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Quantitative Evaluation of the Lethal Impact of High Temperature from Summer Sunlight on the Life Stages of the Sawtoothed Grain Beetle, *Oryzaephilus surinamensis* L. Under the climatic conditions of the city of Kirkuk.

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Abstract. *This study aimed to evaluate the lethal efficacy of high temperatures from sunlight during July and August on the larvae and adults of the sawtoothed grain beetle,* Oryzaephilus surinamensis *L. Insect colonies were obtained from local wheat grain stores in Kirkuk markets, containing adult individuals of this insect. They were utilized by rearing them in an incubator at 30±2°C and 70±5% relative humidity in the laboratories of the College of Education for Women, Department of Life Sciences. The resulting larvae and adults were then used to conduct the experiments of this study. Advanced-stage larvae were taken and placed in Petri dishes at a rate of ten larvae per dish. Similarly, one-week-old adults were taken and placed in Petri dishes at a rate of ten adults per dish, with three replicates for each treatment. They were then exposed to direct sunlight using three exposure periods (10:00 AM, 12:00 PM, and 2:00 PM) for durations of (15, 30, 45) minutes during July and August 2025 under the conditions of Kirkuk city. The results of the study indicated a direct correlation between temperature intensity and mortality rate. Larvae recorded slightly higher resistance levels than adults, as temperatures in the first weeks of July were the most lethal for both stages, and the last weeks of August had the least killing effect on both stages. The study concluded that the technique of solar heat exposure during summer is a promising non-chemical strategy that can be incorporated into integrated pest management programs.*

Keywords: *Sunlight, Thermal stress, Sawtoothed grain beetle,* Oryzaephilus surinamensis.

INTRODUCTION

The sawtoothed grain beetle is considered a primary pest that can cause devastating damage to stored grains worldwide, resulting in significant economic losses due to its feeding on grains and their products and contamination [1]. The intensive use of chemical pesticides to control this insect has also led to numerous problems, most notably the observed development of resistance, in addition to product contamination and increased risks to human health and the environment [2, 3]. The search for natural, non-chemical alternatives has become imperative. Physical control methods, including the use of gamma radiation, low-temperature technology, carbon dioxide, light traps, yellow sticky traps, ultrasonic waves, pneumatic discharge, diatomaceous earth, and high temperatures such as the technique of using direct sunlight, are successful alternative methods that rely on using high heat to eradicate pests without leaving residues [4, 5, 6]. The climate of many regions is characterized by peak temperatures, especially during July and August, providing an opportunity to apply the direct solar exposure technique as part of an integrated pest management program [7, 8].

MATERIALS AND METHODS

Samples of adult *Oryzaephilus surinamensis* beetles were collected from infested rice grains gathered from grain stores in local markets of Kirkuk city during June 2025. After confirming that the insect samples belonged to a single species, the sawtoothed grain beetle, through identification by Professor Dr. Fadel Abbas – College of Medicinal and Industrial Plants, University of Kirkuk, they were reared in the laboratory of the Department of Life Sciences, College of Education for Women, University of Kirkuk. The insects were cultured by placing them in sterilized 1-liter glass jars, using sound, uninfested rice grains that had been placed in a freezer for 48 days and then transferred to the glass jars as a preferred food medium. The jars were covered with a well-ventilated muslin cloth and secured with rubber bands to prevent the insects from escaping. They were placed in an incubator at 30±2°C and 70±5% relative humidity to produce new generations [9, 10].

The insects were divided into two groups: one-week-old adult insects, and larvae in late stages [3, 4, 11]. Groups of 10 adult insects were placed in sterilized Petri dishes with three replicates, and groups of ten larvae were placed in other Petri dishes with three replicates. They were then exposed to direct sunlight on the building rooftop during three daytime periods (10:00 AM, 12:00 PM, 2:00 PM), using three exposure durations for each time (15, 30, 45) minutes. Results were recorded after measuring the temperatures at those times, while the control sample was kept at room conditions (28°C). Samples were transferred after each treatment to room conditions, and mortality percentage was recorded after 24 hours, considering an insect dead if it showed no movement when gently prodded [10, 12]. The study experiments were designed using a Complete Randomized Design (C.R.D.). Arithmetic means of treatments were compared using Duncan's Multiple Range Test at a 0.05 probability level. Results were analyzed using SAS version 6 software.

RESULTS AND DISCUSSION

Table 1. The effect of solar radiation temperature on the mortality rate of the adults Sawtoothed beetle *Oryzaephilus surinamensis* during July.

time	15 min	30 min	45 min	mean time
10:..	100.0 a	100.0 a	100.0 a	100.0 a
12:..	100.0 a	100.0 a	100.0 a	100.0 a
02:..	100.0 a	100.0 a	100.0 a	100.0 a
control	0.0 b	0.0 b	0.0 b	0.0 b
mean priod	75.0 a	75.0 a	75.0 a	

Similar letters in same column mean that there are no significant differences between them at a probability level of 0.05

The results showed a direct correlation between increased temperature and exposure duration on raising the mortality percentages for both adults and larvae of *Oryzaephilus surinamensis*. Table 1 shows that mortality rates for adults reached 100% at all exposure times (10:00 AM, 12:00 PM, 2:00 PM) and for all exposure durations (15, 30, 45) minutes during July, which is characterized by high daytime temperatures in Iraq in general and Kirkuk city in particular, where temperatures ranged between 43-49°C. Meanwhile, no mortality was recorded for the control samples kept at room conditions [13].

Table 2. The effect of solar radiation temperature on the mortality rate of the adults Sawtoothed beetle *Oryzaephilus surinamensis* during August.

time	15 min	30 min	45 min	mean time
10:..	50.75 b	67.50 ab	100.0 a	72.75 b
12:..	100.0 a	100.0 a	100.0 a	100.0 a
02:..	100.0 a	100.0 a	100.0 a	100.0 a
control	0.0 c	0.0 c	0.0 c	0.0 c
mean priod	62.68 a	66.87 a	75.0 a	

Similar letters in same column mean that there are no significant differences between them at a probability level of 0.05

Table 2 shows significant differences in mortality rates of adult sawtoothed grain beetles depending on the times and durations of solar heat exposure during August in Kirkuk city. It is known that temperatures began to decline during the days of August, especially in its last two weeks, where daytime temperatures ranged between 35-43°C. Table 2 indicates that the highest mortality rates were at times (12:00 PM and 2:00 PM) for all exposure durations (15, 30, 45) minutes, which reached 100%. Meanwhile, mortality rates during (10:00 AM) and for exposure durations (15 and 30) minutes were (50.75, 67.50)% respectively, showing a decrease in the number of dead insects, indicating that this heat level is insufficient for control [14].

Table 3. The effect of solar radiation temperature on the mortality rate of the Sawtoothed beetle *Oryzaephilus surinamensis* larvae during July.

time	15 min	30 min	45 min	mean time
10:..	10.75 c	67.50 b	100.0 a	59.41 b
12:..	100.0 a	100.0 a	100.0 a	100.0 a
02:..	100.0 a	100.0 a	100.0 a	100.0 a
control	0.0 c	0.0 c	0.0 c	0.0 c
mean priod	52.68 c	66.87 b	75.0 a	

Similar letters in same column mean that there are no significant differences between them at a probability level of 0.05

The results in Table 3 show no significant differences between exposure durations for larval heat stress in August during the hours (12:00 and 2:00) PM for all durations (15, 30, 45) minutes, as larval mortality reached 100%, demonstrating the effectiveness of these times for control. Also, during 10:00 AM at a 45-minute exposure duration, mortality reached 100%. However, the results showed a significant decrease in mortality percentage and significant differences at exposure durations (15, 30) minutes during 10:00 AM, reaching (10.75, 67.50)% respectively.

Table 4. The effect of solar radiation temperature on the mortality rate of the Sawtoothed beetle *Oryzaephilus surinamensis* larvae during August.

time	15 min	30 min	45 min	mean time
10:..	20.75 c	57.50 b	97.50 a	58.58 b
12:..	82.50 ab	95.00 a	100.0 a	92.50 a
02:..	82.50 ab	97.50 a	100.0 a	93.33 a
control	0.0 c	0.0 c	0.0 c	0.0 c
mean priod	46.43 b	62.50 a	74.37 a	

Similar letters in same column mean that there are no significant differences between them at a probability level of 0.05

Larvae were more tolerant to heat stress than adults, requiring longer exposure time to increase mortality rates [8]. Results in Table 4 show significant differences between exposure durations during daytime hours in August. The effect was lethal to sawtoothed grain beetle larvae at a rate of 100% for a 45-minute exposure during times (12:00 and 2:00) PM, showing no significant differences with mortality rates at a similar exposure duration but during 10:00 AM, which was 97.50%. Also, there were no significant differences with a

30-minute exposure during times (12:00 and 2:00) PM, each reaching 95.00 and 97.50% respectively. The lowest effect was recorded during a 15-minute exposure at 10:00 AM, reaching 20.75%. Mortality rates were 82.50% for a 15-minute exposure at both times (12:00, 2:00) PM.

Tables 1, 2, 3, and 4 illustrate the cumulative effect of solar heat and exposure duration. For example, in Table 4 at a temperature of 35-37°C, larval mortality was 20.75% for a 15-minute exposure at 10:00 AM in August, while this rate increased to 97.50% when the exposure duration was increased to 45 minutes during the same time. This indicates that the success of this technique depends not only on high temperature but also on maintaining this heat for a sufficient period to allow thermal energy to reach all larval stages hidden among grains [15, 16].

Comparing data in Table 2 with Table 4, larvae showed significantly greater resistance than adults at most temperatures. The average mortality rates for adults in Table 2 were (62.68, 66.87, 75.00)% for exposure durations (15, 30, 45) minutes respectively across all times, while the average mortality rates for larvae in Table 4 were (46.43, 62.50, 74.37)% for the same exposure durations as adults. This variation in heat stress resistance can be attributed to physiological and morphological factors, as the larval cuticle may have greater thickness or efficiency in producing heat shock proteins (HSPs) which function to protect cells from damage [14, 17].

CONCLUSIONS

This study concludes that high temperatures during July and August in Kirkuk city have a lethal effect on the life stages of the sawtoothed grain beetle, with larvae exhibiting superior tolerance. These results provide a scientific basis for applying and developing solar exposure technology as an effective, economical, and environmentally friendly technique within integrated pest management programs. This approach can contribute to reducing reliance on chemical pesticides, improving the safety and quality of stored products, and thus reducing economic losses caused by this important pest.

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Conflict of Interest Statement: *The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*