecundity and longevity of mealybug at various levels of fenoxycarb

The maximum fecundity was documented at greater level of fenoxycarb 2.4% (143.66%) followed by 1.2% (137.58%), 0.6% (129.47%), 0.3% (117.38%), 0.15% (109.28%) respectively. Maximum longevity was observed at maximum level of fenoxycarb 2.4% (39.62%) followed by 1.2% (31.54%), 0.6% (25.68%), 0.3% (21.37%), 0.15% (17.46%) respectively (Table 4). Laboratory bioassay revealed that after 3 days of experiment with the pesticide, fenoxycarb was less effective at LC_{10} (0.17 ppm) (0.03-0.36). While after 7-day experiment, it was more efficient at LC_{10} (0.08 ppm) (0.05-0.12). It was the most effective after the 7-day exposure due to the lowest LC_{20} (0.03 ppm) (0.01-0.07) (Table 5).

Table 4. Means comparisons for the fecundity of *P. solenopsis* at different levels of fenoxycarb application.

Concentration (%)	Fecundity	Longevity
	Mean ± S. E	
0.15	109.28 ± 1.08^{F}	17.46 ± 1.08^{E}
0.3	117.38 ± 1.38^{E}	21.37 ± 1.23^{D}
0.6	129.47 ± 1.49^{D}	25.68 ± 1.35^{C}
1.2	137.58 ± 1.54^{C}	31.54 ± 1.49^{B}
2.4	143.66 ± 0.61^{B}	39.62 ± 1.57^{A}
Control	151.72 ± 0.69^{A}	42.08 ± 1.65^{A}

Table 5. LC_{10}, LC_{20}, LC_{30}, LC_{40}, and LC_{50} values of pesticide fenoxycarb after 3 and 7 days of exposure

Treatment	Days	(ppm)	FD limit	Slope ± S.E	x^2
LC_{10}	3	0.17	0.03-0.36	0.38±0.09	0.74
	7	0.08	0.05-0.12	0.55±0.07	1.44
LC_{20}	3	0.88	0.47-1.31	0.38±0.09	0.74
	7	0.03	0.01-0.07	0.55±0.07	1.44
LC_{30}	3	2.40	1.61-4.48	0.38±0.09	0.74
	7	0.09	0.03-0.16	0.55±0.07	1.44
LC_{40}	3	5.19	3.11-15.32	0.38±0.09	0.74
	7	0.20	0.09-0.31	0.55±0.07	1.44
LC_{50}	3	10.02	5.13-46.23	0.38±0.09	0.74
	7	0.39	0.24-0.54	0.55±0.07	1.44

Experiment 02

1^st^ Generation

The findings demonstrated that mortality depends on concentration; after 3 days of 1st instar, mortality was maximum (44.08%) accordingly with the higher concentration (LC_{50} = 10.02%) and less at (LC_{10} = 0.17%) respectively while no mortality was observed in the control group. Maximum fecundity and longevity were higher (94.34 crawlers/female) and (48.74 days), respectively. The sex ratio was estimated higher (2.99) in the control group and the least (2.28) was observed at (LC_{50} = 10.02%). After 7 days, 1st instar mortality (78.13%) was found maximum at concentration (LC_{50} = 0.39%). The same inline results were observed on adult females' percent mortality (68.52%), at (LC_{50} = 0.39%). Maximum fecundity was (88.58 crawlers/female) in control group. The higher longevity was (37.94 days) in control, whereas least (24.65 days) was at (LC_{50} = 0.39%). The sex ratio was (2.05) in control (Table 6).

2nd Generation

After 3 days of 1st instar, mortality was maximum (47.19%) at higher levels (LC_{50} = 10.02%). Maximum fecundity was significantly higher (85.19 crawlers/female) in control and minimum fecundity (33.24 crawlers/female) was noted at the concentration (LC_{50} = 10.02%). The sex ratio was higher (2.65) in non-treated group. After 7 days of 1st instar maximum mortality (82.47%) was at (LC_{50} = 0.39%). Maximum fecundity (80.31 crawlers/female) was recorded in control, while minimum fecundity (33.45 crawlers/female) was observed at higher concentration (LC_{50} = 0.39%). Maximum longevity (32.91 days) was recorded in control. The sex ratio was maximum (1.58) in control group (Table 6).

3rd Generation

After 3 days, 1st instar showed maximum mortality (38.71%) at concentration (LC_{50} = 10.02%). The same results were observed for adults (28.29%) at higher concentrations (LC_{50} = 10.02%). Maximum fecundity (96.71 crawlers/female) and longevity (55.63 days) was observed in the control. The sex ratio was higher (2.69) in control while the minimum sex ratio (2.46) was observed at (LC_{10} = 0.17%). After 7 days, 1st instar showed maximum mortality (68.32%) at concentration (LC_{50} = 0.39%). A similar trend was observed for adult mortality (63.07%) at concentrations (LC_{50} = 0.39%). Maximum fecundity was significantly higher (90.11 crawlers/female) in control, followed by (63.41 crawlers/female) while least fecundity (43.88 crawlers/female) was showed at (LC_{50} = 0.39%). Maximum longevity was maximum (46.21 days) and sex ratio was highest (1.81) in the control group (Table 7).

4th Generation

After 3 days, 1st instar of *P. solenopsis* showed maximum mortality (38.01%) at higher concentration (LC_{50} = 10.02%) and minimum at (LC_{10} = 0.17%). Maximum fecundity was maximum (94.53 crawlers/female) in control. The maximum longevity was (54.72 days) in control while minimum longevity (37.83 days) was observed at a higher concentration (LC_{50} = 10.02%). The sex ratio was higher (2.75) in control. After 7 days, maximum mortality (67.59%) was observed at the dose level (LC_{50} = 0.39%). The fecundity was maximum (91.21 crawlers/female) in control group, while least fecundity (44.89 crawlers/female) was observed at a higher concentration (LC_{50} = 0.39%). The sex ratio was higher (2.19) in control, while the minimum sex ratio (1.33) was observed at (LC_{10} = 0.01%) (Table 7).

Mortality, fecundity, and longevity of cotton mealybug treated with fenoxycarb and at 3 and 7 days

The 1st instar and adult of cotton mealybug were found to decline after generations at sub-lethal dilutions that exposed the resistance of development from G1 to G4 after 3 days and maximum after 7 days of interval (Table 8). At 3 days, hormoligosis was observed in fecundity at LC_{10} (0.17%) in G1 (52.28) and in G4 (58.27) while LC_{50} (10.02%) in G1 (37.84) and G4 (42.73). At 7 days PAI of LC_{10} (0.01%) in G1 (58.61) and in G4 (63.50) while LC_{50} (0.39%) in G1 (37.67) and in G4 (44.89). At 3 days PAI, swift® hormoligosis was observed in longevity at LC_{10} (0.17%) in G1 (43.57) and G4 (48.19) while LC_{50} (10.02%) in G1 (32.58) and G4 (27.83). At 7 days PAI of LC_{10} (0.01%) in G1 (37.78) and in G4 (43.29) while LC_{50} (0.39%) in G1 (24.65) and in G4 (28.43) (Table 9).

Table 6. Means of different concentration of fenoxycarb (Swift® 6.9 EW) on mortality, longevity, fecundity, and sex ratio) after 3rd and 7th days of 1st and 2nd generation

LC values	1st generation					2nd generation				
	Percent Mortality		Fecundity (Crawlers/ female)	Longevity (Days)	Sex ratio	Percent Mortality		Fecundity (Crawlers/ female)	Longevity (Days)	Sex ratio
	1st Instar	Adult female				1st Instar	Adult female			
3 days										
LC_{50} = (10.02%)	44.08 ± 1.34^{A}	35.24 ± 1.54^{A}	37.84 ± 1.74^{E}	32.58 ± 2.44^{D}	2.28 ± 0.66^{E}	47.19 ± 0.74^{A}	38.79 ± 0.94^{A}	33.24 ± 0.91^{E}	23.35 ± 1.84^{E}	2.61± 1.13^{A}
LC_{40} = (5.19%)	40.19 ± 0.47^{B}	32.20 ± 0.67^{B}	39.73± 1.37^{E}	35.23 ± 1.57^{D}	2.39 ± 1.35^{D}	45.31 ± 1.88^{A}	36.50 ± 2.47^{A}	37.39± 1.35^{D}	26.48 ± 2.17^{D}	2.59± 1.17^{E}
LC_{30} = (2.40%)	36.58 ± 2.62^{C}	28.17± 2.72^{C}	43.40± 1.62^{D}	38.94 ± 1.12^{C}	2.44 ± 2.76^{C}	41.69± 2.55^{B}	31.41± 1.52^{B}	41.73± 1.62^{C}	29.40± 1.52^{CD}	2.56± 1.12^{B}
LC_{20} = (0.88%)	33.50 ± 0.76^{D}	24.61± 1.83^{D}	49.24± 0.77^{C}	41.39 ± 0.73^{BC}	2.59 ± 2.55^{B}	39.31 ± 1.46^{B}	28.71 ± 2.46^{C}	44.57± 2.43^{C}	31.83 ± 2.32^{BC}	2.54± 1.25^{D}
LC_{10} = (0.17%)	30.94 ± 1.87^{D}	21.50 ± 0.99^{E}	52.28 ± 0.87^{B}	43.57 ± 0.89^{B}	2.73 ± 1.88^{A}	37.41 ± 0.99^{C}	26.30 ± 1.33^{C}	48.31 ± 1.82^{B}	33.24 ± 0.89^{B}	2.47± 0.86^{C}
Control	0.0	0.00	94.34 ± 2.39^{A}	48.73 ± 1.59^{A}	2.99 ± 2.45^{F}	0.0	0.00	85.19 ± 0.96^{A}	43.61 ± 1.36^{A}	2.65± 1.33^{F}
7 days										
LC_{50} = (0.39%)	78.13 ± 2.24^{A}	68.52 ± 0.94^{A}	37.67 ± 1.24^{F}	24.65 ± 2.14^{E}	1.24 ± 1.09^{E}	82.47 ± 2.11^{A}	73.79 ± 1.55^{A}	33.45 ± 0.99^{F}	17.94 ± 1.44^{C}	1.56± 0.66^{A}
LC_{40} = (0.20%)	73.51 ± 1.57^{B}	61.73 ± 1.87^{B}	43.48 ± 0.77^{E}	27.69 ± 1.37^{D}	1.30 ± 1.77^{D}	78.15 ± 1.07^{B}	69.67 ± 2.59^{B}	37.47 ± 0.77^{E}	20.89 ± 0.97^{C}	1.55± 0.78^{E}
LC_{30} = (0.09%)	69.11 ± 1.64^{C}	56.44 ± 2.32^{C}	49.80 ± 2.62^{D}	30.87 ± 1.52^{C}	1.46 ± 0.88^{B}	73.25± 2.32^{C}	63.63± 1.68^{C}	42.19± 1.52^{D}	24.78± 1.65^{B}	1.53± 0.98^{B}
LC_{20} = (0.03%)	65.85 ± 0.88^{D}	51.62 ± 0.79^{D}	53.73 ± 0.93^{C}	34.53 ± 0.73^{B}	1.53 ± 2.22^{A}	69.44 ± 1.33^{D}	58.33 ± 2.43^{D}	49.68 ± 1.73^{C}	27.28 ± 2.53^{B}	1.49± 1.47^{C}
LC_{10} = (0.01%)	61.94 ± 1.89^{E}	48.41 ± 1.99^{E}	58.61 ± 2.59^{B}	37.78 ± 1.69^{A}	1.59 ± 0.76^{A}	67.30 ± 0.89^{D}	53.67 ± 0.98^{E}	53.30 ± 2.29^{B}	32.52 ± 1.39^{A}	1.46± 1.19^{D}
Control	0.00	0.00	88.58 ± 2.49^{A}	37.94 ± 0.79^{A}	2.05 ± 1.88^{F}	0.00	0.00	80.31 ± 1.49^{A}	32.91 ± 0.89^{A}	1.58± 1.68^{F}

Table 7. Means of different concentrations of fenoxycarb (Swift® 6.9 EW) on the mortality, longevity, fecundity, and sex ratio of after 3rd and 7th days in 3rd and 4th generation

LC values	3rd generation: Percent Mortality 1st Instar	Adult female	Fecundity (Crawlers/ female)	Longevity (Days)	Sex ratio	4th generation: Percent Mortality 1st Instar	Adult female	Fecundity (Crawlers/ female)	Longevity (Days)	Sex ratio
3 days										
LC_{50} = (10.02%)	38.71 ± 1.11^{A}	28.29 ± 1.33^{A}	42.68 ± 0.89^{E}	37.79 ± 1.55^{E}	2.66± 1.13^{A}	39.01 ± 2.26^{A}	27.29 ± 2.13^{A}	42.23 ± 1.56^{F}	37.31 ± 0.99^{D}	2.68 ± 1.78^{A}
LC_{40} = (5.19%)	36.50 ± 0.71^{A}	25.17 ± 0.93^{B}	46.60 ± 1.77^{D}	39.70 ± 2.43^{DE}	2.58± 1.17^{B}	37.41±1.33^{AB}	24.08 ± 1.44^{B}	45.42 ± 0.97^{E}	39.43 ± 1.13^{CD}	2.63 ± 2.55^{C}
LC_{30} = (2.40%)	33.41 ± 1.55^{B}	22.87 ± 2.12^{C}	49.49 ± 1.68^{D}	41.58 ± 0.99^{CD}	2.54± 1.12^{C}	34.50 ± 2.44^{B}	21.49 ± 2.22^{B}	50.31 ± 2.33^{D}	42.22± 0.78^{C}	2.57± 2.26^{D}
LC_{20} = (0.88%)	30.28 ± 0.88^{C}	19.49±1.33^{CD}	54.30 ± 2.52^{C}	44.49 ± 1.42^{BC}	2.51± 1.25^{D}	29.19 ± 1.42^{C}	18.31 ± 1.34^{C}	53.39 ± 1.87^{C}	45.30 ± 1.38^{B}	2.51± 1.15^{E}
LC_{10} = (0.17%)	27.09 ± 2.15^{D}	17.38 ± 0.99^{D}	58.17 ± 1.69^{B}	47.28 ± 0.89^{B}	2.43± 0.86^{E}	26.27 ± 0.98^{C}	16.20 ± 0.88^{C}	57.08 ± 2.48^{B}	48.19 ± 1.11^{B}	2.42± 0.86^{B}
Control	0.0	0.00	96.71 ± 2.23^{A}	55.63 ± 2.33^{A}	2.69± 1.33^{F}	0.00	0.00	94.53 ± 0.96^{A}	54.72 ± 2.19^{A}	2.75± 1.35^{F}
7 days										
LC_{50} = (0.39%)	68.32 ± 0.99^{A}	63.07 ± 0.89^{A}	43.88 ± 0.96^{F}	27.70 ± 2.48^{D}	1.59± 0.66^{A}	67.59 ± 2.68^{A}	63.29 ± 2.44^{A}	44.89 ± 2.44^{F}	28.43 ± 1.65^{E}	1.57 ± 0.96^{A}
LC_{40} = (0.20%)	65.23 ± 2.13^{B}	58.78 ± 0.73^{B}	48.60 ± 1.43^{E}	31.59 ± 1.67^{C}	1.55± 0.78^{B}	64.68±1.88^{AB}	57.24 ± 1.57^{B}	49.52 ± 0.57^{E}	32.32 ± 0.99^{D}	1.52 ± 2.22^{B}
LC_{30} = (0.09%)	61.51 ± 1.56^{C}	52.57 ± 0.62^{C}	53.83 ± 2.26^{D}	35.48 ± 0.88^{B}	1.51± 0.98^{C}	62.50 ± 2.83^{B}	51.12 ± 2.62^{C}	54.74 ± 1.62^{D}	36.21 ± 2.53^{C}	1.47 ± 0.88^{C}
LC_{20} = (0.03%)	58.27 ± 2.23^{D}	47.50 ± 0.57^{D}	59.32 ± 1.56^{C}	40.37 ± 2.39^{A}	1.44± 1.47^{D}	57.09 ± 1.82^{C}	46.41 ± 1.73^{D}	58.59 ± 0.73^{C}	39.11± 1.46^{BC}	1.40 ± 1.77^{D}
LC_{10} = (0.01%)	53.19 ± 0.77^{E}	42.73 ± 0.95^{E}	63.41 ± 1.01^{B}	43.18 ± 1.37^{A}	1.39± 1.19^{E}	52.28 ± 0.97^{D}	43.62 ± 0.89^{D}	62.50 ± 0.89^{B}	42.29 ± 0.77^{B}	1.33± 1.59^{E}
Control	0.00	0.00	90.11 ± 0.89^{A}	46.21 ± 0.39^{A}	1.81± 1.68^{F}	0.00	0.00	88.11 ± 0.79^{A}	49.21 ± 0.48^{A}	1.79± 1.28^{F}

Table 8. Hormoligosis of 1st instar and adult of female cotton mealybug treated by fenoxycarb at 3rd and 7th days

Pesticide					Fenoxycarb (swift® 6.9 EW)				
					Mortality (1st instar)				
LC at 3 days	**G1**	**G2**	**G3**	**G4**	**LC at 7 days**	**G1**	**G2**	**G3**	**G4**
LC_{50} = (10.02%)	44.08	47.19	38.71	38.01	LC_{50} = (0.39%)	78.13	82.47	68.32	67.59
LC_{40} = (5.19%)	40.19	45.31	36.50	36.41	LC_{40} = (0.20%)	73.51	78.15	65.23	64.68
LC_{30} = (2.40%)	36.58	41.69	33.41	32.50	LC_{30} = (0.09%)	69.11	73.25	61.51	62.50
LC_{20} = (0.88%)	33.50	39.31	30.28	29.19	LC_{20} = (0.03%)	65.85	69.44	58.27	57.09
LC_{10} = (0.17%)	30.94	37.41	27.09	26.27	LC_{10} = (0.01%)	61.94	67.44	53.19	52.28
CG	0.00	0.00	0.00	0.00	CG	0.00	0.00	0.00	0.00
					Mortality (Adult)				
LC at 3 days	**G1**	**G2**	**G3**	**G4**	**LC at 7 days**	**G1**	**G2**	**G3**	**G4**
LC_{50} = (10.02%)	35.24	38.79	28.29	27.29	LC_{50} = (0.39%)	68.52	73.79	63.07	62.29
LC_{40} = (5.19%)	32.20	36.50	25.17	24.08	LC_{40} = (0.20%)	61.73	69.67	58.78	57.24
LC_{30} = (2.40%)	28.17	31.41	22.87	21.49	LC_{30} = (0.09%)	56.44	63.63	52.57	51.12
LC_{20} = (0.88%)	24.61	28.71	19.49	18.31	LC_{20} = (0.03%)	51.62	58.33	47.50	46.41
LC_{10} = (0.17%)	21.50	26.30	17.38	16.20	LC_{10} = (0.01%)	48.41	53.67	42.73	42.62
CG	0.00	0.00	0.00	0.00	CG	0.00	0.00	0.00	0.00

CG = Control Group + = Hormoligosis result positive

Table 9. Hormoligosis of fecundity and longevity of cotton mealybug treated with Fenoxycarb at 3rd and 7th days

Pesticide					Fenoxycarb (swift® 6.9 EW)				
					Fecundity				
LC at 3 days	**G1**	**G2**	**G3**	**G4**	**LC at 7 days**	**G1**	**G2**	**G3**	**G4**
LC_{50} = (10.02%)	37.84	33.24	42.68	42.73	LC_{50} = (0.39%)	37.67	33.45	43.88	44.89
LC_{40} = (5.19%)	39.73	37.39	46.60	46.69	LC_{40} = (0.20%)	43.48	37.47	48.60	49.52
LC_{30} = (2.40%)	43.40	41.73	49.49	50.31	LC_{30} = (0.09%)	49.80	42.19	53.83	54.74
LC_{20} = (0.88%)	49.24	44.57	54.30	54.39	LC_{20} = (0.03%)	53.73	49.68	59.32	58.59
LC_{10} = (0.17%)	52.28	48.31	58.17	58.27	LC_{10} = (0.01%)	58.61	53.30	63.41	63.50
CG	94.34	85.19	96.71	94.53	CG	88.58	80.31	90.11	91.21
					Longevity				
LC at 3 days	**G1**	**G2**	**G3**	**G4**	**LC at 7 days**	**G1**	**G2**	**G3**	**G4**
LC_{50} = (10.02%)	32.58	23.35	37.79	37.83	LC_{50} = (0.39%)	24.65	17.94	27.70	28.43
LC_{40} = (5.19%)	35.23	26.48	39.70	39.75	LC_{40} = (0.20%)	27.69	20.89	31.59	32.32
LC_{30} = (2.40%)	38.94	29.40	41.58	42.22	LC_{30} = (0.09%)	30.87	24.78	35.48	36.21
LC_{20} = (0.88%)	41.39	31.83	44.49	45.30	LC_{20} = (0.03%)	34.53	27.28	40.37	39.11
LC_{10} = (0.17%)	43.57	33.24	47.28	48.19	LC_{10} = (0.01%)	37.78	32.52	43.18	43.29
CG	48.73	43.61	55.63	54.72	CG	37.94	32.91	46.21	42.01

CG = Control Group + = Hormoligosis result positive

DISCUSSION

The certain insecticides can be used safely, while others have carcinogenic, mutagenic and teratogenic effects on animals along with its persistence in the ecosystem. Also, their increase in the food chain threatens non-target species which is very much concerned with regard to environmental health. These facts are of profound interest to farmers, health scientists, manufacturers, and customers. The Insect Growth Regulators (IGRs) are the modern for both organizational and industrial insect management methods. The IGRs control of pests species is far higher than traditional insecticides and are substantial alternative for integrated pest management (IPM) program in targeted insect pest control [30]. The cotton mealybug is an invasive species of polyphagous insects that cause severe economic damage to many crops particularly cotton [31].

In the present study, mortality of first instar and adult was observed decreasing after 3 days of the interval with decreasing concentration. After seven days of the interval, percent of insects death was observed decreasing over the generation at different dilutions of swift® insecticide, which shows that production of resistance from G1 to G4 was not established. Present findings were supported by Abbas and coauthors [32], where fipronil, pyriproxyfen, acetamiprid, diafenthinuron, bifenthrin, chlorfenapyr and chlorpyrifos were used against the cotton mealybug. At sublethal concentrations, a variety of insecticides were tested for efficacy against mealybugs throughout the world, which showed the reduction of population in different generations [33,34].

The study showed that hormoligosis increases dramatically in generations at sublethal doses ($P < 0.05$). But fecundity rate highly decreased at lethal dose of LC_{50}. which exposed that fenoxycarb is more effective. Vojoudi and coauthors [35] studied the similar effects that sublethal concentrations LC_{25} of lufenuron strongly affected spider mites' life characteristics and, subsequently, influenced mite population growth in the next generations. Ayub and coauthors [36] revealed that sublethal doses (LC_{10} and LC_{30}) had significant effects on the second instar developmental time of *P. fuscipes* compared with that of the control. The sublethal doses of profenofos negatively affected the development and biological activities of rove beetle. In our experiment it was observed that offspring, the developmental period of eggs, larvae, and pupae increased substantially in the next generations. Extending the pre-adult development period may raise exposure danger to natural enemies [37]. As other researchers have reported, fenoxycarb normally retains a juvenile character by expanding the untimely phases [38–40].

The IGRs are used against the pests of different crops because they absorb and form and toxic residues pool in the tissue of leaves. This kind of IGRs residual absorption develops by post-application intervals, reducing their residual toxicity on the treated leaf-surface [41,42]. Post-application behaviour of IGRs molecules of this kind ensures a progressive rise in toxicity against sucking insects pests and a consistent drop in contact toxicity against parasitoids, predators [41] and other non - target fauna of arthropods [42]. The toxicity of insecticide was recorded in same trend line as estimated by Abbas and coauthors [32] in which they check the efficacy of ten pesticides, including fipronil, spintoram, lamdacyhalothrin, pyriproxyfen, acetamiprid, nitenpyram, diafenthinuron, bifenthrin, chlorfenapyr and chlorpyrifos at different concentrations against the *Phenacoccus solenopsis*. In the present study, the longevity of female cotton mealybug increases in case of swift® throughout the generations at both 3 and 7 days interval which shows that sub lethal dose level has more efficacy. Present findings were not supported by Vojoudi and coauthors [35] because they check the efficacy of abamectin, chlorpyriphos, and spinosad on the longevity of different target pest cotton bollworms. They also concluded that spinosad and chlorpyriphos are the effective insecticides against cotton bollworm. The present findings of sex ratio were not supported by Kalola and coauthors [43] because the target insect, dose selection and insecticide was different. They checked the efficacy of different insecticides like profnofos against *Thrips tabaci*. They concluded that profenofos is most effective against the *Thrips tabaci.*

The resistance level to insecticides negatively affected the level of improvement on reproductive ability as less improvement was recorded for strains with higher resistance. However, Fenoxycarb may be more appropriate to treat the pest depending on lethal and sublethal results than other insecticides.

CONCLUSION

The usage of non-selective insecticides is optimistic for protecting natural enemies and thus has profound consequences for the pest population dynamics. The greater mortality was recorded at a concentration of fenoxycarb 2.4%. Laboratory bioassay showed that after 3 days of experiment, fenoxycarb was less effective at concentration LC_{10} (0.17 ppm). The 1st instar showed maximum mortality at the concentration (LC_{50} = 10.02%). The maximum fecundity, sex ratio and longevity were found in control. The sex ratio was higher in control while the minimum at (LC_{10} = 0.17%). The 1st instar and adult of cotton mealybug were found to decline after generations at sub-lethal dilutions that exposed the resistance of development from G1 to G4 after 3 days and maximum after 7 days of interval. At 3 days, hormoligosis was observed in fecundity at LC_{10} (0.17%) in G1 and G4 while LC_{50} (10.02%) was observed in G1 and G4. In Pakistan, pesticide resistance in cotton mealybug might can be controlled if efficient and variety of pesticides are used in alternation, besides additional IPM strategies, at the starting level of resistance improvement.

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