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Stage-specific Toxicity and Efficacy of Different Insecticides in the Management of White Grub (*Brahmina coriacea*)

Shubham Sharma*, Kuldeep Singh Verma, Suman Sanjta and Prajjval Sharma

Department of Entomology, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur – 176062, Himachal Pradesh, India; sh9746262@gmail.com

Abstract

Brahmina coriacea* (Hope) is a prominent white grub species and a serious soil-dwelling pest, causing considerable damage to various agricultural and horticultural crops in the northwestern Himalayan region of India. The present study assessed the toxicity of selected insecticides against third-instar grubs, adults, and eggs of *B. coriacea* under laboratory conditions. Among the tested insecticides, chlorantraniliprole was the most effective across all life stages, recording the lowest LD_{50} values in grubs (1.41 µg per grub) and adults (0.23 µg per beetle), and the highest egg mortality (53.14%). Bifenthrin showed comparable toxicity to chlorantraniliprole in grubs, while carbofuran and chlorpyriphos exhibited moderate effectiveness; fipronil was consistently the least toxic. Adults were more susceptible than grubs, as indicated by lower LD_{50} values. Egg mortality increased significantly with exposure period, i.e. 18.43% at 3 days to 49.44% at 14 days after treatment, demonstrating a clear time-dependent effect. Overall, chlorantraniliprole emerged as the most potent insecticide against *B. coriacea.* The findings highlight the importance of considering life-stage differences in insecticide efficacy and provide a scientific basis for optimising pest management strategies targeting *B. coriacea.

Keywords: Coleoptera, Chlorantraniliprole, Mortality, Insecticides, Scarabaeidae, Toxicity, White grub

White grubs (Coleoptera: Scarabaeidae) constitute a major group of soil-inhabiting pests that cause extensive damage to a wide range of agricultural and horticultural crops worldwide[1,2]. The larval stages, commonly known as grubs, feed voraciously on plant roots, resulting in poor nutrient uptake, wilting, stunted growth, and, in severe infestations, complete plant mortality[3]. In the northwestern Himalayan region of India, white grubs pose a significant threat to agricultural systems, with larvae causing severe damage to underground crops such as potato through root and tuber feeding, while adults infest fruit crops, including apple, by feeding on foliage[4]. Among the different species reported, *Brahmina coriacea* (Hope) is of considerable economic importance and has been frequently associated with significant crop losses in Himachal Pradesh and adjoining regions[5].

The management of phytophagous scarabs is particularly challenging due to their concealed soil-dwelling habit during the larval stage, nocturnal activity of adults, and relatively long-life cycle[6]. While cultural and biological control measures provide partial suppression, chemical control through insecticides remains the most reliable and rapid approach for managing severe infestations[7]. However, the

*Author for correspondence

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effectiveness of insecticides largely depends on their toxicity across different developmental stages of the insect[8]. Third-instar grubs, being the most destructive feeding stage, are often the primary targets for control, whereas adults play a crucial role in reproduction and population build-up, and eggs represent the initial stage where early intervention may help suppress population establishment. Therefore, evaluating the susceptibility of eggs, grubs, and adults is essential for developing comprehensive and stage-specific management strategies.

In this context, determination of the median lethal dose (LD_{50}) serves as a fundamental tool in toxicological studies, providing a quantitative estimate of insecticide potency[9]. Such information is crucial for comparing the efficacy of different insecticides, optimising application rates, and minimising risks to non-target organisms and the environment. Despite the economic importance of *B. coriacea*, detailed information on the comparative toxicity of insecticides against its eggs, larval, and adult stages under controlled conditions is lacking.

Therefore, the present study was undertaken to evaluate the toxicity of selected insecticides against eggs, third-instar grubs, and adults of *B. coriacea*; median lethal dose (LD_{50}) values for grubs and adults were estimated using concentration–mortality bioassays and probit analysis, while egg mortality was assessed at different exposure periods. The outcomes of this study are expected to provide a scientific basis for the rational selection and application of insecticides across different life stages, thereby contributing to the development of effective and sustainable management strategies for this important pest.

MATERIALS AND METHODS

Toxicity of Insecticides against Grubs and Adults of *Brahmina coriacea*

The toxicity of selected insecticides, namely bifenthrin (Bicep 10 EC), carbofuran (Carbofuran 3 CG), chlorantraniliprole (Coragen 18.5 SC), chlorpyriphos (Termite 20 EC), and fipronil (Fipronil 5 SC), against third-instar grubs and adults of *B. coriacea* was evaluated using concentration–mortality bioassays to determine LD_{50} values. Stock solutions of the insecticides were prepared and serially diluted with acetone to obtain a range of concentrations. The applied doses (µg/individual) were calculated based on the percentage of active ingredient present in the respective commercial formulations.

For third-instar grubs, a 1 µL aliquot of each dilution was applied topically to the pronotum, whereas in adults, the same volume was applied to the posterior-ventral surface of the abdomen using a calibrated micropipette. Following treatment, insects were individually transferred to 30 mL plastic cups containing approximately 20 g of moist, sterilised soil to simulate natural conditions. All experimental units were maintained under controlled laboratory conditions at 25 ± 2 °C, 70 ± 5% relative humidity, and a 16:8 h (L:D) photoperiod.

Mortality was recorded 24 hours after treatment, and individuals showing no response to gentle probing were considered dead. Each concentration was tested on ten insects with three replications, along with an untreated control. Mortality was expressed as a percentage and corrected for control mortality using Abbott's formula[10]. The corrected mortality data were subjected to probit analysis[11] to estimate LD_{50} values along with their 95% fiducial limits.

Effect of Insecticides on Egg Mortality of *Brahmina coriacea*

Freshly laid eggs (<24 h old) of *B. coriacea* were collected from laboratory-maintained adults and used for bioassay. The eggs were carefully handled to avoid mechanical damage. Each egg was subjected to the topical application of test treatments. The treatments consisted of the same insecticides as described above, applied at concentrations equivalent to 0.5 × LD_{50} for third-instar grubs. A fixed volume of 1 µL per egg was applied using a calibrated micropipette directly onto the chorion surface. Control eggs received an equal volume of acetone only. After treatment, eggs were placed in sterile Petri dishes lined with moist filter paper to maintain optimal humidity and prevent desiccation, and were incubated under controlled

laboratory conditions. Observations on egg hatchability were recorded on the 3rd and 14th day after treatment using a stereo-zoom microscope. Eggs were considered hatched when larval emergence was clearly visible. Egg mortality was confirmed based on distinct visual symptoms, including darkening of the egg, shrinkage or desiccation, and failure of the embryo to hatch by the end of the observation period. Each treatment was replicated thrice, and fifteen eggs per replicate were maintained to ensure the reliability of results.

Statistical Analysis

The observed data on egg hatchability were converted into per cent egg mortality, and values were corrected for natural mortality in the control using Abbott's formula. The corrected mortality values were subjected to arcsine square root transformation before statistical analysis. The data were analysed using a two-factor completely randomised design. Statistical analysis was performed using OPSTAT software.

RESULTS AND DISCUSSION

Toxicity of Insecticides against Third-instar Grubs of *Brahmina coriacea*

The toxicity of different insecticides against third-instar grubs of *B. coriacea* varied significantly, as indicated by differences in LD_{50} values. Among the tested insecticides, chlorantraniliprole exhibited the highest toxicity with the lowest LD_{50} value of 1.41 µg per grub, which was statistically at par with bifenthrin (1.84 µg per grub). Bifenthrin showed moderate toxicity and did not differ significantly from chlorantraniliprole, but was more toxic than carbofuran (2.58 µg per grub) and chlorpyriphos (2.54 µg per grub), which were statistically similar to each other. The least toxic insecticide was fipronil, recording the highest LD_{50} value of 3.03 µg per grub, and it differed significantly from all other treatments (Table 1).

The 95% fiducial limits for all insecticides were relatively narrow, indicating the reliability of the estimates. The slope values ranged from 1.31 ± 0.14 to 1.54 ± 0.15, suggesting a fairly consistent response of the grub population to the tested insecticides (Table 1). The chi-square (χ^2) values were non-significant at the given degrees of freedom, indicating a good fit of the probit model to the observed data.

Significant variation in toxicity among the tested insecticides against third-instar grubs of *B. coriacea* indicates differential susceptibility linked to the chemistry and mode of action of the compounds. The superior performance of chlorantraniliprole is in agreement with the findings of Koranga *et al.*,[12] who also reported its highest efficacy against different larval instars of *B. coriacea*, with markedly lower LC_{50}

Table 1. Median lethal dose (LD_{50}) of different insecticides against third instar grubs of *Brahmina coriacea*

Insecticide	Range of Doses Tested (µg Per grub)	LD_{50}* (µg per grub)	95% Fiducial Limit (µg per grub)	Slope ± SE	χ^2 (df)
Bifenthrin	0.30 – 19.2	1.84^{ab}	1.42 – 2.34	1.48 ± 0.15	3.08 (5)
Carbofuran	0.30 – 19.2	2.58^{bc}	1.96 – 3.36	1.34 ± 0.14	3.21 (5)
Chlorantraniliprole	0.30 – 19.2	1.41^{a}	1.14 – 1.73	1.33 ± 0.14	2.08 (5)
Chlorpyriphos	0.30 – 19.2	2.54^{bc}	2.04 – 3.15	1.54 ± 0.15	2.22 (5)
Fipronil	0.30 – 19.2	3.03^{c}	2.41 – 3.82	1.31 ± 0.14	2.29 (5)

***a,b,c LD_{50} values with different alphabetical superscripts are significantly different ($p < 0.05$) based on the overlap of 95% fiducial limits.*

values compared to other insecticides. Such higher potency of chlorantraniliprole may be attributed to its action on ryanodine receptors, leading to disruption of muscle function and rapid paralysis. The statistically comparable toxicity of bifenthrin suggests that pyrethroids can still provide effective control, which aligns with earlier reports highlighting their quick knockdown effect under laboratory exposure conditions.

Complementing laboratory findings, field studies on related scarab species have also demonstrated the practical effectiveness of newer insecticides. For instance, a field trial against *Holotrichia serrata* in pigeon pea showed that imidacloprid 600 FS at 1 ml/l significantly reduced grub populations (0.31 grubs/m^2), achieved 80.98% larval reduction, limited plant damage to 4.47%, and resulted in the highest yield of 1823 kg/ha, underscoring the value of effective chemical control under field conditions[13]. The least effectiveness of fipronil in the present study differs from some field-based observations[14], where it performed better, likely due to its persistence and soil-mediated action, factors that are not fully replicated in laboratory bioassays.

Toxicity of Insecticides against Adults of *Brahmina coriacea*

The susceptibility of adult *B. coriacea* to the tested insecticides showed clear variation, as reflected by their LD_{50} values. Among all treatments, chlorantraniliprole demonstrated the highest efficacy, recording the lowest LD_{50} value of 0.23 µg per beetle, and was significantly superior to most of the other insecticides (Table 2).

Carbofuran (0.38 µg per beetle) exhibited intermediate toxicity and remained statistically comparable with chlorantraniliprole. In contrast, bifenthrin (0.31 µg per beetle), chlorpyriphos (0.39 µg per beetle), and fipronil (0.45 µg per beetle) formed a statistically similar group, indicating relatively lower toxicity against adults. Among these, fipronil was the least effective, as evidenced by the highest LD_{50} value (Table 2).

The 95% fiducial limits were reasonably narrow for all insecticides, suggesting precision in the estimated values. The slope values ranged from 1.30 ± 0.21 to 1.59 ± 0.23, indicating a uniform dose–response relationship across treatments (Table 2). The chi-square (χ^2) values were low and non-significant at the respective degrees of freedom, confirming the adequacy of the probit model in describing the observed mortality data.

The differential susceptibility of adult *B. coriacea* to various insecticides observed in this study aligns with earlier reports on scarab beetle management, where chemical control efficacy varied with active ingredient and mode of application. Previous investigations by Koranga *et al.*,[15] demonstrated that systemic and contact

Table 2. Median lethal dose (LD_{50}) of different insecticides against adults of *Brahmina coriacea*

Insecticide	Range of Doses Tested (µg per beetle)	LD_{50}* (µg per beetle)	95% Fiducial Limit (µg per beetle)	Slope ± SE	χ^2 (df)
Bifenthrin	0.05 –1.6	0.31^{b}	0.29 – 0.33	1.55 ± 0.22	0.08 (4)
Carbofuran	0.05 – 1.6	0.38^{ab}	0.27 – 0.55	1.31 ± 0.21	1.91 (4)
Chlorantraniliprole	0.05 – 1.6	0.23^{a}	0.20 – 0.27	1.59 ± 0.23	0.59 (4)
Chlorpyriphos	0.05 – 1.6	0.39^{b}	0.29 – 0.55	1.33 ± 0.21	1.62 (4)
Fipronil	0.05 – 1.6	0.45^{b}	0.36 – 0.57	1.30 ± 0.21	0.78 (4)

$^{*,a,b}LD_{50}$ values with different alphabetical superscripts are significantly different ($p < 0.05$) based on the overlap of 95% fiducial limits.

insecticides, such as dimethoate and indoxacarb, exhibited higher toxicity against adults in leaf dip and topical assays, whereas spinosad and fenazaquin were comparatively less effective. Similarly, field studies on related scarabs, such as *Heteronychus loideres*, indicated that organophosphates (e.g., chlorpyrifos) and carbamates (e.g., carbofuran) provided superior control and higher yield benefits, while botanicals offered moderate suppression[16]. In the present study, chlorantraniliprole and carbofuran exhibited the highest toxicity among tested compounds, consistent with their systemic and neurotoxic modes of action, whereas bifenthrin, chlorpyriphos, and fipronil were comparatively less effective, highlighting species- and stage-specific variations in susceptibility.

The probit–log dose relationships of different insecticides against third instar grubs and adults of *B. coriacea* revealed a clear stage-dependent variation in susceptibility. Across all insecticides, the probit lines for adults are consistently shifted upward and to the left relative to those of third instar grubs, indicating greater susceptibility of adults (Figure 1). This is

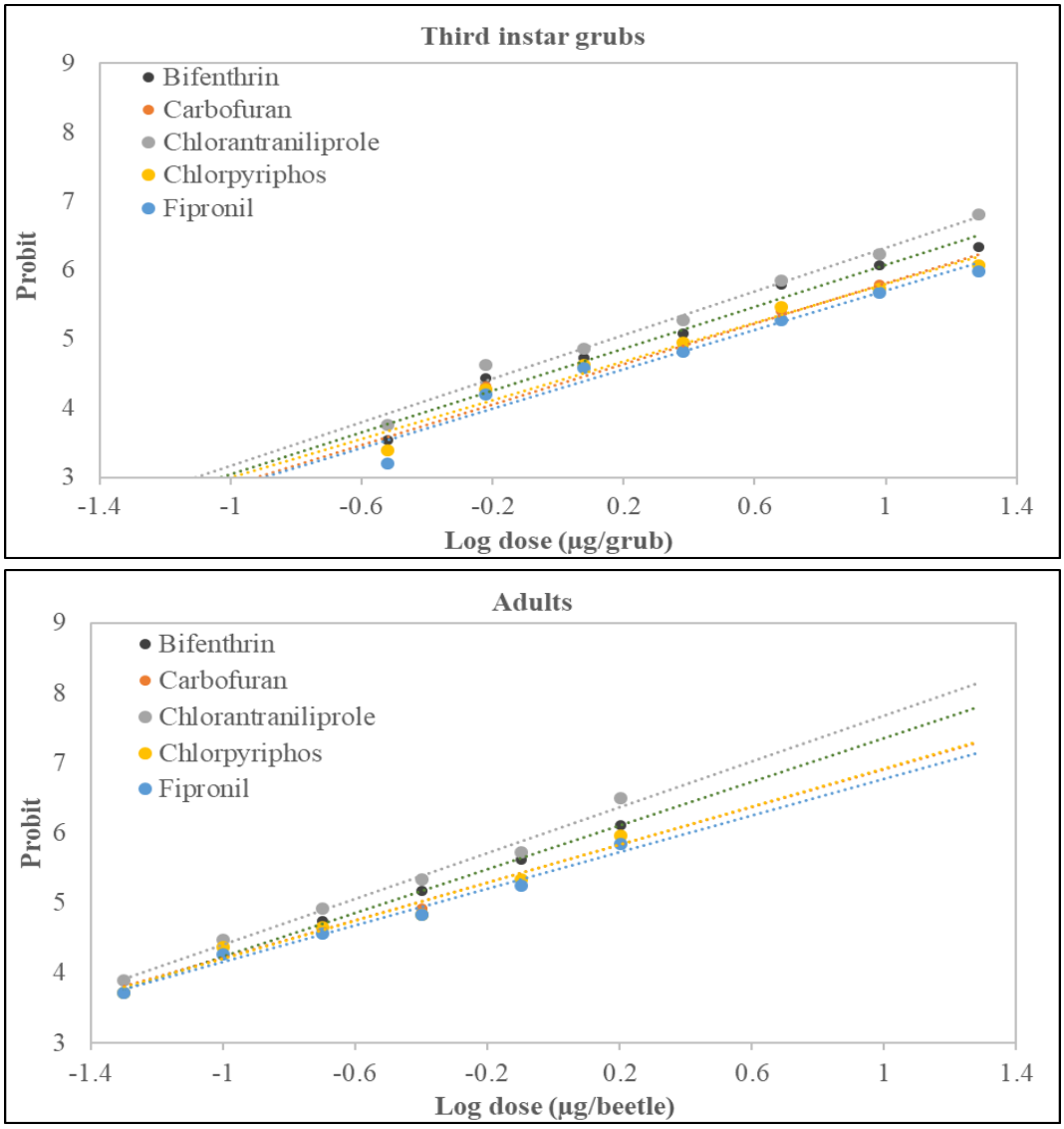


Figure 1. Dose - mortality response of different insecticides against third instar grubs and adults of *Brahmina coriacea*.

further supported by markedly lower LD_{50} values in adults (0.23–0.45 µg per beetle) compared to grubs (1.41–3.03 µg per grub), demonstrating that a higher dose is required to achieve similar mortality in the larval stage (Table 1, Table 2). Although the slopes of the regression lines are broadly comparable between stages, the consistent separation between them suggests a uniform difference in sensitivity rather than variability in response. The reduced susceptibility of grubs may be attributed to stage-specific physiological differences, particularly their comparatively lower metabolic rate and reduced activity, which can delay the onset of toxic effects following topical exposure. In contrast, adults are more active and exhibit higher metabolic and respiratory activity, which may enhance the distribution of insecticide within the body and accelerate toxic action. Additionally, the site of application could have influenced uptake, as insecticide applied on the ventral abdomen of adults may allow more efficient absorption than application on the prothoracic region of grubs. These factors together likely contribute to the consistently higher sensitivity observed in adults compared to third instar grubs.

Egg Mortality Response to Insecticides in *Brahmina coriacea*

Egg mortality of *B. coriacea* was significantly influenced by both insecticides and exposure period. Overall, mortality increased markedly from the 3rd to the 14th day after treatment, indicating a time-dependent effect of the insecticides (Table 3). Among the treatments, chlorantraniliprole recorded the highest egg mortality with a mean value of 53.14%, followed by bifenthrin (41.45%) and chlorpyriphos (37.59%), which were statistically at par with each other. Carbofuran showed moderate effectiveness with a mean mortality of 24.10%, whereas fipronil was the least effective, recording the lowest mean egg mortality (13.39%) and differing significantly from the other treatments. A clear increase in mortality was observed over time across all insecticides, with mean mortality rising from 18.43% at 3 days to 49.44% at 14 days after treatment. This trend suggests a progressive toxic effect of the insecticides on egg viability. The main effects of insecticides and exposure period were significant ($CD_{0.05}$ = 5.99 and 3.789, respectively), while their interaction was non-significant, indicating that the relative performance of insecticides remained consistent across both observation periods (Table 3).

The effects of insecticides and exposure period on egg mortality are significant ($CD_{0.05}$ = 5.99 and 3.789, respectively), whereas their interaction is non-significant.

These findings are consistent with previous reports on scarab beetles and other soil arthropods. For

Table 3. Effect of insecticides on egg mortality (%) at different exposure periods

Insecticide	Corrected Egg Mortality (%)		
	3rd Day	14th Day	Mean
Bifenthrin	21.80 (27.65) *	61.11 (51.58)	41.45 (39.61)
Carbofuran	12.09 (19.72)	36.11 (36.90)	24.10 (28.31)
Chlorantraniliprole	34.07 (35.62)	72.22 (58.22)	53.14 (46.92)
Chlorpyriphos	16.85 (23.74)	58.33 (49.82)	37.59 (36.78)
Fipronil	7.33 (15.70)	19.44 (26.05)	13.39 (20.87)
Mean	18.43 (24.48)	49.44 (44.52)	

**Means in parentheses are angular transformed values*

example, studies on Japanese beetle (*Popillia japonica*) eggs demonstrated that neonicotinoid applications, such as imidacloprid, reduced predation and directly affected egg survival in a time-dependent manner, with measurable effects as early as one week after treatment and persisting for up to four weeks[17]. Similarly, Koranga *et al.*,[18] reported that chlorantraniliprole was highly effective in suppressing oviposition in *B. coriacea*, followed by bifenthrin and chlorpyriphos, underscoring the superior activity of these compounds against early life stages. The dose-dependent reduction in oviposition observed in these studies aligns with the progressive increase in egg mortality recorded in our experiments. Moreover, the time-dependent mortality patterns indicate that repeated monitoring post-application is essential for accurately evaluating control efficacy. Overall, the consistent performance of these insecticides across exposure periods suggests they can be reliably applied even with minor variations in timing, although integrating chemical treatments with cultural or biological measures could further enhance sustainable management strategies.

CONCLUSION

The present investigation demonstrated clear stage-specific variation in the susceptibility of *B. coriacea* to the tested insecticides. Across life stages, adults were consistently more susceptible than third instar grubs, as evidenced by substantially lower LD_{50} values and the leftward shift of probit lines, indicating that lower doses were sufficient to achieve comparable mortality. Among the insecticides evaluated, chlorantraniliprole emerged as the most potent compound against both grubs and adults, while fipronil was the least effective. Carbofuran, bifenthrin and chlorpyriphos exhibited intermediate toxicity, with relatively comparable responses within each stage. The egg stage also exhibited a distinct response pattern, with mortality increasing significantly over time, highlighting a strong time-dependent effect of insecticides on egg viability. Chlorantraniliprole again proved most effective, whereas fipronil showed minimal ovicidal activity. Overall, the study underscores the importance of considering life-stage-specific susceptibility in designing management strategies for this pest. The higher sensitivity of adults suggests that targeting this stage through the timely application of effective insecticides, particularly chlorantraniliprole, may enhance control efficiency. Additionally, the progressive increase in egg mortality over time indicates that certain insecticides can contribute to population suppression beyond immediate effects. These findings provide a useful basis for optimising chemical control strategies against *B. coriacea* under field conditions.

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CONFLICT OF INTEREST

The authors declare no competing interests.

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AUTHORS CONTRIBUTION

ShS: Conceptualized the study, conducted the investigation, curated the data, performed the formal analysis, and wrote the original manuscript and subsequent revisions. KSV: Supervised and validated the study, contributed to visualization, and reviewed the manuscript. SS: Supervised and validated the study, contributed to visualization, and reviewed the manuscript. PS: software support, validated the results, prepared visualizations, reviewed, and edited the manuscript.