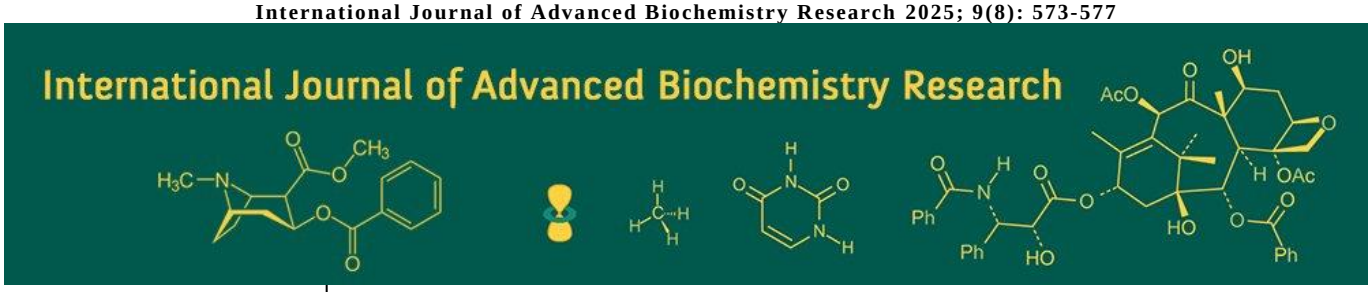

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Evaluating the safety of insecticides on the predatory beetle, *Cryptolaemus montrouzieri* (Mulsant)

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Abstract
The mealybugs are soft-bodied sap-sucking insect pests catalogued under the group of scale insects (Hemiptera: Coccoidea) with the worldwide distribution of about 2000 species. Here, in the context of conservation of natural enemies, we explored the efficacy on predator. eight insecticides viz imidacloprid (0.005%), acetamiprid (0.02%), clothiniadin (0.003%), bifenthrin (0.05%), fipronil 15% + flonicamid (0.10%), sulfoxaflor (0.075%), spirotetramat (0.12%), buprofezin (0.20%) were tested under laboratory. Study on relative toxicity of different insecticides on larvae and adults of Cryptolaemus montrouzieri (Mulsant) revealed that treatments of imidacloprid 17.8 SL @ 0.005% and acetamiprid 20 SP @ 0.02% proved toxic to the larvae and adults of C. montrouzieri. Clothiniadin 50% WDG @ 0.003% and bifenthrin 10% EC 0.05% proved to be moderately toxic to larva as well as adult. Fipronil 15% + Flonicamid 15% WDG @ 0.10%, sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% were relatively safer insecticides against the grubs and adult of *C. montrouzieri* with the significantly lowest mortality .Buprofezin 25 SC @ 0.20% show least mortality.

Keywords: *Cryptolaemus montrouzieri*, insecticides and toxicity

Introduction
Mealybugs (Hemiptera: Pseudococcidae) constitute a diverse group of sap-feeding insects, including over 2, 000 described species across roughly 300 genera. They are easily recognized by the waxy, powder-like covering exhibited by adult females. Among these, the papaya mealybug (*Paracoccus marginatus*) and the striped or white mealybug (*Ferrisia virgata*) are of particular concern due to their extensive host range and pest impact.

The papaya mealybug, *P. marginatus*, is a small phloem-feeder that inflicts damage by extracting sap and depositing honeydew on plant surfaces. This sugary excretion fosters the growth of sooty mold, which diminishes photosynthetic efficiency and can lead to chlorosis, distorted growth, and premature leaf and fruit drop (Krishnan *et al.*, 2016) [5]. Adult females remain largely immobile, while the first-instar nymphs (crawlers) actively disperse by crawling and may travel further via wind or the movement of infested plant material (Tanwar 2010) [8]. Honeydew also attracts tending ants, which engage in mutualistic interactions by protecting mealybugs from natural enemies (Krishnan *et al.*, 2016) [5]

Similarly, *F. virgata* is a broadly polyphagous pest affecting more than 200 plant genera and numerous tropical and temperate crops. Its feeding activity leads to honeydew excretion, which promotes sooty mold development—particularly from fungi such as *Capnodium* and *Cladosporium*—resulting in reduced light transmission and impaired photosynthesis Infestations often appear as conspicuous white clusters cloaked in wax and fungal growth, detracting from crop quality and marketability, and causing severe physiological damage, including chlorosis and premature abscission. *F. virgata* is also linked to the transmission of pathogens such as Cocoa swollen shoot virus and Citrus tristeza virus, adding a phytosanitary dimension to its economic threat (Corquodale and Hodges 2017) [1].

Understanding the biological traits, dispersal mechanisms, and ecological interactions of *P. marginatus* and *F. virgata* particularly their honeydew-mediated associations with ants and fungal growth, is critical for designing effective Integrated Pest management (IPM) strategies. This study aims to elucidate these factors to support the development of targeted and sustainable pest control measures.

The Australian ladybird beetle, *Cryptolaemus montrouzieri*, has been extensively utilized in biological control programs due to its predation on a broad spectrum of pest species. (Dumaniya *et al.*, 2015) [2]. The coccinellid has been introduced into at least 64 countries/territories to control more than 16 pest species. *C. montrouzieri* is a polyphagous predator that exploits hosts in at least eight hemipteran families (Kairo *et al.*, 2013) [4].

Materials and Methods

Dry film method

To evaluate the toxicity of various insecticides at field-recommended concentrations on both larval and adult stages of *Cryptolaemus montrouzieri*, the dry film method was utilized under controlled laboratory conditions. Insecticide solutions were prepared at specified concentrations based on recommended field application rates. Third instar larvae and adults of *C. montrouzieri* were used for this experiment. Each solution was evenly applied to both the bottom and inner walls of sterile Petri dishes measuring 1.5 × 10 cm, ensuring complete surface coverage. After application, the treated Petri dishes were placed under a fan at room temperature until the solvent fully evaporated, leaving behind a uniform layer of insecticidal residue on the inner surfaces. Once the dishes were dried, healthy grubs and adults of *C. montrouzieri* were introduced into the treated dishes, with each treatment replicated adequately to ensure statistical reliability.

Method of recording observations

To evaluate the toxicity of insecticides, third instar larvae and adults of *C. montrouzieri* were treatment. Mortality of *C. montrouzieri* larva and adult were observed and calculated at time interval of 24 h, 48 h, and 72 h. The data was statistically analyzed. The laboratory experiment was conducted using completely randomized design (CRD) with 8 treatments with one untreated (control), replicate thrice.

Results

1.1 Mortality of grubs at 24 h after application

The results on toxicity of different insecticides to grubs of *C. montrouzieri* at 24 h after the application have been tabulated in Table no 1 and Figure 1. The results of the present study indicate that the highest percent of mortality was observed in imidacloprid 17.8 SL @ 0.005% (40.00 percent) followed by acetamiprid 20 SP @ 0.02% (38.00 percent) and both these treatments were at par to each other. However, the latter treatment was also found at par with clothiniadin 50% WDG @ 0.003% (31.33 percent) which in turn was at par with bifenthrin 10% EC 0.05% (27.33 percent) and proved to be moderately toxic. Fipronil 15% + Flonicamid 15% WDG @ 0.10%, sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% were relatively safer insecticides against the grubs of *C. montrouzieri* with the significantly lowest mortality of 20.00, 12.00 and 4.00 percent, respectively. Buprofezin 25 SC @ 0.20% and untreated (control) were found to be non-toxic with no mortality as represented in Table 1.

1.2 Mortality of grubs at 48 h after application

The present studies revealed (Table 1 and Fig. 1) that the imidacloprid 17.8 SL @ 0.005% was significantly more toxic after 48 h of application of insecticides with a percent mortality of 48.67 followed by acetamiprid 20 SP @ 0.02% (46.67 percent) and were at par to each other. The treatment of clothiniadin 50% WDG @ 0.003% and bifenthrin 10% EC 0.05% were found moderately toxic and showed at par toxicity with 40.00 and 34.00 percent mortality of *C. montrouzieri*. Though, the latter treatment was further found at par with fipronil 15% + flonicamid 15% WDG @ 0.10%, treatment which resulted in 29.33 percent mortality of grubs. Sulfoxaflor 21.8% SC @ 0.075% was found less toxic insecticide against the grubs of *C. montrouzieri* with significantly lower mortality of 20.67 followed by spirotetramat 150 OD @ 0.12% (10.00 percent). Buprofezin 25 SC @ 0.20% and untreated (control) were found to be non-toxic with no mortality.

1.3 Mortality of grubs at 72 h after application

The *C. montrouzieri* at 72 h after the application (Table 1 and Fig. 1) revealed that imidacloprid 17.8 SL @ 0.005% recorded the significantly higher mortality of (57.33%) of the grubs and proved to be most toxic followed by acetamiprid 20 SP @ 0.02% (55.33 percent), clothiniadin 50% WDG @ 0.003% (47.33 percent) and bifenthrin 10% EC 0.05% (43.33%). With moderate toxicity, treatment of fipronil 15% + flonicamid 15% WDG @ 0.10%, caused 38.00 percent grubs mortality of *C. montrouzieri* followed by sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% treatments which exhibited 26.00 and 15.33 percent mortality, respectively. Significantly lowest grub mortality of 1.33 percent was recorded in buprofezin 25 SC @ 0.20%. No mortality was observed in untreated control.

2.1 Mortality of adults at 24 h after application

The results on toxicity of different insecticides to adults of *C. montrouzieri* at 24 h after the application have been tabulated in Table no 2 and depicted in Fig. 2. The results of the present study indicate that the highest percent of mortality was observed in imidacloprid 17.8 SL @ 0.005% (42.67 percent) followed by acetamiprid 20 SP @ 0.02% (40.00 percent) and both these treatments were at par to each other. clothiniadin 50% WDG @ 0.003% and bifenthrin 10% EC 0.05% were found moderately toxic and showed at par toxicants with 32.67 and 29.33 percent mortality against the adults of *C. montrouzieri*. Result revealed that no mortality to the adults of *C. montrouzieri* at 24 h of exposure was noted due to treatment with buprofezin 25 SC @ 0.20% and untreated (control). Besides, fipronil 15% + flonicamid 15% WDG @ 0.10%, sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% caused very low (22.00, 14.67 and 6.00 percent) mortality to the adults of *C. montrouzieri.*

2.2 Mortality of adults at 48 h after application

It is evident from the data in Table 2 and Figure 2; there were significant differences in adults of *C. montrouzieri* mortality among treatments. Imidacloprid 17.8 SL @ 0.005% was significantly more toxic after 48 h of application of insecticides with a mortality of 48.67 percent followed by acetamiprid 20 SP @ 0.02% (46.67 percent) and were at par to each other. The treatment of clothiniadin 50% WDG @ 0.003% and bifenthrin 10% EC 0.05% were found moderately toxic and showed at par toxicity with 42.00 and 38.00 percent mortality of *C. montrouzieri*. fipronil 15% + flonicamid 15% WDG @ 0.10%, sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% caused with significantly lower percent mortality of 31.33,

24.00 and 15.33, respectively. Being very least toxic treatment against adults of *C. montrouzieri*, buprofezin 25 SC @ 0.20% treatment gave 1.33 percent mortality.

2.3 Mortality of adults at 72 h after application

From the results of 72 h after the application, it was observed that all the treatment showed significant mortality against adults of *C. montrouzieri* (Table no 2 and Fig. 2). Among the treatments, highest toxicity was recorded for imidacloprid 17.8 SL @ 0.005% treatment which had 60.67 percent mortality to adults of *C. montrouzieri*. However, it was found at par with acetamiprid 20 SP @ 0.02% treatment which gave 57.33 percent mortality in pest population. It was followed by clothiniadin 50% WDG @ 0.003% (47.33 percent) and bifenthrin 10% EC 0.05% treatments which comprised the next group of toxicants with non-significant difference and caused 49.33 and 45.33 percent mortality. fipronil 15% + flonicamid 15% WDG @ 0.10%, exhibited lower toxicants against adults of *C. montrouzieri* and brought about 40.67 percent mortality and it was followed by sulfoxaflor 21.8% SC @ 0.075% and spirotetramat 150 OD @ 0.12% treatments which exhibited 28.687 and 18.67 percent mortality, respectively. Giving very least low morality to adults of *C. montrouzieri*, buprofezin 25 SC @ 0.20% treatment could cause 1.33 percent. No mortality was observed in untreated control.

The results of the present study are in close agreement with Planes *et al.* (2013) [7] who found that the spirotetramat to be safe for both larvae and adults *C. montrouzieri*. Kakde *et al.* (2014) [3] who revealed that imidacloprid (0.005%) and acetamiprid (0.004%) were found highly toxic, as they caused more than 80 percent mortality on 1 day after application. Nidheesh *et al.* (2020) [6] found buprofezin 25 SC nontoxic to *C. montrouzieri*.

Table 1: Toxicity of different insecticides against grubs of *Cryptolaemus montrouzieri* by dry film method.

Treatment	Concentration (%)	Mean percent mortality (hours after treatment)			
		24 h	48 h	72 h	Mean
Buprofezin 25 SC	0.20	0.00 (0.00)	0.00 (0.00)	1.33 (6.63)	0.44 (3.82)
Spirotetramat 150 OD	0.12	4.00 (11.54)	10.00 (18.43)	15.33 (23.05)	9.78 (18.22)
Fipronil 15% + Flonicamid 15% WDG	0.10	20.00 (26.57)	29.33 (32.79)	38.00 (38.06)	29.11 (32.65)
Sulfoxaflor 21.8% SC	0.075	12.00 (20.27)	20.67 (27.04)	26.00 (30.66)	19.56 (26.25)
Clothiniadin 50% WDG	0.003	31.33 (34.04)	40.00 (39.23)	47.33 (43.47)	39.56 (38.97)
Bifenthrin 10% EC	0.05	27.33 (31.52)	34.00 (35.67)	43.33 (41.17)	34.89 (36.20)
Acetamiprid 20 SP	0.02	38.00 (38.06)	46.67 (43.09)	55.33 (48.06)	46.67 (43.09)
Imidacloprid 17.8 SL	0.005	40.00) (39.23)	48.67 (44.24)	57.33 (49.22)	48.67 (44.24)
Control (Untreated)	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.Em.±		1.69	1.83	1.99	1.84
C.D. at 5%		5.13	5.56	6.04	5.57

Figures in parentheses are arcsine transformed values

Table 2: Toxicity of different insecticides against adults of *Cryptolaemus montrouzieri* by dry film method.

Treatment	Concentration (%)	Mean percent mortality (hours after treatment)			
		24 h	48 h	72 h	Mean
Buprofezin 25 SC	0.20	0.00 (0.00)	1.33 (6.63)	1.33 (6.63)	0.89 (5.41)
Spirotetramat 150 OD	0.12	6.00 (14.18)	15.33 (23.05)	18.67 (25.60)	13.33 (21.42)
Fipronil 15% + Flonicamid 15% WDG	0.10	22.00 (27.97)	31.33 (34.04)	40.67 (39.62)	31.11 (33.90)
Sulfoxaflor 21.8% SC	0.075	14.67 (22.52)	24.00 (29.33)	28.67 (32.37)	22.44 (28.28)
Clothiniadin 50% WDG	0.003	32.67 (34.86)	42.00 (40.40)	49.33 (44.62)	41.33 (40.01)
Bifenthrin 10% EC	0.05	29.33 (32.79)	38.00 (38.06)	45.33 (42.32)	37.56 (37.79)
Acetamiprid 20 SP	0.004	40.00 (39.23)	50.00 (45.00)	57.33 (49.22)	49.11 (44.49)
Imidacloprid 17.8 SL	0.005	42.67 (40.78)	52.67 (46.53)	60.67 (51.16)	52.00 (46.15)
Control (Untreated)	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.Em.±		1.60	1.72	2.05	1.79
C.D. at 5%		4.86	4.55	6.21	5.42

Figures in parentheses are arcsine transformed values

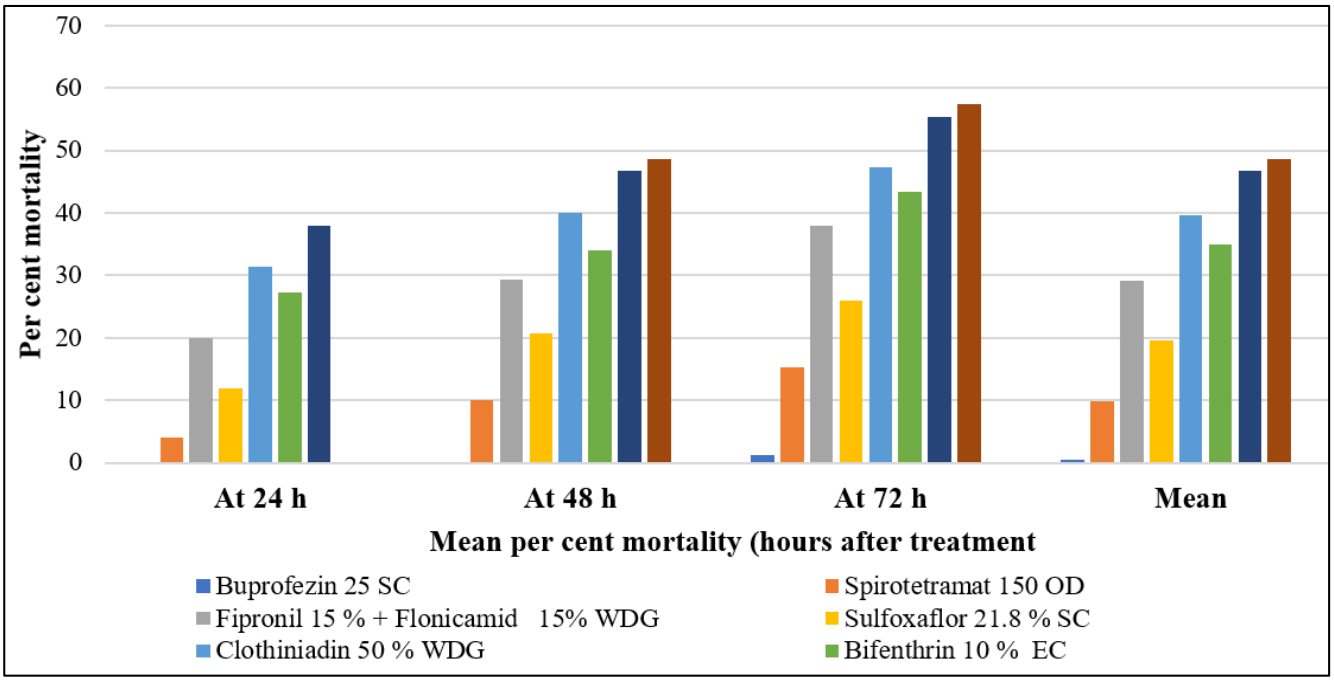

Fig 1: Toxicity of different insecticides against grubs of *C. montrouzieri* by dry film method.

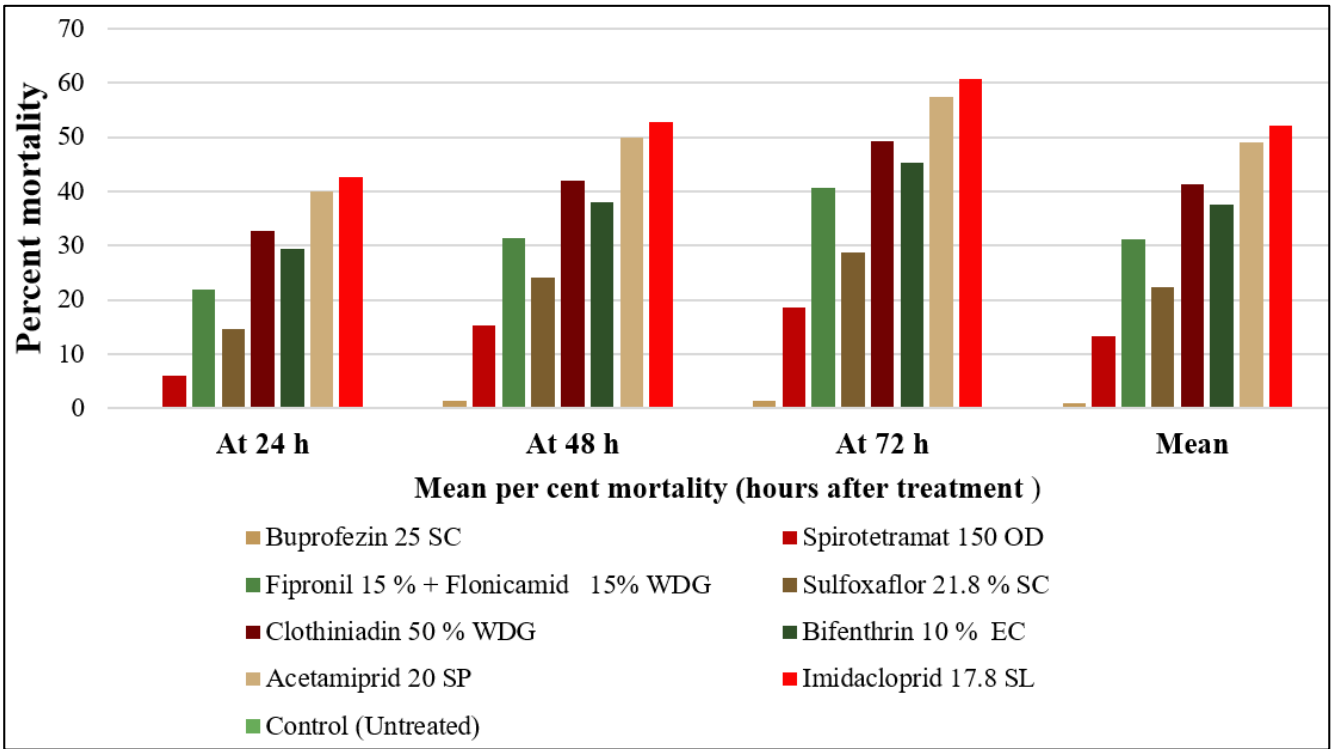

Fig 2: Toxicity of different insecticides against adult of *C. montrouzieri* by dry film method.

Conclusion

For effective integration of *C. montrouzieri* in pest management, it is recommended to utilize insecticides like buprofezin 25 SC @ 0.20% that exhibit low toxicity to this predator. Such practices will ensure the conservation of beneficial insects while achieving desired pest control outcomes.

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