

Emergence Rates of the Peach Fruit Fly (*Bactrocera zonata*), (Saunders) (Diptera: Tephritidae)

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تأثير درجات الحرارة العالية المُحفَّزة معمليا على معدلات خروج الحشرات البالغة لذبابة فاكهة الخوخ

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Received: 08-07-2025; Accepted: 15-09-2025; Published: 05-10-2025

الملخص

تُعد ذبابة فاكهة الخوخ (*Bactrocera zonata*) من الآفات الحشرية شديدة الضرر، حيث تصيب مجموعة واسعة من المحاصيل الثمرية، مسببة خسائر اقتصادية قد تصل إلى 95%. هدفت هذه الدراسة إلى تقييم تأثير درجات الحرارة المرتفعة (25°C، 32°C، و40°C) على معدلات خروج الحشرات البالغة من مرحلة العذراء، بالإضافة إلى دراسة إمكانية استخدام الحرارة كوسيلة فيزيائية غير كيميائية لمكافحة الآفة. تم تنفيذ التجربة على مدى أسبوع في وحدة تربية الحشرات، كلية الزراعة، جامعة الإسكندرية. لكل معاملة حرارية، تم إعداد ثلاث مكررات، تحتوي كل منها على 20 عذراء موضوعة في أطباق بتري بقطر 9 سم، تحت ظروف بيئية مضبوطة، وتمت مراقبة خروج البالغين يوميًا. أظهرت النتائج أن أعلى معدل خروج (90%) تحقق عند درجة حرارة 25°C، بينما انخفض المعدل إلى 52% عند 32°C، وتراجع بشكل حاد إلى 13% عند 40°C. تشير هذه النتائج إلى أن درجات الحرارة المرتفعة تؤثر سلبًا على تطور العذراء وخروج البالغين، مما يدعم إمكانية استخدام الحرارة كبديل صديق للبيئة عن المبيدات الكيميائية في مكافحة *B. zonata*. الكلمات المفتاحية: الخوخ، *Bactrocera zonata*، تطور العذراء، الإجهاد الحراري، المعالجة الحرارية، مكافحة غير الكيميائية، الإدارة الحرارية للآفات، جامعة الإسكندرية.

الكلمات المفتاحية: الخوخ، *Bactrocera zonata*، تطور العذراء، الإجهاد الحراري، المعالجة الحرارية، مكافحة غير الكيميائية، الإدارة الحرارية للآفات، جامعة الإسكندرية.

Abstract:

The peach fruit fly (*Bactrocera zonata*) is a highly destructive insect pest that infests a wide range of fruit crops, causing economic losses of up to 95%. This study aimed to evaluate the impact of elevated temperatures (25°C, 32°C, and 40°C) on adult emergence rates from the pupal stage and to assess the potential of heat as a non-chemical physical method for pest control. The experiment was conducted over one week at the Insect Breeding Unit, Faculty of Agriculture, Alexandria University. For each temperature treatment, three replicates were prepared, each containing 20 pupae placed in 9 cm Petri dishes. Dishes were maintained under controlled environmental conditions and monitored daily for adult emergence. Results showed that the highest emergence rate (90%) occurred at 25°C, while emergence declined to 52% at 32°C and dropped sharply to 13% at 40°C. These findings suggest that elevated temperatures adversely affect pupal development and adult emergence, thus

supporting the potential use of heat as an environmentally friendly alternative to chemical control strategies against *B. zonata*.

Keywords: *Bactrocera zonata*, peach fruit fly, pupal development, temperature stress, heat treatment, non-chemical control, thermal pest management, Alexandria University.

1. INTRODUCTION

Bactrocera zonata (Diptera: Tephritidae) is recognized as one of the most economically damaging fruit fly species, particularly in warm and subtropical regions such as Libya, Egypt, and Sudan (EPPO, 2022a). The primary damage arises from the female's oviposition into ripening fruits, which leads to tissue decay, microbial infections, and a significant reduction in marketability. In severe cases, infestation rates can exceed 90%, posing serious threats to both local consumption and international export potential (Bilal et al., 2021).

This pest's high reproductive capacity, broad host range, and adaptability to diverse climatic conditions have rendered conventional control methods—especially chemical pesticides—increasingly ineffective and environmentally problematic. Prolonged reliance on insecticides has contributed to resistance development, ecological imbalance, and health risks to humans and non-target organisms (Mahmood et al., 2016).

In response to these challenges, there is growing interest in alternative control strategies, including biological, behavioral, and physical approaches (Bilal et al., 2021). Among physical factors, temperature plays a critical role in the insect's life cycle, particularly during the pupal-to-adult transition. The pupal stage represents a sensitive developmental checkpoint, where exposure to suboptimal temperatures can disrupt metamorphosis, reduce emergence rates, and impair adult fitness (Xu et al., 2023; Podlesnik, 2025).

Given the increasing environmental and health concerns associated with pesticide use, Mahmood et al. (2016) emphasize the importance of exploring sustainable alternatives. These include integrated pest management (IPM), biological control agents, and organic farming practices that minimize chemical inputs. Such strategies aim to promote ecological balance, safeguard biodiversity, and ensure long-term environmental stability (Awde et al., 2023).

This study investigates the impact of elevated temperatures (25°C, 32°C, and 40°C) on the emergence rates of adult *B. zonata* from pupae, aiming to identify temperature thresholds that could inform sustainable, non-chemical pest control strategies

2. Materials and Methods:

2.1 Experimental Design

The experiment was conducted over a one-week period at the Insect Breeding Unit, Faculty of Agriculture, Alexandria University. *Bactrocera zonata* pupae were sourced from a laboratory-maintained colony reared under standardized conditions:

- Temperature: $25 \pm 2^\circ\text{C}$
- Relative humidity: $65 \pm 5\%$
- Photoperiod: 14 hours light / 10 hours dark

The pupal stage was specifically chosen to evaluate the impact of elevated temperatures on adult emergence success. No other developmental or behavioral parameters were assessed, ensuring that the findings reflect only the thermal influence on pupal survival.

2.2 Temperature Treatments

Three temperature levels were tested: 25°C (control), 32°C, and 40°C. Each treatment was replicated three times, with each replicate consisting of a 9 cm Petri dish containing 20 pupae.

- Petri dishes were placed in thermal incubators calibrated to the designated temperatures.
- All other environmental conditions were kept constant across treatments to isolate the effect of temperature.

2.3 Observation Protocol

Pupal dishes were monitored daily for seven consecutive days. The number of fully emerged adult flies was recorded for each replicate to determine emergence success.

2.4 Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, Version 26.0, with a significance level set at $p < .05$.

- Emergence rate data were analyzed using one-way analysis of variance (ANOVA) to assess the effect of temperature.

- When significant differences were found, Tukey's HSD post hoc test was applied to compare mean emergence rates among treatments.

3.Results and Discussion:

The present study demonstrated a significant influence of temperature on the emergence rates of *Bactrocera zonata* adults from pupae. Observational data revealed that thermal conditions directly affect the success of metamorphosis, suggesting that the pupal stage is particularly sensitive to environmental temperature fluctuations. At 25 °C, the emergence rate peaked at 90% (54 of 60 pupae), indicating that this temperature constitutes an optimal thermal zone for pupal development. This finding aligns with the observations of Choudhary *et al.* (2020), who emphasized the role of moderate temperatures in facilitating enzymatic reactions, hormonal regulation, and tissue differentiation during insect development. The high emergence rate at this temperature suggests that metabolic activities proceed without physiological disruptions, allowing pupae to complete transformation efficiently.

In contrast, increasing the temperature to 32 °C reduced the emergence rate to 51.7% (31 emerged, 29 non-emerged). This decline indicates the onset of thermal stress, possibly linked to disruptions in biochemical processes such as protein synthesis and lipid metabolism, which are critical during metamorphosis. Such stress may impair cellular integrity and increase susceptibility to oxidative damage. Although this intermediate temperature range still permits development, it does so at greater physiological cost and reduced viability, consistent with previous studies on the thermal tolerance of tephritid flies.

The Sankey diagram (Figure 1) visualizes the flow from total pupae to emerged and non-emerged adults at each temperature. At 25 °C, most pupae successfully emerged, whereas at 32 °C and particularly at 40 °C, the proportion of non-emerged individuals increased sharply. This visualization clearly illustrates how increasing temperature shifts the balance from successful emergence toward failure, underscoring the sensitivity of pupal development to thermal stress.

At the highest tested temperature (40 °C), the adult emergence rate dropped sharply to 13.3% (8 emerged, 52 non-emerged), approaching the upper lethal threshold for pupal survival in *B. zonata*. Exposure to such extreme heat may trigger acute physiological stress, including protein denaturation, mitochondrial dysfunction, and hormonal disruption, all of which are critical for metamorphosis and adult development. These results cannot be attributed to rearing conditions, as baseline parameters (humidity, photoperiod, diet) were consistent with established protocols. Similar findings have been reported by Ali *et al.* (2016), who demonstrated that exposure to temperatures above 38 °C markedly increases pupal mortality, and by White and Elson-Harris (1992), who documented the species' limited tolerance to elevated thermal extremes.

The grouped bar chart (Figure 2) presents the number of emerged and non-emerged adults at each temperature, reinforcing the pattern observed in Figure 1. At 25 °C, emergence was highest, with a notable decline at 32 °C and a dramatic reduction at 40 °C, where most pupae failed to emerge. The pattern suggests that temperature strongly influences emergence success, with optimal development occurring at 25 °C and severe impairment under heat stress. Results from the flight ability test of *B. zonata* reared on natural fruit and semi-artificial diet indicated that the percentage of adult emergence was 49.33% and 70.67% for pupae reared on guava fruit and semi-artificial diet, respectively (Rafiaa A. Rabab *et al.*, 2016).

Table 1 summarizes the quantitative differences in emergence rate and mean $\pm$ SD values across treatments. Statistically significant differences (Tukey's HSD, $p < .05$) were recorded between all temperature pairs, with the largest gap between 25 °C and 40 °C ($p < .001$). The results collectively confirm that elevated pupal temperatures have a detrimental impact on emergence success, likely through thermal stress-induced physiological disruption, in agreement with findings on other insect species (Awde *et al.*, 2023).

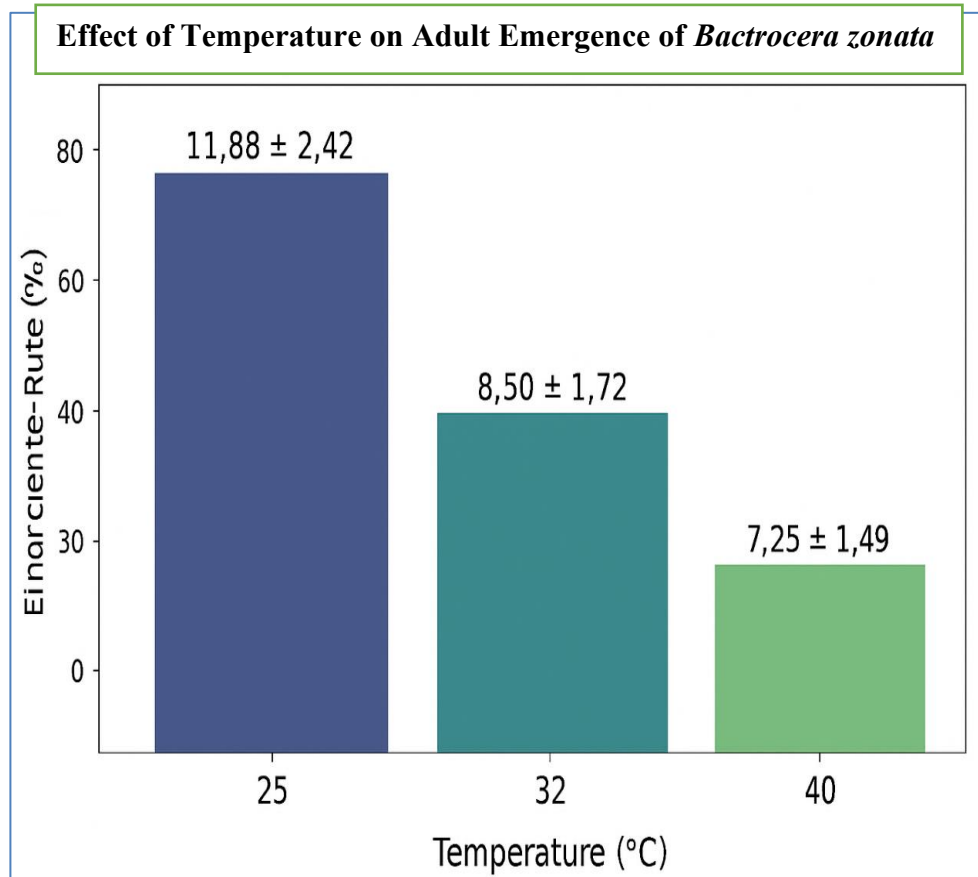
Table 1. Effect of Temperature on Adult Emergence of *Bactrocera zonata*

Temperature (°C)	Total Pupae	Adults Emerged	Emergence Rate (%)	Mean $\pm$ SD
25	60	54	90.0 a	11.88 $\pm$ 2.42 a
32	60	31	51.7 b	8.50 $\pm$ 1.72 b
40	60	8	13.3 c	7.25 $\pm$ 1.49 c

Different letters (a, b, c) indicate statistically significant differences at $P < 0.05$ according to Tukey's HSD test. Significant differences were recorded between: 25°C and 32°C ($P < 0.05$), 25°C and 40°C ($P < 0.001$), 32°C and 40°C ($P < 0.05$).

Adult emergence rates of *Bactrocera zonata* pupae exposed to three temperature treatments (25 °C, 32 °C, and 40 °C). Emergence rates (mean $\pm$ SD) declined significantly with increasing temperature. Different superscript letters (a, b, c) denote statistically significant differences ($p < .05$) based on Tukey's HSD post hoc test. Table 2 further illustrates the distribution of emerged and non-emerged adults across temperature treatments, confirming the trend observed in Figures 1 and 2.

Figure 3 provides a visual representation of pupal outcomes under varying temperature treatments, highlighting the increased rate of emergence failure at higher temperatures. This supports the quantitative findings presented earlier



Sankey Diagram Showing Adult Emergence Flow at Different Temperatures

Visual representation of the flow from total pupae to emerged and non-emerged adults at 25 °C, 32 °C, and 40 °C. The diagram highlights the progressive shift toward emergence failure as temperature increases.

Table2: Effect of Temperature on Pupa Emergence

Non-emerged	Adults Emerged	Temperature (°C)
6	54	25
29	31	32
52	8	40

Table2 Explanation: Illustrates the impact of temperature on the emergence of adult insects from pupae. At 25°C, the highest emergence rate was observed, with 54 adults successfully emerging and only 6 remaining non-emerged. As the temperature increased to 32°C, the emergence rate declined, showing a more balanced distribution between emerged and non-emerged individuals. At 40°C, emergence was significantly reduced, with only 8 adults emerging and 52 failing to do so. These results suggest that moderate temperatures (around 25°C) are optimal for pupal development, while higher temperatures negatively affect emergence success.

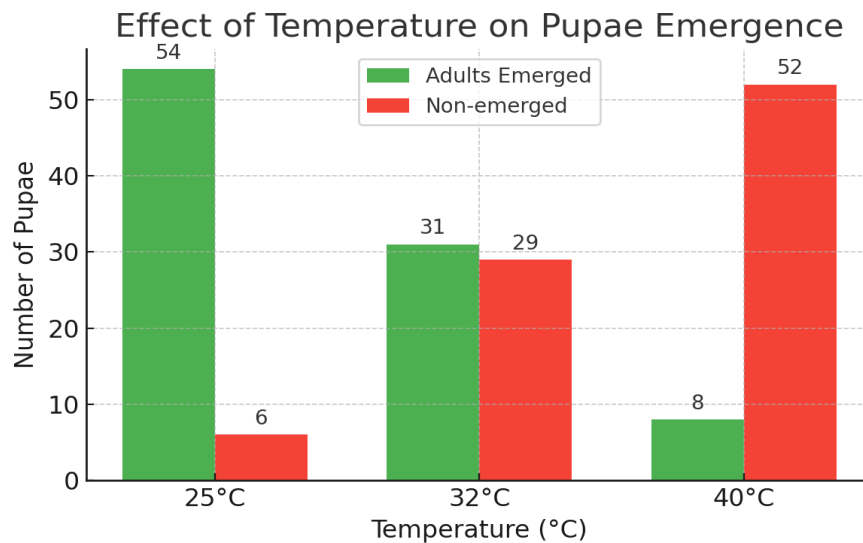


Figure 2. Comparison of Emerged and Non-Emerged Adults at Each Temperature.

Grouped bar chart comparing the number of emerged versus non-emerged adults at 25 °C, 32 °C, and 40 °C. Error bars represent mean $\pm$ SD, highlighting the decline in developmental success under thermal stress.

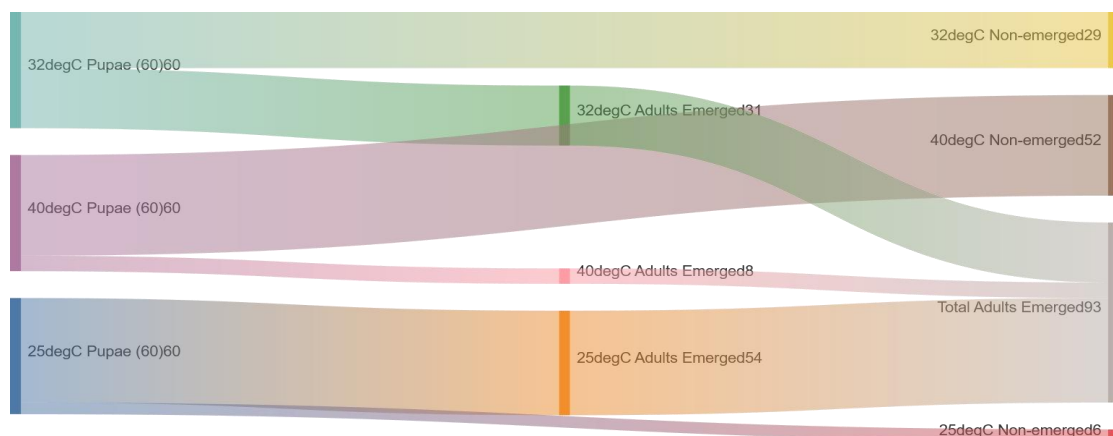


Figure 3. Visual representation of the flow from total *Bactrocera zonata* pupae to emerged and non-emerged adults at 25 °C, 32 °C, and 40 °C.

The diagram highlights the progressive shift toward emergence failure as temperature increases, emphasizing the thermal sensitivity of the pupal stage.

The findings of this study clearly demonstrate that the developmental success of *Bactrocera zonata* during the pupal stage is highly sensitive to environmental temperature fluctuations. Moderate thermal conditions, particularly around 25 °C, significantly enhanced adult emergence rates, indicating that this temperature provides an optimal physiological environment for successful metamorphosis. These results support the hypothesis that temperature acts as a key regulator of metabolic and hormonal pathways essential for insect development.

Conversely, elevated temperatures—especially those approaching or exceeding 32 °C—substantially reduced emergence rates. The sharp decline observed at 40 °C suggests the existence of a thermal threshold beyond which pupal survival is severely compromised. This adverse effect is likely due to heat-induced physiological stress, including protein denaturation, enzymatic inhibition, and disruption of developmental signaling mechanisms.

These findings contribute meaningfully to the broader understanding of *B. zonata*'s ecological responses to thermal stress and underscore the role of temperature as a limiting factor in its life cycle. Moreover, the data presented offer a valuable foundation for predictive modeling in pest management strategies, particularly under

scenarios of climate variability. Targeting vulnerable developmental stages within specific temperature ranges may provide novel opportunities for population suppression in integrated pest management (IPM) programs.

References:

1. Ali, M. A. (2016). Effect of temperature on the development and survival of immature stages of the peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *African Journal of Agricultural Research*, 11(36), 3375–3381.
2. Awde, D. N., Řeřicha, M., & Knapp, M. (2023). Increased pupal temperature has reversible effects on thermal performance and irreversible effects on immune system and fecundity in adult ladybirds. *Communications Biology*, 6, Article 838.
3. Bilal, H., Khan, M. A., Shah, M., & Ahmad, M. (2021). Management of *Bactrocera zonata* through application of different tactics: A review. *Current Research in Agriculture and Farming*, 2(3), 8–16.
4. Choudhary, J. S., Mali, S. S., Naaz, N., Singh, S., & Prabhakar, C. S. (2020). Predicting the population growth potential of *Bactrocera zonata* using temperature development growth models and their validation under fluctuating temperature conditions. *Phytoparasitica*, 48(1), 1–13. <https://doi.org/10.1007/s12600-019-00777-4>
5. EPPO. (2022a). *Bactrocera zonata* datasheet. EPPO Global Database. <https://gd.eppo.int/taxon/DACUZO>
6. Mahmood, I., Imadi, S. R., Shazadi, K., Gul, A., & Hakeem, K. R. (2016). Effects of pesticides on environment. In K. R. Hakeem, M. Akhtar, & S. Abdullah (Eds.), *Plant, Soil and Microbes* (pp. 253–269). Springer. https://doi.org/10.1007/978-3-319-27455-3_13
7. Podlesnik, J. (2025). Pupal development and thermal tolerance in *Tenebrio molitor*. *Insects*, 16(4), 402.
8. Rabab, R. A., Al-Eryan, M. A., El-Minshawy, A. M., & Gadelhak, G. G. (2016). Laboratory rearing of the peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) on semi-artificial diet based on soybean protein. *Alexandria Journal of Agricultural Sciences*, 61(3), 175–183.
9. White, I. M., & Elson-Harris, M. M. (1992). *Fruit flies of economic significance: Their identification and bionomics*. CAB International.
10. Xu, X., Zhang, Y., Li, H., & Chen, J. (2023). Impacts of high temperature on pupal development in *Apis cerana*. *Frontiers in Ecology and Evolution*. <https://www.frontiersin.org/journals/ecology-and-evolution>