Research Article

Acute Toxicity of Pyriproxyfen and Buprofezin Insecticides on Mortality, Natality and Longevity of Cotton Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae)

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Abstract | Cotton mealybug (CMB), *Pheanacoccus solenopsis* is highly deleterious insect pests of agricultural crops. It is polyphagous by nature and can feed on diversity of host plants. Different concentrations of Pyriproxyfen and Buprofezin are Insect Growth Regulator (IGR) were bio-assayed against 3rd instar of CMBat Integrated Pest Management Laboratory, Department of Entomology, University of Agriculture, Faisalabad, during 2016. The results revealed that mortality of 3rd instar of *P. solenopsis* increased with increase in concentration of Pyriproxyfen and Buprofezin at three days of post application interval (PAI). Pyriproxyfen 0.5% and Buprofezin at 2% concentration induced mortality of *P. solenopsis* up to (82.52%) and (87.60%) respectively at PAI of 3 days after application. At 0.25%concentration of Pyriproxyfen and 1% of Buprofezin mortality of CMB was observed up to 59.72% and 63.04%respectivelyon 3rdday after application. Similarly Pyriproxyfen at 0.125% concentration and Buprofezin0.5% resulted in mortality of 43.93% and 49.01% respectively.Concentrations 0.0625% and 0.25% of Pyriproxyfen andBuprofezincaused 24.63% and 31.46% mortality respectively at PAI of 3 days.Pyriproxyfen andBuprofezinat 0.03125%, 0.0125%concentrations caused 7.08% and 12.7% mortality respectively of *P. solenopsis* at PAI of 3 days. It is concluded that Buprofezin remained more toxic at all concentrations as compared with Pyriproxyfen. This information is very useful when formulating management strategy of CMB in future.

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Introduction

Cotton mealybug (CMB), *Phenacoccus solenopsis* is highly deleterious insect pests of agricultural crops. Geographically it has been distributed throughout the globe (Hodgson *et al.*, 2008). In Pakistan, it was observed for the first time in Agriculture Research Station, Vehari (Punjab) and some other places in Sanghar, Sindh. In 2005, it was proliferated throughout the country, and affected 11 major cotton producing districts with drastic losses (12-40%) in 2006-2007 (Arif *et al*., 2009; Abbas *et al*., 2010). In 2006, its infestation was the key diminutive factor of cotton productions to 3.1 million bales (Kakakhel, 2007; Arif *et al*., 2009; Abbas *et al*., 2010). From India (Nagrare *et al*., 2011) and China (Wang *et al*., 2009) it has been documented as potential threat.

CMB is polyphagous by nature, because from herbaceous weeds to woody plants, *P. solenopsis* has feeding diversity on various host plants ranging 154 host-plant species out of which 64 weeds, 20 field crops, 25 shrubs and trees, 45 ornamental plants, belonging to a total of 53 plant families (Arif *et al*., 2009) encompassing Malvaceae, Solanaceae, Asteraceae, Euphorbiaceae, Amaranthaceae and Cucurbitaceae, whereas Ben-Dov *et al*. (2009) reported it from 174 host plants at disposal of 55 families. However, only cotton, okra, tomato, sesame, brinjal, sunflower and China rose are subjected to economic damage (Arif *et al*., 2009).

Biological parameters of cotton mealybug differ with respect to climatic conditions and availability of the host plants. Mostly its females reproduce partheno-genetically, laying eggs in ovisacs containing 150-600 eggs. It takes 3-9 days to hatch eggs into nymphs which lasts for about 22-25 days. These nymphs finally grow into adults in 15-30 days under optimum conditions of temperature and humidity. About hundreds of nymphs could be produced by *P. solenopsis* with a capacity of 6000 eggs per generation (Abbas *et al*., 2007). This high reproductive rate, pouch-ovoviviparity and thick waxy-coating on body make it very successful pest of cotton (Hodgson *et al*., 2008). The infested plants dry up due to its phyto-toximial sucking of cell sap from leaves, tender shoots/ twigs, branches and reproductive. The honeydew secreted by adult-females and nymphs on leaves invigorates the development of sooty mold ultimately hampering the process of photosynthesis, which eventually results in death of plants tissues (Saeed *et al*., 2007; Saini and Ram, 2008; Arif *et al*., 2009; Abbas *et al*., 2010). Primary symptoms of *P. solenopsis* infestation are wrinkled shoots and leaflets, distorted and bushy branches, presence of white powdery material on leaves, shoots and stem, appearance of honey dew, reduced number of bolls, chlorosis, flowers remain unopened, stunted growth, deformation and ultimately death of plants (Nagrare *et al*., 2011). The farmers completely rely on insecticides to manage this notorious pest.

This research article contains information related with acute toxic effect of Pyriproxyfen and Buprofezin insecticides on Mortality, natality and longevity of cotton mealybug, *Phenacoccussolenopsis*.

Materials and Methods

Experiment was conducted in Integrated Pest Management Laboratory, Department of Entomology, University of Agriculture, Faisalabad, Pakistan (31.4278°N, 73.0758°E). Following materials and methods were escorted during execution of the whole trial.

Field collection and rearing of Phenacoccus solenopsis

The adults and neonates of *P. solenopsis* species were collected randomly from chemically untreated plants of cotton (*Gossypiumhirsutum*), mulberry (*Morusalba*) and China rose (*Hibiscus rosa-sinensis*) plantation at Entomological Research area of the University of Agriculture Faisalabad. Infested twigs were cut using a clipper and brought to the laboratory. All debris, undesirable insects and other organisms were separated and disposed off. The population of 3rd instar of CMB was shifted on air-dried pumpkins kept in transparent rectangular jars of dimension 3ft× 3ft × 3ft using camel hairbrush. Facetious food of mealybug (pumpkins) was changed after 5-6 days interval or until fruit remain undried.

Pesticides

Experiment was executed employing two insect growth regulators (Buprofezin 25% WP and Pyriproxyfen 10.8 % EC) to examine their sub-lethal impacts on cotton mealybug.

Preparation of insecticide dilutions

Both insecticide used for experimentation are commercially available and procured from the local market of Multan and were brought to laboratory. Five concentrations of each chemical (Table 1) were prepared using the stock solutions method. The stock solution of the highest concentration of both Pyriproxyfen and Buprofezin was used for preparing successive serial dilutions. Succeeding concentrations were formulated by taking half of the stock solution and diluting that using distilled water to the required volume. Subsequent solutions were also made by using the aforesaid method.

Table 1: *Trade name, active ingredients, dose rates and concentrations of insect growth regulator.*

Trade name	Company name	Active ingredient	Dose rate	Concentrations
Pyriproxyfen 10.8 EC	Syngenta	Pyriproxyfen	125ml/acre	0.03125, 0.0625, 0.125, 0.25, 0.5
Buprofezin 25 WP	Syngenta	Buprofezin	500 g/acre	0.125,0.25,0.5,1,2

Bioassay studies

The pumpkin spray method was employed to carry out the bioassay. For this purpose, fresh pumpkins were purchased from the market and brought to the laboratory. All the fruits were washed with deterged water and kept on blotting paper till vaporization of all the moisture from the surface area. This made the fruit free from impurities. When, these pumpkins were ready for further use. The contamination-free pumpkins were sprayed with specified concentrations using sprayers and were shifted to filter paper separately. After sometime when pumpkins were completely dried, an experimental unit was prepared using transparent wide-mouthed plastic bottles of size 14×5 inches. Each insecticidal treatment had five successive concentrations with three replications so fifteen such bottles were used each having one treated pumpkin inside. One bottle with a non-treated pumpkin was used as a control. Twenty adult females were isolated from culture and shifted carefully to treatment jars using camel hairbrush.

After subjecting the insect to specified insecticidal concentrations, data for mortality, natality, fecundity and longevity was recorded. For this purpose, the insect from each bottle was transferred to Petri dishes using a soft hair brush. Organisms were deliberately observed under a microscope. Insects exhibiting no movement in appendages even after slight touch were considered dead. Similarly, the number of ovisacs, and several instars emerging out from ovisac were counted vigilantly.

Statistical analysis

All the data established was subjected to percentage corrected mortality. Mortality data will be subjected to Probit analysis (Finney, 1971) to deduce the sub-lethal concentrations i.e. LC_{10}, LC_{20}, LC_{30}, LC_{40}, LC_{50}.Standard error of all insecticidal treatments replicated thrice was calculated by dividing the standard deviation with sample size.

Results and Discussion

Mortality, natality and longevity of cotton mealybug, Phenacoccus solenopsis for various concentrations of Pyriproxyfen (Pyriproxyfen® 10 EC) at C.I. 95 % after 3 days.

Mortality of Phenacoccus solenopsis

The results revealed that a concentration dependent mortality was observed in *P. solenopsis*. The mortality of *P. solenopsis* increased with increase in concentration of Pyriproxyfen at three days of post application interval. The maximum mortality in *P. solenopsis* (82.52%) was recorded at highest concentration (0.5%) of Pyriproxyfen at PAI of 3 days. Exposure of *P. solenopsis* to 0.25% concentration of Pyriproxyfen demonstrated 59.72% mortality at PAI of 3days. However exposure of *P. solenopsis* to 0.125% concentration explained 43.93% mortality at PAI of 3 days. Adults of *P. solenopsis* treated with 0.0625% concentration of Pyriproxyfen demonstrated 24.63% mortality at PAI of 3 days.The lowest concentration of pyriproxyfen (0.03125%) caused 7.08% mortality in *P. solenopsis* at PAI of 3 days. According to results Pyriproxyfen demonstrated mortality in *P. solenopsis* in range of 7.08-82.52% being significantly higher at higher concentrations (0.5%) and lower at low concentration (0.03125%) of Pyriproxyfen (**Table 2**).

Natality of Phenacoccus solenopsis

Theresults revealed that the natality (no. of ovisacs/20 females) of *P. solenopsis* increased with decrease in concentration of Pyriproxyfen at three days of post application interval. The maximum natality in *P. solenopsis* (21.67 nymphs/ 20 females) was recorded at control. Exposure of *P. solenopsis* to 0.03125% concentration of Pyriproxyfen demonstrated 17.33 no. of ovisacs at PAI of 3 days. However exposure of *P. solenopsis* to 0.0625% concentration explained 15.3 no. of ovisacs at PAI of 3 days. Adults of *P. solenopsis* treated with 0.125% concentration of Pyriproxyfen caused natality of 14.00 (no. of ovisacs) in *P. solenopsis* at PAI of 3 days. While, *P. solenopsis* treated with 0.25% concentration of Pyriproxyfen revealed natality of 11.33 no. of ovisacs. The highest concentration of Pyriproxyfen caused natality to decrease up to 8.00 no. of ovisacs. These results demonstrate that Pyriproxyfen demonstrated natality (no. of ovisacs/20 females) in range of 8.00-21.76 no. of ovisacs being significantly lower at higher concentrations (0.5%) and higher at low concentration (0.03125%) of Pyriproxyfen (Table 2).

Table 2: *Percentage mortality, Natality and longevity of cotton mealybug, Phenacoccus solenopsis (Hemiptera: Pseudococcidae) at various concentrations of Pyriproxyfen (Pyriproxyfen® 10 EC) at exposure interval of 3 days.*

Concentrations of pyriproxyfen	Biological parameters of *Phenacoccussolenopsis*				
	Mortality (%) (Mean±S.E)	Natality (Ovisacs No.s) (Mean±S.E)	Natality (nymphs/20 Ovisacs) (Mean±S.E)	Male longevity (days) (Mean±S.E)	Female longevity (days) (Mean±S.E)
0.5%	$82.52^{A} \pm 1.16$	$8.00^{C} \pm 0.12$	$360.34^{F} \pm 0.07$	$2.00^{C} \pm 0.07$	$28.07^{E} \pm 0.29$
0.25%	$59.716^{B} \pm 1.13$	$11.33^{BC} \pm 1.05$	$562.33^{E} \pm 1.02$	$2.37^{C} \pm 0.12$	$32.27^{D} \pm 0.32$
0.125%	$43.926^{C} \pm 1.11$	$14.00^{BC} \pm 1.92$	$656.33^{D} \pm 1.05$	$3.07^{C} \pm 0.18$	$37.43^{C} \pm 0.54$
0.0625%	$24.628^{D} \pm 1.06$	$15.34^{AB} \pm 2.01$	$870.34^{C} \pm 1.08$	$4.27^{B} \pm 0.23$	$40.92^{B} \pm 0.72$
0.03125%	$7.0842^{E} \pm 1.01$	$17.33^{AB} \pm 2.09$	$980.33^{B} \pm 1.14$	$4.83^{AB} \pm 0.27$	$42.65^{AB} \pm 0.86$
Control	$0.00^{F} \pm 0.00$	$21.67^{A} \pm 2.14$	$1287.3^{A} \pm 1.24$	$5.46^{A} \pm 0.32$	$44.64^{A} \pm 0.91$

Note: ± is the standard error of three replications.

The results revealed that the natality (nymphs/20 ovisacs) of *P. solenopsis* decreased with increase in concentration of Pyriproxyfen at three days of post application interval. The maximum natality in *P. solenopsis* (1287.3 nymphs/20 ovisacs) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.03125% concentration of Pyriproxyfen demonstrated 980.33 nymphs/20 ovisacs at PAI of 3days.However exposure of *P. solenopsis* to 0.0625% concentration explained 870.34 nymphs/20 ovisacs at PAI of 3 days. Adults of *P. solenopsis* treated with 0.0125% concentration of Pyriproxyfen demonstrated 656.33 nymphs/20 ovisacs at PAI of 3 days. The concentration of 0.25% revealed natality of 562.33 nymphs/20 ovisacs in *P. solenopsis* at PAI of 3 days. The highest concentration of pyriproxyfen (0.5%) caused 360.34 nymphs/20 ovisacs in *P. solenopsis* at PAI of 3 days. These results demonstrate that Pyriproxyfen demonstrated natality in *P. solenopsis* in range of 360.34-980.33 nymphs/20 ovisacs being significantly lower at higher concentrations (0.5%) and higher at low concentration (0.03125%) of Pyriproxyfen (Table 2).

Longevity of Phenacoccus solenopsis

The results revealed that the male longevity (days) of *P. solenopsis* decreased with increase in concentration of Pyriproxyfen at three days of post application interval. The maximum longevity in *P. solenopsis* (5.46 days) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.03125% concentration of Pyriproxyfen demonstrated 4.83 days longevity at PAI of 3 days.However exposure of *P. solenopsis* to 0.0625% concentration explained 4.27 days natality at PAI of 3 days. Adults of *P. solenopsis* treated with 0.0125% concentration of Pyriproxyfen demonstrated longevity of 3.07 days at PAI of 3 days. The concentration of 0.25% revealed longevity of 2.37days in *P. solenopsis* at PAI of 3 days. The highest concentration of pyriproxyfen (0.5%) caused 2.00 days longevity in *P. solenopsis* at PAI of 3 days. These results demonstrate that Pyriproxyfen demonstrated natality in *P. solenopsis* in range of 2.00-5.46 days being significantly lower at higher concentrations (0.5%) and higher at low concentration (0.03125%) of Pyriproxyfen (Table 2).

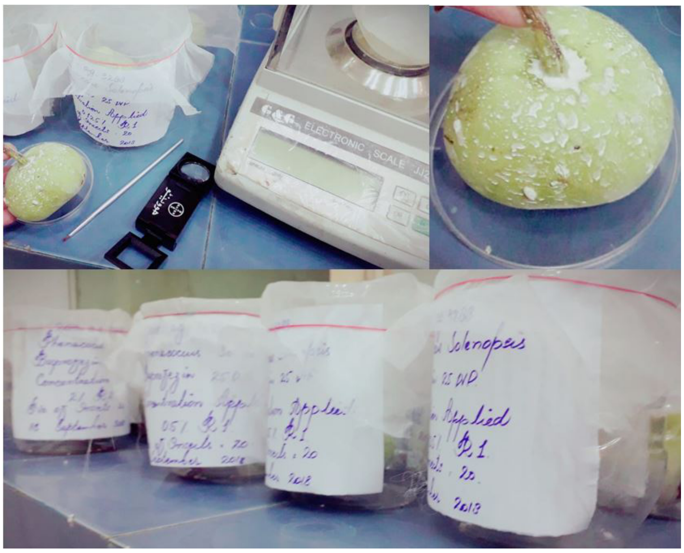

Figure 1: *Diagram of laboratory method performed during experimental study.*

The results revealed that the female longevity (days) of *P. solenopsis* decreased with increase in concentration of Pyriproxyfen at three days of post application interval. The maximum longevity in *P. solenopsis* (44.64 days) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.03125% concentration of Pyriproxyfen demonstrated 42.65days longevity at PAI of 3 days. However, exposure of *P. solenopsis* to 0.0625% concentration explained 40.92 days natality at PAI of 3 days. Adults of *P. solenopsis* treated with

0.0125% concentration of Pyriproxyfen demonstrated longevity of 37.43 days at PAI of 3 days. The concentration of 0.25% revealed longevity of 32.27 days in *P. solenopsis* at PAI of 3 days. The highest concentration of pyriproxyfen (0.5%) caused 28.07 days longevity in *P. solenopsis* at PAI of 3 days. These results demonstrate that Pyriproxyfen demonstrated natality in *P. solenopsis* in range of 28.07-44.64 days being significantly lower at higher concentrations (0.5%) and higher at low concentration (0.03125%) of Pyriproxyfen (Table 2).

Mortality, natality and longevity of cotton mealybug, Phenacoccus solenopsis for various concentrations of Buprofezin (Buprofezin® 25 WP) at C.I. 95 % after 3 days

Mortality of *Phenacoccus solenopsis*: The results revealed that a concentration dependent mortality was observed in *P. solenopsis*. The mortality of *P. solenopsis* increased with increase in concentration of Buprofezin at three days of post application interval. The maximum mortality in *P. solenopsis* (87.60%) was recorded at highest concentration (2%) of Buprofezin at PAI of 3 days. Exposure of *P. solenopsis* to 1% concentration of Buprofezin demonstrated 63.04% mortality at PAI of 3 days. However, exposure of *P. solenopsis* to 0.5% concentration explained 49.01% mortality at PAI of 3 days. Adults of *P. solenopsis* treated with 0.25% concentration of Buprofezin demonstrated 31.46% mortality at PAI of 3 days. The lowest concentration of Buprofezin (0.125%) caused 12.17% mortality in *P. solenopsis* at PAI of 3 days. These results demonstrate that Buprofezin demonstrated mortality in *P. solenopsis* in range of 12.17-87.60% being significantly higher at higher concentrations (2%) and lower at low concentration (0.125%) of Buprofezin (Table 3).

Natality of Phenacoccus solenopsis

The results revealed that the natality (no. of ovisacs/20 females) of *P. solenopsis* increased with decrease in concentration of Buprofezin at three days of post application interval. The maximum natality in *P. solenopsis* (23.00 no. of ovisacs/20 females) was recorded at control. Exposure of *P. solenopsis* to 0.125% concentration of Buprofezin demonstrated 18.00 no. of ovisacs at PAI of 3days.However exposure of *P. solenopsis* to 0.25% concentration explained 15.00 no. of ovisacs/20 females at PAI of 3 days. Adults of *P. solenopsis* treated with 0. 5% concentration of Buprofezin caused natality of 14.00 (no. of ovisacs) in *P. solenopsis* at PAI of 3 days while, *P. solenopsis* treated with 1% concentration of Buprofezin revealed natality of 12.00 no. of ovisacs. The highest concentration of Buprofezin (2%) caused natality to decrease up to 7.00 no. of ovisacs. These results demonstrate that Buprofezin demonstrated natality (no. of ovisacs) in range of 7.00-23.00 no. of ovisacs being significantly lower at higher concentrations (2%) and highest at low concentration (0.125%) of Pyriproxyfen (Table 3).

The results revealed that the natality (nymphs/20 ovisacs) of *P. solenopsis* decreased with increase in concentration of Buprofezin at three days of post application interval. The maximum natality in *P. solenopsis* (1287.0 nymphs/20 ovisacs) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.125% concentration of Buprofezin demonstrated 980.00 nymphs /20 ovisacs at PAI of 3 days. However, exposure of *P. solenopsis* to 0.25% concentration explained 870.00 nymphs/20 ovisacs at PAI of 3 days. Adults of *P. solenopsis* treated with 0.5% concentration of Buprofezin demonstrated 656.00 nymphs /20 ovisacs at PAI of 3 days. The concentration of 1% revealed natality of 562.00 nymphs/20 ovisacs in *P. solenopsis* at PAI of 3 days. The highest concentration of Buprofezin (2%) caused 360.00 nymphs/20 ovisacs in*P. solenopsis* at PAI of 3 days. These results demonstrate that Buprofezin demonstrated natality in *P. solenopsis* in range of 360.00-980.00 nymphs /20 ovisacs being significantly lower at higher concentrations (2%) and higher at low concentration (0.125%) of Buprofezin (Table 3).

Longevity of Phenacoccus solenopsis

The results revealed that the male longevity (days) of *P. solenopsis* decreased with increase in concentration of Buprofezin at three days of post application interval. The maximum longevity in *P. solenopsis* (4.61 days) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.125% concentration of Buprofezin demonstrated 4.09 days longevity at PAI of 3days. However, exposure of *P. solenopsis* to 0.25% concentration explained 3.93 days natality at PAI of 3 days. Adults of *P. solenopsis* treated with 0.5% concentration of Buprofezin demonstrated longevity of 3.21 days at PAI of 3 days. The concentration of 1% revealed longevity of 2.20 days in *P. solenopsis* at PAI of 3 days. The highest concentration of Buprofezin (2%) caused 1.97 days longevity in *P. solenopsis* at PAI of 3 days. These results showed that Buprofezin demonstrated natality in *P. solenopsis* in range of 1.97-4.61 days being significantly lower at higher concentrations (0.125%) and higher at low concentration (2 %) of Buprofezin (Table 3).

The results revealed that female longevity (days) of *P. solenopsis* decreased with increase in concentration of Buprofezin at three days of post application interval. The maximum longevity in *P. solenopsis* (41.27 days) was recorded at control at PAI of 3 days. Exposure of *P. solenopsis* to 0.125% concentration of Buprofezin demonstrated 36.45 days longevity at PAI of 3 days. However, exposure of *P. solenopsis* to 0.25% concentration explained 33.79 days natality at PAI of 3 days. Adults of *P. solenopsis* treated with 0.5% concentration of Buprofezin demonstrated longevity of 30.50 days at PAI of 3 days. The concentration of 1% revealed longevity of 25.78 days in *P. solenopsis* at PAI of 3 days. The highest concentration of pyriproxyfen (2%) caused 21.73 days longevity in *P. solenopsis* at PAI of 3 days. These results demonstrate that Buprofezin demonstrated natality in *P. solenopsis* in range of 21.73-41.27 days being significantly lower at higher concentrations (2%) and higher at low concentration (0.125%) of Buprofezin (Table 3).

LC_{10} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Psudococcidae) at C.I. 95 % after 3 days exposure

Table 4 demonstrates that the 10% population of adult *Phenacoccus solenopsis* Tinsley killed after 3 days exposure on pretreated pumpkin fruits with sub-lethal concentrations of Pyriproxyfen and Buprofezin including control to determine their toxicological outputs.

After three days exposure, LC_{10} values for pyriproxyfen and buprofezin were 0.03% and 0.02% respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. The performance of tested insecticides varied significantly as the fiducial limits for tested insecticides did not overlap each other.

LC_{20} values of Pyriproxyfen® and Buprofezin® for Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure

Table 5 demonstrates that the 20% population of adult *Phenacoccussolenopsis* Tinsley killed after 3 days exposure on pretreated pumpkin fruits with sub-lethal concentration of Pyriproxyfen (Pyrproxyfen® 10EC) and Buprofezin (Buprofezin® 25 WP) including control to determine their toxicological outputs.

After three days exposure, LC_{20} values for Pyriproxyfen (Pyriproxyfen ® 10EC) and Buprofezin (Buprofezin® 25WP) were 0.06% and 0.04% respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. The performance of tested insecticides varied significantly as the fiducial limits for tested insecticides did not overlap each other.

Table 3: *Mortality, natality and longevity of cotton mealybug, Phenacoccus solenopsis (Hemiptera: Pseudococcidae) at various concentrations of Buprofezin (Buprofezin® 25 WP) at exposure interval of 3 days.*

Concentration of buprofezin	Biological parameters of *Phenacoccu ssolenopsis*				
	Mortality (%) (Mean±S.E)	Natality (Ovisacs N0.s) (Mean±S.E)	Natality (nymphs/ 20 ovisac) (Mean±S.E)	Male Longevity (days) (Mean±S.E)	Female Longevity (days) (Mean±S.E)
2%	87.60^{A} ± 0.98	7.00^{E}±0.26	360.00^{F}±0.96	1.97^{D}±0.04	21.73^{D}±1.45
1%	63.04^{B}± 0.23	12.00^{D}±0.35	562.00^{E}±1.14	2.20^{D}±0.06	25.78^{CD}±1.76
0.5%	49.01^{C}± 0.67	14.00^{CD}±0.49	656.00^{D}±1.28	3.21^{C}±0.08	30.50^{BC}±2.02
0.25%	31.46^{D}± 0.34	15.00^{C}±0.63	870.00^{C}±1.64	3.93^{B}±0.12	33.79^{AB}±2.06
0.125%	12.17^{E}± 0.58	18.00^{B}±0.72	980.00^{B}±1.87	4.09^{AB}±0.15	36.45^{AB}±2.17
Control	0.00^{F} ±0.00	23.00^{A}±0.81	1287.0^{A}±2.16	4.61^{A}±0.17	41.27^{A}±2.24

Note: ± *is the standard error of three replications.*

Table 4: *LC_{10} values of Pyriproxyfen® and Buprofezin® for Phenacoccus solenopsis Tinsley (Hemiptera: Psudococcidae) at C.I. 95 % after 3 days exposure.*

Insecticides	Field recommended dose	LC_{10}	FD limit	Slope ± S.E.	χ^2	df	P
Pyriproxyfen	125ml/acre	0.03	0.02-0.04	0.94±0.08	4.49	3	0.21
Buprofezin	500 g/acre	0.02	0.02-0.03	0.89±0.08	3.57	3	0.32

Note: ± *is the standard error of three replications, LC50: Lethal concentration required to kill 50% of the test organism, df: degree of freedom, P: probability.*

LC_{30} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure

Table 6 demonstrates that the 30% population of adult *Phenacoccussolenopsis* Tinsley killed after 3 days exposure on pretreated pumpkin fruits with sub-lethal concentration of Pyriproxyfen and Buprofezinincluding control to determine their toxicological outputs.

After three days exposure, LC_{20} values for Pyriproxyfen and Buprofezin were 0.09% and 0.07%, respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. The performance of tested insecticides varied significantly as the fiducial limits for tested insecticides did not overlap each other.

LC_{40} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure

Table 7 demonstrates that the 40% population of adult *Phenacoccussolenopsis* Tinsley killed after 3 days exposure on pretreated pumpkin fruits with sublethal concentration of Pyriproxyfen and Buprofezin including control to determine their toxicological outputs.

After three days exposure, LC_{40} values for Pyriproxyfen and Buprofezinwere 0.13% and 0.10% respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. The performance of tested insecticides varied significantly as the fiducial limits for tested insecticides did not overlap each other.

LC_{50} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure

Table 8 demonstrates that the 50% population of adult *Phenacoccussolenopsis* Tinsley killed after 3 days exposure on pretreated pumpkin fruits with sublethal concentration of Pyriproxyfenand Buprofezinincluding control to determine their toxicological outputs.

After three days exposure, LC_{50} values for Pyriproxyfen and Buprofezin were 0.19% and 0.15% respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. The performance of tested insecticides varied significantly as the fiducial limits for tested insecticides did not overlap each other.

Table 5: *LC_{20} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure.*

Insecticides	Field recommended dose	LC_{20}	FD limit	Slope	χ^2	Df	P
Pyriproxyfen	125ml/acre	0.06	0.04-0.07	0.94±0.08	4.49	3	0.21
Buprofezin	500 g/acre	0.04	0.03-0.06	0.89±0.08	3.57	3	0.32

Note: ± *is the standard error of three replications; LC50: Lethal concentration required to kill 50% of the test organism; df: degree of freedom; P: probability.*

Table 6: *LC_{30} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure.*

Insecticides	Field recommended dose	LC30	FD limit	Slope	χ^2	DF	P
Pyriproxyfen	125ml/acre	0.09	0.08-0.10	0.94±0.08	4.49	3	0.21
Buprofezin	500 g/acre	0.07	0.06-0.09	0.89±0.08	3.57	3	0.32

Note: ± *is the standard error of three replications; LC50: Lethal concentration required to kill 50% of the test organism; df: degree of freedom; P: probability.*

Table 7: *LC_{40} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure.*

Insecticides	Field recommended dose	LC40	FD limit	Slope	χ^2	DF	P
Pyriproxyfen	125ml/acre	0.13	0.10-0.15	0.94±0.08	4.49	3	0.21
Buprofezin	500 g/acre	0.10	0.09-0.13	0.89±0.08	3.57	3	0.32

Note: ± *is the standard error of three replications; LC50: Lethal concentration required to kill 50% of the test organism; df: degree of freedom; P: probability.*

Table 8: *LC_{50} values of Pyriproxyfen® and Buprofezin® for Phenacoccussolenopsis Tinsley (Hemiptera: Pseudococcidae) at C.I. 95 % after 3 days exposure.*

Insecticides	Field recommended dose	LC50	FD limit	Slope	χ^2	DF	P
Pyriproxyfen	125ml/acre	0.19	0.16-0.22	0.94±0.08	4.49	3	0.21
Buprofezin	500 g/acre	0.15	0.13-0.18	0.89±0.08	3.57	3	0.32

Note: ± *is the standard error of three replications; LC50: Lethal concentration required to kill 50% of the test organism; df: degree of freedom; P: probability*

The experiment was an attempt to investigate the transgenerational effects of some biological traits of cotton mealybug *Phenacoccus solenopsis* when exposed to some sublethal concentrations of selective insecticides. Five concentrations of two insecticides Pyriproxyfen (Pyriproxyfen® 10.8 EC) and (Buprofezin® 25 WP) were exposed under laboratory conditions. For that purpose, pumpkin fruits, treated with five different concentrations (field recommended doses) of each insecticide, Pyriproxyfen (Pyriproxyfen® 10.8 EC) and Buprofezin (Buprofezin® 25 WP) and control were used to expose them against adults to find sublethal concentrations using mortality data and then exposure of predetermined sublethal concentrations to examine hormesis effects.

The objective of first experiment was to determine the sublethal concentrations of Pyriproxyfen (Pyriproxyfen® 10.8 EC) and Buprofezin (Buprofezin® 25WP) and other biological outputs of *P. solenopsis* against these insecticides.

Present results revealed that maximum mortality in *P. solenopsis* (82.52%) was recorded at highest concentration (0.5%) of Pyriproxyfen at PAI of 3 days. According to results Pyriproxyfen demonstrated mortality in *P. solenopsis* in range of 7.08-82.52% being significantly higher at higher concentrations (0.5%) and lower at low concentration (0.03125%) of Pyriproxyfen. The maximum natality in *P. solenopsis* (21.67 nymphs/20 females) was recorded at control. Exposure of *P. solenopsis* to 0.03125% concentration of Pyriproxyfen demonstrated 17.33 no. of ovisacs at PAI of 3 days.

Results revealed that after 3days exposure interval LC_{10} concentrations for Pyriproxyfen®, and Buprofezin® appeared as 0.03% and 0.02%, LC_{20} values as 0.06% and 0.04%, LC_{30} values as 0.09% and 0.07%, LC_{40} values as 0.13% and 0.10%, LC_{50} values as 0.19% and 0.15%.

According to He *et al*. (2013) the potential sublethal effects of different insecticides occurred on biological characteristics (the fecundity, honeydew excretion and feeding behavior) of sucking insectpest. Sublethal doses of insecticide reduced phloems feeding of insects. Similarly, fecundity rates and the honeydew excretions of adults exposed to these concentrations were also decreased than the controls revealing no stimulations in biological endpoints at these sublethal concentrations.

The sublethal and lethal effects of insecticide in red pumpkin beetle, *A. foveicollis* (Lucas) were also reported by (Ibrahim and Rezali, 2014). Six different concentrations of insecticide and a control were applied to adult insects. Considering LC_{50} (0.005 mg a.i. L-1) as a sublethal concentration, effects were investigated for different biological parameters. Results exhibited a decreased fecundity and survival rate of adult beetle, whereas longevity reduced up to 29 days as compared to the control. No resurgence or hormesis was observed in *Aulacophorafoveicollis* against insecticide.

According to Pakyari *et al*. (2016) there exist functional retaliations of *C. Montrouzieri* (Coleoptera: Coccinellidae) a predator of *P. citri* against sublethal doses of Abamectin and Fenpropathrin. The 4th instar nymphs of *Planococcuscitri* Risso were used as prey. varying densities (2, 4, 8, 16, 32, 64 and 128) of prey were employed at temperature of 28 ± 1 °C, 60%± 10% relative humidity and a photoperiod of 16:8 h (L: D). The results documented a decreased consumption of prey and search rates by *C. montrouzieri* at increasing sublethal concentrations from LC_{10} to LC_{30} of both insecticides. The handling times of females was in all cases lower than in the control. However, maximum handling time observed in LC_{10} of Fenpropathrin. The attack rate was minimum in LC_{30} of Abamectin. Sublethal concentrations (LC_{10} to LC_{30}) of Abamectin increased the maximum theoretical predation but the highest theoretical maximum predation was recorded for LC_{20} of Fenpropathrin.

According to Haddi *et al.* (2016) the sublethal effects of imidachloprid were investigated on sexual fitness in four couple combinations (exposed couple, unexposed couple, exposed males and exposed females) of newly emerged brown stink bug *E. heros* (Hemiptera: Heteroptera: Pentatomidae) adults. The results exhibited that sublethal exposure of insecticide (1% of recommended field rate) had no effect on survival, but eventuated with greater mating frequencies. Mating duration got short in couples with exposed females, while those with unexposed females exhibit higher locomotory and fecundity rates and low respiration rates. It was strained that sexual fitness of male brown stink bug was increased when intimated with insecticidal stress at early stages of adulthood.

Yusmalinar *et al.* (2017) evaluated the sub harmful impacts of insecticide and permethrin on the productive ability of resistance population of housefly (*Muscadomestica* Linn) (Diptera: Muscidae) for 10 generations. The results showed that LC5of permethrin and imidachloprid enhanced fecundity and fertility in resistant population of *M. domestica* as compared to LC15 and control. The results confirmed the occurrence of reproductive hormesis in house fly due to sublethal doses of insecticides.

Conclusions and Recommendations

Continuous administration of sub-lethal concentrations can induce stimulations in different biological traits demonstrating surprising biological capacity of insects to cope with stressors. The mortality of *P. solenopsis* increased with increase in concentration of Pyriproxyfen and Buprofezin at three days of post application interval. The maximum mortality in *P. solenopsis* (82.52%) and (87.60%) was recorded at highest concentration (0.5%) and (2%) of Pyriproxyfen and Buprofezin, respectively at PAI of 3 days. The lowest concentration of pyriproxyfen and Buprofezin (0.03125%), 0.0125% caused 7.08% and 12.7% mortality respectively in *P. solenopsis* at PAI of 3 days. According to results Pyriproxyfen and Buprofezin demonstrated mortality in *P. solenopsis* in range of 7.08-82.52%, 12.17-87.60% being significantly higher at higher concentrations(0.5%), (2%) and lower at low concentration (0.03125%), (0.125%) of Pyriproxyfen and Buprofezin, respectively. After three days exposure, LC_{50} values for Pyriproxyfen and Buprofezin were 0.19% and 0.15% respectively. The results authenticated the Buprofezin to be more toxic than Pyriproxyfen at its recommended field dose after three days of post application interval. Contemplation of this aspect is necessary when integrating the pest management programs. It is concluded Buprofezin induced more toxicity than Pyriproxyfen for the management of cotton mealybug when formulating strategy in the Integrated Pest Management programs in future.

Novelty Statement

In the present studies, comparative toxicity of Buprofezin and Pyriproxyfen has been studied. Based on the results, it was found that Buprofezin is more toxic and effectively controlled cotton mealybug than Pyriproxyfen, because after three days exposure, LC50 values for Pyriproxyfen and Buprofezin were 0.19% and 0.15% respectively.

Author's Contribution

Tooba Ather: Conducted research study and drafted manuscript.
Muhammad Rafiq Shahid: Equally contributed with first author.
Muhammad Ahsin Ayub, Muhammad Rizwan, Hafeezur Rehman, Umar Farooq and Javed Iqbal: Critically reviewed manuscript.
Muhammad Asim Bhutta, Muhammad Akram and Naveeda Anjum: Helped to draft the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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