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Benzoyl Carbamide Exposure and Ovipositor Dimensions in *Sclerodermus sichuanensis*: A Laboratory Study

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ABSTRACT

Background: Chitin synthesis inhibitors are widely used in insect pest management; however, their potential sublethal effects on beneficial parasitoids remain an important concern for integrated pest management.

Objective: This study investigated concentration-dependent variations in ovipositor length and width in adult female *Sclerodermus sichuanensis* following exposure to benzoyl carbamide.

Methods: A total of 210 adult females were assigned to seven experimental groups, comprising an untreated control and six benzoyl carbamide exposure concentrations, with 30 individuals per group. Ovipositor length and width were measured following a 24-hour exposure period. Group-specific means and standard deviations were calculated from individual observations.

Results: Both ovipositor dimensions exhibited progressive reductions across the exposure groups. Mean ovipositor length decreased from 1805.58 ± 58.57 µm in the control group to 465.60 ± 29.49 µm at the highest concentration, representing a 74.2% reduction. Similarly, mean ovipositor width declined from 865.98 ± 14.70 µm to 226.34 ± 21.15 µm, corresponding to a 73.9% reduction. At 30 mg/mL, ovipositor length and width decreased by 33.4% and 30.7%, respectively, relative to the control.

Conclusion: Benzoyl carbamide exposure was associated with substantial, concentration-dependent alterations in ovipositor dimensions in *S. sichuanensis*. These findings highlight the importance of evaluating morphological responses in beneficial parasitoids when assessing insecticide compatibility with biological control programmes. Further investigations incorporating statistical testing, oviposition performance, and field-based assessments are warranted.

Keywords: *Sclerodermus sichuanensis*; benzoyl carbamide; chitin synthesis inhibitor; ovipositor morphology; parasitoid.

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INTRODUCTION

Chitin synthesis inhibitors (CSIs) represent an important group of insect growth regulators widely incorporated into integrated pest management (IPM) programmes because of their targeted effects on insect development and comparatively low toxicity to vertebrates (Xin et al., 2025). These compounds primarily interfere with chitin biosynthesis, a fundamental process required for the formation and maintenance of the insect exoskeleton. Chitin provides structural strength, mechanical protection, and flexibility to the cuticle, making it essential for successful molting, growth, and metamorphosis (Zhang et al., 2025). Disruption of chitin deposition can consequently impair cuticular development, resulting in abnormal morphology, developmental disturbances, and, in susceptible insects, mortality. Among the compounds used in this category, benzoyl carbamide has attracted attention because of its potential effectiveness against economically important insect pests in agricultural and forestry ecosystems (Ullah et al., 2025).

Despite their advantages, the ecological selectivity of CSIs requires further investigation, particularly regarding their effects on beneficial non-target arthropods. The widespread application of insect growth regulators in agricultural and forest environments may expose organisms that contribute to natural pest suppression, including predatory insects and parasitoid wasps. Parasitoid wasps are particularly important components of biological control systems because their survival, development, and reproductive activities contribute

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substantially to the natural regulation of insect pest populations (Sadanandappa et al., 2023). Although CSIs are generally considered less hazardous to some non-target organisms than many conventional insecticides, exposure to biologically active concentrations may produce sublethal effects that are not necessarily reflected in immediate mortality assessments. Such effects may involve developmental abnormalities, structural modifications, impaired physiological functions, and potential alterations in reproductive performance (Ding et al., 2026).

Sclerodermus sichuanensis is an important hymenopteran parasitoid associated with the biological suppression of wood-boring beetles, particularly cerambycid pests that cause considerable damage to forest trees and timber resources (Gao et al., 2023). Its role in forestry pest management highlights the importance of maintaining healthy parasitoid populations when implementing chemical control strategies. Among the morphological structures associated with its reproductive biology, the ovipositor is particularly important because it facilitates host penetration and egg deposition. This specialized structure contains a sclerotized cuticle that provides mechanical support and rigidity required for effective oviposition. Its morphological dimensions, particularly length and width, are therefore relevant structural characteristics that may influence functional performance (Wang et al., 2025). Any chemical interference with cuticular development or structural integrity could potentially alter ovipositor morphology, although effects on reproductive function would require separate experimental confirmation.

Previous investigations have demonstrated that insecticides with different modes of action can influence parasitoid life-history characteristics, survival, reproductive performance, and host exploitation (Bayram & Doğanlar, 2026). These findings emphasize the importance of considering both lethal and sublethal effects when evaluating the compatibility of chemical pest control strategies with beneficial arthropods (Ahmed et al., 2025). Furthermore, studies examining the interaction between bioinsecticides and parasitoids have highlighted the need to select pest management compounds that minimize adverse effects on natural enemies (Lisi et al., 2024). Environmental and biological factors may also influence parasitoid development and reproductive performance. For example, photoperiod has been investigated as a factor affecting developmental duration and reproduction in *S. sichuanensis*, demonstrating the importance of considering developmental conditions when assessing potential changes in reproductive characteristics (Kang et al., 2025).

The evaluation of insecticide-induced morphological alterations requires accurate and reproducible measurement techniques. Quantitative assessment of structural characteristics can help identify concentration-dependent changes, while advances in analytical and detection technologies provide broader methodological context for sensitive biological measurements (Ghodrati et al., 2023). At the molecular level, investigations of chitin synthase disruption in arthropods have demonstrated the importance of chitin biosynthesis for normal development and reproduction, supporting its relevance as a target for pest management (Hajdusek et al., 2026). Additionally, studies examining chitin distribution in insect epithelial structures have provided further evidence of its involvement in the development of specialized cuticular features (Nakazato & Otaki, 2023). The structural contribution of cuticular chitin to insect form and function further supports the biological rationale for investigating reproductive structures that depend on cuticular integrity (Muthukrishnan et al., 2020).

Although the insecticidal activity of benzoyl carbamide has been investigated in pest management contexts, its potential effects on the reproductive structures of beneficial parasitoids remain insufficiently understood. In particular, limited information is available regarding concentration-dependent morphological responses in the ovipositor of *S. sichuanensis*. This knowledge gap is important because morphological alterations may occur even at exposure levels that do not necessarily cause immediate mortality. Furthermore, identifying the concentrations at which such changes become evident may provide valuable information for assessing the potential risks associated with incorporating CSIs into integrated pest management programmes.

Therefore, the present study was designed to investigate the sublethal effects of benzoyl carbamide on ovipositor morphology in adult female *S. sichuanensis*. Specifically, the study evaluated concentration-dependent changes in ovipositor length and width following exposure to different concentrations of the insecticide. By characterizing these morphological responses, this research aims to provide preliminary evidence regarding the non-target effects of benzoyl carbamide on an ecologically important parasitoid and contribute to the development of more selective and environmentally compatible pest management strategies.

METHODOLOGY

A controlled laboratory-based experimental study was conducted at the Provincial Key Laboratory of Forest Conservation, Sichuan Agricultural University, Sichuan, China, to investigate the effects of benzoyl carbamide exposure on the ovipositor morphology of adult female *Scleroderma sichuanensis*. Colonies of *S. sichuanensis* were maintained under standardized laboratory conditions, with *Tenebrio molitor* pupae serving as hosts for parasitoid rearing. The wasps were maintained in glass tubes measuring 7 mm in diameter and 6 cm in length at a temperature of 25 ± 1°C and a relative humidity of 60–70%. These environmental conditions were maintained consistently throughout the experimental period to minimize environmental variation that could influence insect physiology and morphological characteristics.

Benzoyl carbamide (95% purity), supplied in dust concentrate form and obtained from Shanghai, China, was used as the experimental insecticide. A stock preparation was prepared using distilled water, from which six working concentrations of 5, 15, 30, 50, 75, and 100 mg/mL were established. The experimental design comprised seven groups, including six insecticide-treated groups and one untreated control group. Each group consisted of 30 adult female *S. sichuanensis*, resulting in a total experimental sample of 210 individuals. The concentration-gradient approach was employed to facilitate comparisons of morphological characteristics across different exposure levels. Following insecticide exposure, the wasps were maintained under the same controlled laboratory

conditions (25 ± 1°C and 60–70% relative humidity) for 24 hours to standardize the post-exposure assessment period.

Following the 24-hour post-exposure period, the genital complexes were carefully dissected from the adult female wasps for subsequent morphometric examination. Particular attention was given to the ovipositor, and its length and width were recorded as the primary morphological parameters. Measurements were expressed in micrometers (µm) using a calibrated image-analysis system comprising a digital camera mounted on a microscope and connected to a computer. Image calibration was performed to ensure measurement accuracy and consistency across specimens. Identical imaging and measurement procedures were applied to all experimental groups to minimize technical variability and ensure comparability of morphometric observations.

The recorded measurements were organized according to the corresponding insecticide concentrations and control group. Descriptive statistics, including means and standard deviations, were used to summarize ovipositor length and width. Differences among the seven experimental groups were evaluated using one-way analysis of variance (ANOVA). The assumptions of normality and homogeneity of variance were assessed using the Shapiro–Wilk and Levene's tests, respectively. Where significant overall differences were identified, Tukey's post-hoc test was considered appropriate for pairwise comparisons. If parametric assumptions were not satisfied, the Kruskal–Wallis test followed by an appropriate multiple-comparison procedure was considered. Statistical significance was established at $p < 0.05$, using [CONFIRM: statistical software and version].

To minimize potential experimental bias, insect-rearing conditions, post-exposure intervals, and morphometric assessment procedures were standardized across all treatment groups. Individual-level measurements were retained for statistical evaluation, with each wasp considered the biological unit of observation. The experiment was conducted under institutional laboratory conditions. The original morphometric measurements and corresponding statistical analysis files were retained to support data verification and experimental reproducibility.

RESULTS

All 210 tabulated specimens had recorded measurements for both outcomes. Table 1 summarizes descriptive values recalculated directly from the manuscript's specimen-level table. Mean ovipositor length and width were progressively smaller across increasing nominal treatment concentrations. Compared with the untreated control, the highest group had a 74.2% lower mean length and 73.9% lower mean width. Figure 1 visualizes the group means without implying inferential significance

Table 1. Descriptive ovipositor measurements calculated from the 30 individual values in each group (n = 30/group). SD, standard deviation; ↓, percentage decrease relative to control. The nominal concentration units are retained from the source document pending author verification.

Group	Length (µm), mean ± SD	Length range (µm)	Width (µm), mean ± SD	Width range (µm)	Length ↓ (%)	Width ↓ (%)
Control	1805.58 ± 58.57	1710.89–1900.34	865.98 ± 14.70	841.67–890.45	—	—
5 mg/mL	1690.59 ± 58.59	1595.89–1785.67	811.36 ± 20.56	777.45–845.23	6.4	6.3
15 mg/mL	1467.13 ± 58.49	1370.56–1560.45	725.15 ± 21.59	690.34–760.34	18.7	16.3
30 mg/mL	1203.19 ± 43.99	1130.56–1275.89	600.08 ± 21.62	565.34–635.67	33.4	30.7
50 mg/mL	965.62 ± 29.49	915.56–1015.67	470.04 ± 21.92	434.34–505.34	46.5	45.7
75 mg/mL	695.65 ± 29.51	645.89–745.89	336.37 ± 20.89	303.45–370.56	61.5	61.2
100 mg/mL	465.60 ± 29.49	415.89–515.67	226.34 ± 21.15	191.45–260.45	74.2	73.9

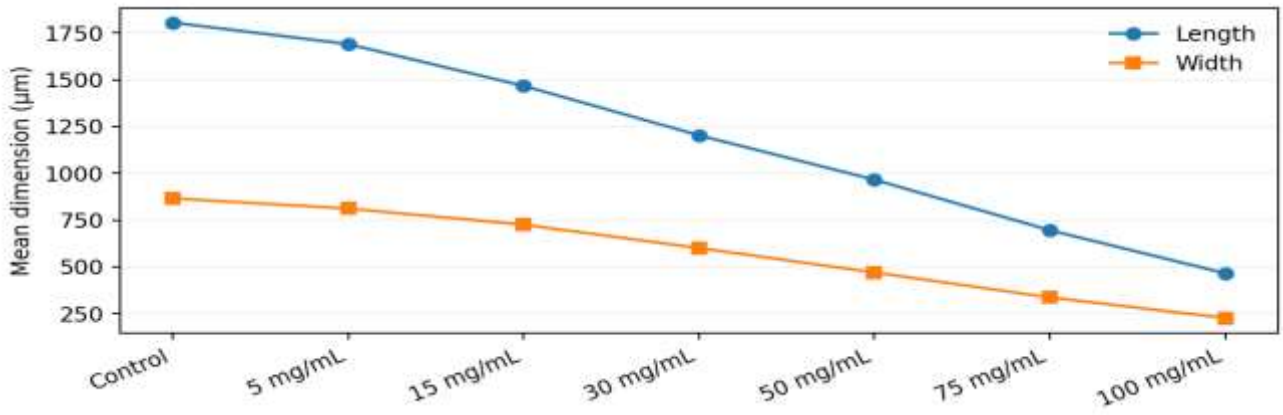


Figure 1. Mean measured ovipositor dimensions by reported exposure group. Lines are descriptive displays of group means and do not show within-group uncertainty or statistical significance.

DISCUSSION

The present study demonstrated a clear concentration-associated reduction in both ovipositor length and width of *Sclerodermus sichuanensis* following exposure to benzoyl carbamide. The progressive decline in these morphometric parameters across the tested concentrations suggests that exposure to this insecticide may adversely affect the morphological integrity of reproductive structures in this parasitoid species. Parasitoid wasps are important natural enemies in biological control systems, and their reproductive characteristics play an essential role in successful host exploitation and population maintenance (Burke & Sharanowski, 2024). Previous research has also emphasized the ecological significance of parasitoid wasps and the relationship between their biological characteristics, host interactions, and reproductive performance (Fei et al., 2023). In this context, the observed reductions in ovipositor dimensions raise concerns regarding the potential non-target effects of benzoyl carbamide on beneficial parasitoids involved in biological pest management.

Both ovipositor dimensions exhibited substantial reductions with increasing insecticide concentrations. At 30 mg/mL, ovipositor length and width decreased by approximately 33.4% and 30.7%, respectively, compared with the untreated control. The reductions became more pronounced at higher concentrations, reaching 74.2% for length and 73.9% for width at 100 mg/mL. This relatively consistent pattern suggests that both dimensions were affected across the concentration gradient. Previous investigations have established that disruption of chitin synthesis can adversely affect arthropod development and survival, providing a biological basis for investigating structural responses to chitin synthesis inhibitors (Schmid et al., 2021). Furthermore, studies examining synthetic insecticide exposure in Trichogramma chilonis have reported alterations in life-table parameters, indicating that chemical exposure may influence the biological performance of beneficial parasitoids (Salim et al., 2025). However, the specific physiological mechanisms responsible for the morphometric changes observed in the present study remain to be established.

From the perspective of integrated pest management, the compatibility of insecticides with natural enemies is essential for maintaining effective and sustainable pest suppression. Integrated pest management approaches emphasize the coordinated application of biological, chemical, and other control methods to achieve pest regulation while minimizing undesirable ecological consequences (Dasa et al., 2024). Recent research has highlighted the complex effects of pesticide exposure on parasitoid wasps, including potential consequences for survival, development, reproduction, and biological control performance (Theenoor et al., 2024). In addition, experimental investigations involving *S. sichuanensis* have demonstrated that host-related and environmental treatment conditions can influence parasitism and progeny production, emphasizing the sensitivity of parasitoid reproductive performance to external factors (Zheng et al., 2024). These findings provide a broader biological context for interpreting the concentration-associated morphological alterations identified in the present investigation.

One possible explanation for the observed morphological reductions involves interference with chitin biosynthesis and cuticular development. Chitin is an essential structural component of the insect exoskeleton and contributes to the formation, mechanical strength, and integrity of specialized cuticular structures. Advances in understanding insect chitin biosynthesis have demonstrated the complex biological mechanisms involved in chitin production and its essential role in insect development (Yu et al., 2024). Although the present study involved adult female parasitoids rather than immature developmental stages, the observed reductions in ovipositor dimensions may reflect structural alterations associated with insecticide exposure. Nevertheless, the development and functional performance of cuticular structures may be influenced by several physiological processes, and the present findings do not establish direct inhibition of chitin synthesis in adult ovipositor tissues.

The potential implications of these morphological changes extend beyond structural characteristics alone. Research on the non-target effects of pesticides has demonstrated the importance of assessing insecticide impacts on beneficial arthropods, particularly natural enemies that contribute to pest population regulation (Schmidt-Jeffris, 2023). Moreover, investigations of sublethal chemical exposure in parasitoids have highlighted the possibility of altered biological responses at concentrations that do not necessarily produce immediate

mortality (Agathokleous et al., 2023). The ovipositor is an essential reproductive structure involved in host penetration and egg deposition; consequently, substantial reductions in its dimensions could potentially influence host accessibility, penetration efficiency, and successful parasitism. However, the present study did not directly evaluate oviposition behavior, host-parasitization rates, or reproductive success. Therefore, the functional consequences of these morphological alterations remain hypothetical and require further experimental investigation.

The biological relevance of chitin-related structural changes is further supported by previous investigations of insect cuticular development. Chitin biosynthesis, turnover, and regulation are fundamental processes involved in maintaining the structural organization of insect tissues (Zhu et al., 2016). Studies examining arthropod chitin pathways have also identified these biological systems as important targets for pest management, highlighting their relevance to the development of insecticidal compounds (Liu et al., 2019). In addition, research on chitin synthesis inhibitors has described their effects on cuticle formation and insect development, providing mechanistic background for understanding potential structural consequences of exposure (Merzendorfer, 2013). Earlier investigations of benzoylphenylurea compounds demonstrated their insecticidal activity through interference with chitin synthesis, establishing an important foundation for subsequent research on insect growth regulators (Hajjar & Casida, 1978). Similarly, research examining chitin synthesis and degradation as targets for pesticide action has emphasized the importance of these processes in insect development and structural maintenance (Cohen, 1993). Nevertheless, these mechanistic findings cannot independently confirm that the reductions observed in the present study resulted from direct interference with ovipositor chitin synthesis.

Overall, the present findings provide preliminary evidence that benzoyl carbamide exposure is associated with concentration-dependent reductions in ovipositor length and width in adult female *S. sichuanensis*. These observations highlight the need to consider morphological endpoints when assessing the potential non-target effects of insect growth regulators on beneficial parasitoids. Further research should incorporate histological examination, cuticular composition analysis, chitin synthase activity measurements, and reproductive performance assessments to clarify the underlying mechanisms and functional significance of these changes. Additionally, investigations under realistic field exposure conditions are needed to determine whether the observed laboratory responses translate into ecologically meaningful effects on parasitoid populations. Such evidence may contribute to the development of more selective and environmentally compatible pest management strategies.

CONCLUSION

The present study demonstrated concentration-associated reductions in ovipositor length and width in adult female *Scleroderma sichuanensis* following benzoyl carbamide exposure. Both morphometric parameters declined progressively with increasing insecticide concentrations, with reductions reaching approximately 74.2% in length and 73.9% in width at 100 mg/mL relative to the untreated control. These findings suggest that benzoyl carbamide exposure may adversely affect the morphological characteristics of an important reproductive structure in this beneficial parasitoid. Although the potential consequences for host penetration and parasitism performance require further investigation, the observed morphological changes highlight the importance of considering non-target effects when selecting insecticides for pest management. Integrating insecticide applications with biological control programmes through appropriate chemical selection and application timing may help minimize potential risks to beneficial parasitoid populations. Further laboratory and field-based studies are warranted to establish the underlying mechanisms and determine the reproductive and ecological consequences of exposure.

Ethical Approval

This study involved laboratory experiments on adult female Sclerodermus sichuanensis. All experimental procedures were conducted in accordance with relevant institutional guidelines and applicable laboratory research standards.

Informed Consent

Not applicable. This study did not involve human participants or human biological samples.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author, Sumbul Mureed Mastoi, upon reasonable request.

Author Contributions

Conceptualization: Sumbul Mureed Mastoi.
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Data analysis and interpretation: Nazir Ahmed Abro and Faaiz Aslam.
Supervision: Sumbul Mureed Mastoi and Naveed Ahmed Abbasi.
Literature review: Um-e-Fatima Mangrio.
Manuscript drafting: Sumbul Mureed Mastoi.
Critical revision of the manuscript: Sumbul Mureed Mastoi, Gulsher Mangrio, and Naveed Ahmed Abbasi.
All authors reviewed and approved the final manuscript.

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Conflict of Interest

The authors declare that they have no competing interests.

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