EGYPTIAN ACADEMIC JOURNAL OF
BIOLOGICAL SCIENCES
ENTOMOLOGY

A

ISSN
1687-8809

WWW.EAJBS.EG.NET

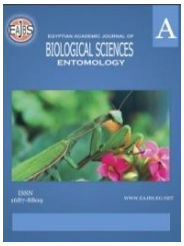
Vol. 16 No. 1 (2023)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 16(1) pp.165-178 (2023)*
DOI: 10.21608/EAJBSA.2023.293366

Egypt. Acad. J. Biolog. Sci., 16(1):165-178(2023)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/



Efficacy of Solar Heating System on Mortality, Reproduction, and Antioxidant Enzymes in *Trogoderma granarium* Everts and *Stegobium paniceum* (L.)

Rasha A. Zinhoum[1], Abeer O. Abotaleb[1], Nilly A. H. Abdelfattah[1]and Shams Fawki[2*]

1-Stored Product Pest Department, Plant Protection Research Institute, Agricultural Research Centre, Giza, 12619, Egypt.

2-Entomology Department, Faculty of Science, Ain Shams University, Abbasiya, 11566, Cairo, Egypt.

***E-mail:** shfawki@sci.asu.edu.eg

ARTICLE INFO

Article History
Received:19/1/2023
Accepted:9/3/2023
Available:14/3/2023

Keywords:
Thermal control, khapra beetle, drugstore beetle, biochemical studies, germination.

ABSTRACT

Solar heating is a promising technique for controlling stored product insect pests. In this study, we investigated the effect of a solar heating system at different exposure times (0, 5, 10, 15, 20 and 30 min) on different developmental stages of *Trogoderma granarium* (Coleoptera: Dermestidae) and *Stegobium paniceum* (L.) (Coleoptera: Anobiidae) on wheat. Exposing wheat to 75 °C for 20 min resulted in complete mortality of adult beetles for both species. Solar heating for immature stages (eggs, larvae, and pupa) resulted in complete suppression in adult emergence after 15 min at 70°C and after 20 min at 75°C in both species. From the bioassay, the pupal stage was the most tolerant stage to solar heating. The effect of solar heating on the two antioxidant enzymes peroxidase (POD) and glutathione S-transferases (GSTs) as well as the total protein amount was also investigated. The total protein content of the larvae of *T. granarium* and the adults of *S. paniceum* exposed to solar heating was significantly lower than the total protein of the parallel control samples. Furthermore, there was a highly significant difference in GST and POD activity between the control and treated samples in both species. In addition, the viability of the wheat grains was not affected by heat treatment. Thus, solar heating is recommended as an effective alternative to chemical control for stored grain insect management.

INTRODUCTION

Protecting cereals and their products against insect pests is a critical concern for future food security. Wheat is the most significant cereal crop as a staple food all over the world, and it plays a key role in the country's food and nutritional security. Wheat provides around 20% of the calories consumed by nearly 55% of the world's population (Kumar *et al.,* 2014). Due to weather fluctuations in several places, global wheat output in 2022 has decreased by 2.7 million metric tonnes (FAO, 2022).

Egypt is the world's largest wheat importer with an annual wheat consumption of approximately 20.5 million tons in 2021–2022: only 9 million tons are produced annually, and 13 million tons are imported from outside (USDA, 2022). Egypt has implemented a strategy to minimize the production-consumption gap by growing wheat fields on newly reclaimed lands, thus, raising grain productivity and reducing post-harvest wheat loss. The

harvest and post-harvest losses along the wheat value chain are estimated at more than 1 million tons of grain. These losses represent about 13–15% of the local wheat production (Yigezu *et al.,* 2021). This huge loss in quantity and quality is mainly due to the attack of storage insects (Kalsa *et al.,* 2019; Demis & Yenewa, 2022).

The Khapra beetle, *Trogoderma granarium* (Everts) (Coleoptera: Dermestidae), which is predominantly known as a pest of stored wheat and is responsible for postharvest losses of up to 30%, is classified as an A2 quarantine organism and one of the 100 worst invasive species in the world (Ahmedani *et al.,* 2011; EPPO, 2011).

The drugstore beetle, *Stegobium paniceum* (L.) (Coleoptera: Anobiidae), is a serious pest that attacks a wide variety of foods and materials. It is quoted as saying that it "eats anything but cast iron." (Cabrera, 2001) Larval feeding causes most of the product damage (Hagstrum and Subramanyam, 2009; Abdelghany *et al.,* 2010).

Globally, fumigation with phosphine (PH_3) is the common technique for controlling stored-product insects because of its efficiency, ease of use, and low cost. However, the high resistance of treated insects to PH_3 is a major disadvantage (Venkidusamy *et al.,* 2017). Thus, it is crucial to create safe alternatives that provide the same advantages as phosphine while avoiding its hazards.

Solar heat has been used as a thermal control method against stored-product insects. Several studies revealed that solar radiation and thermal control are very promising for controlling stored product insect pests without affecting the quality of the treated product (Strang, 2014; Abdullahi *et al.,* 2019; Fawki *et al.,* 2022; FAO, 2023).

The objective of this research is to evaluate the effect of solar heating on all developmental stages of *T. granarium* as well as the larval, pupal, and adult stages of *S. paniceum*. Furthermore, the present study was carried out to investigate the impact of solar heating on the antioxidant enzymes peroxidase (POD), glutathione S-transferases (GSTs), and the total protein of *T. granarium* larvae and *S. paniceum* adults.

MATERIALS AND METHODS

1. Rearing Technique:

The insect stocks (*T. granarium* and *S. paniceum*) that were used in this research were obtained from a stock culture that was maintained at the Department of Stored Grain and Product Pests, Plant Protection Research Institute, Agriculture Research Center, Cairo, Egypt. The insect cultures were maintained in glass jars on 200 g of the food media (*T. granarium* on whole wheat and *S. paniceum* on wheat flour) and covered with muslin. The cutlers were incubated in the optimum rearing conditions at 28 ± 2°C and 65 ± 5% RH. The wheat and flour used for the bioassay were kept in the freezer for 10 days to eliminate any previous insect infestation. The target insect was reared for several generations before starting the experiments.

2. Solar Heat System Technique:

Solar heating was conducted using an obtuse-base-angle metal box described by Fawki *et al.* (2014). The box was designed from 1 mm thick galvanized metal plates with upper dimensions of 51 x 20 cm, length by width. A glass plate was provided in the middle horizontal plane of the box to hold all experimental treatments. This glass plate improves the greenhouse effect and the heating capacity of the box (El-Adawi and Shalaby, 2007) Before sun exposure, a black polystyrene sheet was spread beneath the box to absorb solar radiation. During the experiment, the box was closed with a clear plastic cover (0.15 mm thickness) to generate a greenhouse effect for heat disinfestation of grains and flour samples (Aalfs, 2011). Temperatures, relative humidity inside the box, and ambient weather conditions were recorded using thermometers and hygrometers. All the experiments were done on sunny

clear days between April and August 2020 and 2021. Sun exposure was conducted between 12-3 pm when sun rays are perpendicular to the earth with maximum solar radiation density. Five exposure times of solar heating (5, 10, 15, 20, and 30 min) were tested against (Egg, larvae, pupa and adult) stages of *T. granarium* and (larvae, pupa and adult) stages of *S. paniceum*. All tested treatments were repeated four times, and for each treatment, another untreated group was kept in an incubator at 28 ± 2°C and 65 ± 5% RH as a control group.

3. Effect of Solar Heating on Different Stages of *T. granarium* and *S. paniceum*:

Newly emerged adults (0–24 h) were carefully separated by sieving and transferred to glass tubes containing 10 g of wheat grains in the case of *T. granarium* or wheat flour in the case of *S. paniceum* g (20 adults per tube). The tubes were covered with muslin and placed on the glass plate in the center of the metal heater as previously mentioned. Afterwards, the metal box was covered with a transparent plastic sheet. At the end of each exposure period, the tubes were kept in the laboratory for about 24 h then adult mortality was recorded.

To obtain *T. granarium* eggs for experimentation, 200 unsexed adults, approximately 3 days old, were transferred from the culture to a 250 ml glass jar that contained 125 g of soft white wheat flour for 1 day (Papanikolaou *et al.*, 2019). Then, the separation of adults and eggs from the flour was conducted with a standard testing sieve. The eggs that remained on the mesh openings of the sieve were put in a Petri dish and kept for 3 days before the beginning of the experiments at 28 ± 2°C and 65 ± 5% RH. Egg development takes place within 4.68 and 4.81 days (Kavallieratos *et al.*, 2019). On the fourth day, a group of ten eggs was transferred carefully to a glass dish using a slender-haired brush (ten eggs per dish) then was covered with muslin secured tightly by rubber bands. All treatments were exposed to the sun radiation in the metal box under the same conditions mentioned for the adult stage. After sun exposure, all tested dishes were transferred into an incubator set at 28 ± 2°C and 65 ± 5% RH. The mortality percentage per replicate was calculated. Afterwards, 10 g of wheat was put into each replicate until adult emergence. The number of emerging adults was counted in the treatment and the control groups.

For larval and pupal stages, thirty larvae and thirty pupae were put into glass tubes and provided with 10 g of wheat grains in the case of *T. granarium* or wheat flour in the case of *S. paniceum*. Then covered with muslin secured tightly by rubber bands and exposed to solar radiation in the metal box under the same circumstances as mentioned for the adult stage. After sun exposure, all tubes were transferred to an incubator at 28 ± 2°C and 65 ± 5% RH. For each larval replicate, the larval mortality (%) was recorded while for the pupal stage, the number of adult emergence was recorded for each treatment and the control group as well.

4. Effect of Solar Heating on Germination of Wheat Grains:

The germination experiment was conducted according to the International Seed Testing Association's criteria for grain testing (Wang *et al.*, 2012). To find out the effect of solar heating for 30 min (the longest exposure duration time) on the quality of wheat grains. Glass tubes of all treatments were placed in the heating box along with 20 g of grains and after 24 hours of sun exposure, samples were taken for the germination test.

5. Effect of Solar Heating on Some Biochemical Analyses:

A sample of 1 g of *T. granarium* larvae and *S. paniceum* adults were selected 24 h post-exposure to sun heat for 15 min at 70°C (half of the longest exposure duration time). Treated and untreated samples were kept in the deep freezer until used for physiological analysis. Glutathione S-transferase (GST) and peroxidase (POD) were determined according to the methods of Habig *et al.* (I974) and Hammerschmidt *et al.* (1982), respectively. Adults and larval protein contents were extracted and determined according to the method described by Bradford (1976).

5. Statistical Analysis:

For statistical analysis, the mortality (%) of different insect stages was calculated and corrected using Abbott's formula (Abbott, 1925). The no. of dead insects, insect mortality (%) and adult emergence were analyzed using one-way analysis of variance (ANOVA) and performed at a 5% significance level using (SPSS) computer program. Then a pairwise analysis was performed using Duncan multiple range tests (Duncan, 1955).

RESULTS

1. Effect of Solar Heating on the Adult of *T. granarium* and *S. paniceum*:

Results concerning the evaluation efficacy of solar heating on the adult mortality of *T. granarium* and *S. paniceum* are shown in Table 1. The adult mortality of the two species increased with the increase in exposure periods. Complete adult mortality was observed in both species after 20 min.

Table 1: No. of dead adults and adult mortality of *Trogoderma granarium* and *Stegobium paniceum* post-exposure to different duration of solar energy.

Insect species	Exposure duration (minutes)	Temperature (°C)		no. of dead adults (mean ± SE)	Adult mortality (%)
		Inside the metal heater	Outside the metal heater		
T. granarium	0	0	28	0 ± 0.00 ^{a}	0
	5	43	30	3.33 ± 0.27 ^{b}	16.67
	10	65	32	8 ± 0.47 ^{c}	40
	15	70	35	13 ± 1.25 ^{d}	65
	20	75	37	20 ± 0.00 ^{e}	100
	30	78	40	20 ± 0.00 ^{e}	100
F				129	
P				0.000	
S. paniceum	0	0	28	0 ± 0.00 ^{A}	0.00
	5	43	30	4 ± 0.47^{B}	20
	10	65	32	8.33 ± 0.72 ^{C}	41.66
	15	70	35	14.6 ± 1.91 ^{D}	73.33
	20	75	37	20 ± 0.00 ^{D}	100
	30	78	40	20 ± 0.00 ^{D}	100
F				103.55	
P				0.000	

N.B. Means followed by different letters are significantly different at $P < 0.05$.

2. Effect of Solar Heating on Different Developmental Stages of *T. granarium*:

The number of adult survivorships from different developmental stages of *T. granarium* after sun exposure of infested wheat grains to different duration of solar heating is shown in Table 2. For both eggs and larval groups, complete inhibition of adult emergence was obtained at 70°C after just 15 min of sun exposure, while for the pupal stage, complete inhibition was achieved at 75°C after 20 min exposure to solar heating. This indicates that the pupal stage was the most tolerant stage to solar-powered heat.

Table 2. No. of dead eggs/ larvae, mortality, and no. of emerged adults from different developmental stages of *Trogoderma granarium* after exposure to different duration of solar energy.

Developmental stages	Exposure duration (minutes)	Temperature (°C)		No. of dead (mean ± SE)	Mortality (%)	No. of emerged adults (mean ± SE)	Adults' emergence (%)
		Inside the metal heater	Outside the metal heater				
Egg	0	0	28	1±0.00 ^{a}	8.49	9±0.58 ^{a}	75.48
	5	43	30	6±0.00 ^{b}	47.43	4.67±0.33 ^{bc}	36.75
	10	65	32	11.33±0.33 ^{c}	64.48	3.67±0.67 ^{c}	20.47
	15	70	35	14.00±00 ^{d}	100	0±0.00 ^{d}	0
	20	75	37	15.67±0.00 ^{d}	100	0±0.00 ^{d}	0
	30	78	40	20±00 ^{d}	100	0±0.00 ^{d}	0
F	-	-	-	50.82	-	80.64	-
P	-	-	-	0.00	-	0.00	-
Larva	0	0	28	0±0.00 ^{A}	0.00	10±0.00 ^{A}	100
	5	43	30	0.67±0.33 ^{AB}	6.67	5.33±0.33 ^{B}	53.33
	10	65	32	1.67±0.34 ^{B}	16.67	1.33±0.67 ^{C}	13.33
	15	70	35	3.66±0.66 ^{C}	36.66	0±0.00 ^{D}	0
	20	75	37	8.33 ± 0.66 ^{D}	83.33	0 ±0.00 ^{D}	0
	30	78	40	10 ± 0.00 ^{F}	100	0±0.00 ^{D}	0
F	-	-	-	89.69	-	196.46	-
P	-	-	-	0.00	-	0.00	-
Pupa	0	0	28	-	-	17.67 ± 1.45 $^{A`}$	88.33
	5	43	30	-	-	7 ± 1.53 A $^{B`}$	35
	10	65	32	-	-	4 ± 0.58B $^{C`}$	20
	15	70	35	-	-	2.67 ± 0.88 $^{C`}$	13.33
	20	75	37	-	-	0.00 ± 0.00 $^{C`}$	0
	30	78	40	-	-	0.00 ± 0.00 $^{C`}$	0
F	-	-	-	-	-	42.27	-
P	-	-	-	-	-	0.00	-

N.B. Means followed by different letters are significantly different at $P < 0.05$.

3. Effect of Solar Energy on Different Developmental Stages of *S. paniceum:*

The number of adult survivorships from different developmental stages of *S. paniceum* after exposure of infested wheat grains to different duration of solar heating is shown in Table 3. In the larval stage, complete inhibition of adult emergence was obtained at 70°C after just 15 min of sun exposure, but in the case of the pupal stage, complete adult inhibition was obtained at 75°C after 20 min of exposure. This indicates that the pupal stage was the most tolerant stage of solar heating.

4. Effect of Solar Heating on Some Biochemical Analyses:

Changes in GST, POD enzymes activity and total protein of *T. granarium* larvae and *S. paniceum* adults after exposure to 15 min (half of the longest exposure duration time) of solar heating are shown in Table 4. The total protein content of both *T. granarium* larvae and *S. paniceum* adults that were exposed to 15 min (half of the longest exposure duration time) of solar heating was significantly decreased by half as compared to the control samples, (F=179.5; $P < 0.0002$) and (F=273.2; $P < 0.0001$), respectively. The application of 15 min of solar heating on *T. granarium* larvae resulted in a significant decrease in GST (F=113.38; $P < 0.0004$) compared to the control sample. Contrary a significant increase was observed in GST (F=28.6; $P < 0.006$) of *S. paniceum* adults after exposure to 15 min of solar heating as compared to the control sample. For POD, the enzyme production was significantly increased in both *T. granarium* larvae and *S. paniceum* adults (F=68.58; $P < 0.001$) and (F=206.66; $P < 0.0001$), respectively, when exposed to 15 min of solar heating compared to the control sample.

Table 3: No. of dead insects, mortality and no. of adult emergence from different developmental stages of *Stegobium paniceum* after exposure to different duration of solar energy.

Developmental stages	Exposure duration (minutes)	Temperature (°C)		No. of dead (mean± SE)	Mortality (%)	No. of emerged adults (mean± SE)	Adults' emergence (%)
		Inside the metal heater	Outside the metal heater				
Larva	0	0	28	0 ± 0.00 ^{a}	0	9.67 ± 0.33 ^{a}	96.67
	5	43	30	0.67 ± 0.67 ^{ab}	6.67	5.67± 0.88 ^{b}	56.67
	10	65	32	2.00 ± 0.58 ^{abc}	20	4 ± 0.58 ^{c}	40
	15	70	35	4.67 ± 0.67 ^{abc}	46.67	0 ± 0.00 ^{d}	0
	20	75	37	10 ± 0.00 ^{c}	100	0 ± 0.00 ^{d}	0
	30	78	40	10 ± 00 ^{abc}	100	0 ±0.00 ^{d}	0
F	-	-	-	25.60	-	42.3	-
P	-	-	-	0.00	-	0.00	-
pupa	0	0	28	-	-	19 ± 0.57 ^{a}	95
	5	43	30	-	-	6 ± 0.57 ^{b}	30
	10	65	32	-	-	2.67 ± 0.33 ^{c}	13.33
	15	70	35	-	-	2 ± 1.00 ^{c}	10
	20	75	37	-	-	0 ± 0.00 ^{c}	0
	30	78	40	-	-	0 ± 0.00 ^{c}	0
F	-	-	-	-	-	60.7	-
P	-	-	-	-	-	0.00	-

N.B. Means followed by different letters are significantly different at $P < 0.05$.

Table 4: Changes in total protein, glutathione S-transferase (GST), and peroxidase (POD) enzymes activity in *Trogoderma granarium* larvae and *Stegobium paniceum* adults after solar radiation exposure for 15 min at a temperature range from 43 to 70°C inside a metal box.

Insect species/ stages	Treatment	Total protein (mg/g.b. wt) (mean± SE)	GST (Mmol sub.conj./min/mg protein) (mean ± SE)	POD (Δ mO.D./min/mg protein) (mean ± SE)
***T. granarium* larvae**	**Control**	24.47±0.79 ^{a}	2120 ± 21.01 ^{a}	99.80 ± 4.53 ^{a}
	Treated	12.5± 0.4 ^{b}	1752.67 ± 27.41 ^{b}	165.20 ± 6.48 ^{b}
F		179.5	113.38	68.58
p		0.0002	0.0004	0.001
***S. paniceum* adults**	**Control**	33.1±0.95 ^{A}	1065.67 ± 34.45 ^{A}	150.00 ± 7.65 ^{A}
	Treated	17.1±0.18 ^{B}	1401.67 ± 52.69 ^{B}	307.33 ± 7.85 ^{B}
F		273.2	28.6	206.66
P		0.0001	0.006	0.0001

N.B. Means followed by different letters are significantly different at $P < 0.05$.

5.Effect of Solar Heating on The Germination of Wheat Grains:

Solar heating slightly decreases the wheat germination of treated samples compared to the control group, but this difference was not significant (Table 5) (F=3.12; $P < 0.15$).

Table 5: Effect of solar heating on the germination of wheat grains after 30 min of exposure

Treatment	No. of germinated grains (mean± SE)	Germination (%)
Solar energy	17.33±1.45 ^{a}	69.33 ^{a}
Control	20.33±0.88 ^{a}	81.33 ^{a}
F	0.643	3.12
P	0.152	0.15

DISCUSSION

Using of solar heating system method is one of the management of grains and insect pests with the help of physical agents, such as temperature, humidity, and pressure (Sahadia

and Aziz, 2011). Every insect species has a favourable environment that promotes its growth, healthy development, and high reproductive rates. This environment includes ambient temperature, relative humidity, and photoperiod. Hence, by altering the temperature and relative humidity from their optimum values, it is possible to slow down or even stop the developmental growth of insect pests (Hajam & Kumar, 2022). Different solar heating systems, including metal boxes, plastic sheets, plastic bags, solar pillows, and storage bins have been reported as effective thermal control methods for controlling stored product insects. Thermal control is an eco-friendly technology for controlling insect pests in agricultural commodities that are nontoxic for humans or the environment and have no or limited adverse effect on the quality of the treated product (Abdullahi *et al*., 2019; Fawki *et al*., 2022). The results indicated that there was a positive relationship between the mortality percent of *T. granarium* and *S. paniceum* and different durations of solar heating. The mortality percent was found to be time-dependent, it increased with increasing the duration of the exposure time. The metal heating box can capture solar energy, raising the temperature above ambient, and causing complete mortality in coleopteran beetles used in the current study in just 15 to 20 min. This indicates that exposure to solar heating for 20 min at about 70°C is enough to control both the khapra beetle and the drugstore beetle. In line with these findings, Fields (1992) reported that a temperature above 55°C is enough to kill all stored product pests in a few minutes. Fawki *et al*. (2014) revealed that a metal box heater can kill all adult beetles of *Callosobruchus maculatus* within 15 min at 54°C. In other cases, solar heating has also been reported as a good option against bruchids infesting mung beans, cowpeas, and other pulses. It can make pulses completely free from any insect infestations (Chauhan and Ghaffar, 2002; Mbata *et al.*, 2005; Moumouni *et al.*, 2014).

Present data showed that for both *T. granarium* and *S. paniceum*, a complete suppression in adult emergence has been detected when immature stages such as eggs and larvae exposed to solar radiation for 15 min at 70°C, and for the pupal stage, a complete adult suppression was achieved after exposure for 20 min at 75°C. Our results suggested that 20 min of exposure would control most stored product coleopteran pests by preventing their reproduction or adult emergence. These results agree with Lale and Vidal (2003) and suggest that temperature plays a more influential role than the humidity in limiting the development and survival of stored products coleopterans exposed to different temperature ranges. Brokerhof (2003) reported that the solar tent has proved to be effective in killing all stages of the carpet beetle *Anthrenus verbasci*, the cigarette beetle *Lasioderma serricorne*, the grain weevil *Sitophilus granarius*, and the saw-toothed grain beetle *Oryzaephilus surinamensis* after one day of exposure. Mekasha *et al*. (2006) discovered that after 45 min of exposure in a box heater at 60°C, the various developmental stages of *C. maculatus* infesting adzuki bean seed were completely controlled. Fawki *et al*. (2014) reported that a complete inhibition of adult emergence was achieved when immature stages of *C. maculatus* were exposed to solar heat for 20 min (58–64°C). In addition, the different developmental stages such as egg, larva, and pupa of various *Callosobruchus* spp. have been killed by allowing the exposing infested grains to high temperatures up to 60–65°C for a few minutes or too low temperatures below 12°C (Sahadia and Aziz, 2011). Upadhyay and Ahmad (2011) studied the two pulse seeds (cowpea and moth bean) and found that the eggs and larvae of *C. maculatus* can also be killed by lowering the pressure and increasing temperature. The temperature of the seeds can be increased from 52°C to 65°C when these were kept on a black polythene sheet under the sun. This method causes the death of eggs and developing stages of *Callosobruchus* effectively (Gbaye *et al.*, 2011; Baoua *et al.*, 2012a, b; Ajayi *et al.*, 2021). Lale and Vidal (2003) reported that a heat of 40°C had a dramatic effect on adult bruchid beetles. Mostly, no progeny development occurs or at least results in minimal adult survivals, but with a very low growth rate.

In the current study, the pupae were the most solar heating tolerant of all *S. paniceum* and *T. granarium* stages. This agrees with Johnson *et al.* (2010) who found that the pupal stage of *C. maculatus* was the most heat tolerant. Adler (2002) found that pupae were the most tolerant stage for *L. serricorne*, whereas *C. maculatus* pupae and adults were equally heat tolerant (Loganathan *et al.*, 2011). Lü, J. (2017) reported that the pupae of *S. paniceum* were the most heat-tolerant stage.

The physiological processes of the insect are significantly influenced by the stress conditions (Mowlds *et al.*, 2008; Duarte *et al.*, 2020). Once there is a weakness in the immunity of the insects there will be a chance of more susceptibility to the routine control practices of the pests (Ajamhassani, 2015; El-Samad *et al.*, 2021). The insect's blood cells (hemocytes) are the most important hemolymph components that are sensitive to environmental changes, such as temperature, population density, starvation, nutrition, and other foreign agents such as pollutants, insecticides, the spores of entomopathogenic fungi and bacteria (Lee *et al.*, 2008, Ghasemi *et al.*, 2014; Pourali and Ajamhassani, 2018). In insects, antioxidants and detoxifying enzymes play a main role in protecting tissue from damage through reactive oxygen species (ROS) elimination (Ajam and Mahmoudzadeh, 2020; Koirala *et al.*, 2022). In normal conditions, there is a balance between the two processes of ROS generation and ROS removal. However, this balance is disturbed under environmental stress. Thermal stress is responsible for increasing ROS, which consequently causes oxidative stress and cell damage (Lalouette *et al*., 2011). To maintain cellular homeostasis and prevent ROS damage, organisms have evolved antioxidant systems and anti-oxidative enzymes to eliminate ROS and restore the normal equilibrium level (Toxopeus and Sinclair, 2018). These physiological adaptations have been reported in many insects, including *Corythucha ciliate* (Ju *et al*., 2014), *Bactrocera dorsalis* (Jia *et al*., 2011), *Plutella xylostella* (Zhang, 2015) and *Propylaea japonica* (Zhang *et al*., 2015).

The current data showed that solar heating applied on *T. granarium* larvae and *S. paniceum* adults for 15 min significantly reduced the total protein levels compared to the parallel control sample. The same trend has been also seen in adults and larvae of *Tribolium castaneum* and *Trogoderma granarium* after exposure to non-thermal atmospheric pressure plasma discharge (Abotaleb *et al.*, 2021). An explanation for this could be that the heat stress decreased the insect metabolic processes and this consequently reduces the production of many vital molecules and proteins (Holmstrup *et al.*, 2011). The reduction in total protein levels may be also due to the reduced ability of an insect to convert carbohydrates to proteins (Manjula *et al.*, 2020). Under stressful conditions, the production of ROS might destroy vital molecules such as DNA and proteins (Hermes-Lima, 2004; Korsloot *et al.*, 2004).

In the case of *T. granarium* larvae, the GST was down-regulated in heat-treated larvae compared to the untreated ones, while the POD enzyme was up-regulated. This indicates that POD has a significant role in antioxidative stress management in the larval stage of *T. granarium*. The downregulation in GST production in *T. granarium* larvae has been reported in previous work in response to non-thermal atmospheric pressure plasma discharge (Abotaleb *et al.*, 2021). It has been reported that GSTs enzymes have an optimal range of production in response to thermal stress from 25 to 40°C (Balakrishnan *et al.*, 2018). Some heat shock proteins have been reported to be up-regulated in moderate temperatures less than 40°C and decreased in high temperatures between 40-45°C (Miao *et al.*, 2020). The same trend might be possible in the case of GST and the enzyme production might have different levels according to temperature range. In our work, the temperature was about 70°C and this might explain the downregulation of GST. On the other hand, *S. paniceum* adults showed upregulation of both GST and POD. Therefore, both enzymes seem to have an important role in cellular detoxification.

Another study revealed that GST production in a species of aphids is time-dependent

(Balakrishnan *et al.*, 2018). Thus, the GST level elevated 12 h after insecticidal stress compared to the control group, while after 24 h and 36 h, the GST activity decreased in comparison to the control group (Balakrishnan *et al.*, 2018). It is quite obvious that the oxidative enzymes' activity as well as GST activity is mainly depending on environmental stress severity and the interaction between temperature and time. Therefore, future studies are needed to investigate the antioxidant activity of different oxidative enzymes under different temperature and time combinations. It should be noticed to investigate the enzymatic activity in different developmental stages of the same species, as the enzymatic expression is quite different between different stages of the same species (Enayati *et al.*, 2005).

Several studies go in line with our investigation, exposure to high or low-temperature stress may lead to oxidative damage and generate surplus ROS in insects (An and Choi, 2010). To relieve the adverse oxidative stress, insects increase antioxidant defence to maintain a balance in ROS metabolism (Krishnan *et al*., 2008; Zhu *et al*., 2017). Antioxidative enzymes are the most important components for protecting cells and maintaining homeostasis involved in various stress conditions by scavenging ROS (Toxopeus & Sinclair 2018; Liu *et al.* (2020). This defence system includes several enzymes catalysing the detoxification of ROS. Examples include superoxide dismutase (SOD), catalase (Cat), glutathione peroxidase (GPx) and glutathione-S-transferase (GST) (Hermes-Lima, 2004; Korsloot *et al.*, 2004).

Our findings suggest that there was no adverse effect of solar heating on grain germination. This agrees with previous studies, that solar heating had no significant effect on the cooking time and percentage germination of cowpea seeds (Chauhan and Ghaffar, 2002). Solar disinfestation was also found to be effective in controlling bruchids in pigeon peas without negatively affecting germination (Gunewardena, 2002). It has been reported that solarization had no negative effect on the seed viability of the cowpea seeds exposed to different solar radiation when compared to the control cowpea seeds (Ajayi *et al.*, 2021). It has also been reported that heat treatment prevents insect pests outbreak during storage conditions, and in some cases, stimulates the germination of treated seeds compared to the untreated ones (Maina and Lale, 2004; Fawki *et al.*, 2014).

Conclusion

Solar heating is a safe alternative technique to control khapra beetle *T. granarium* and the drugstore beetle *S. paniceum*. Solar energy treatment had no negative effect on the germination of wheat grains. On the other hand, the pupal stage had higher tolerance to solar heating compared to the other stages. Solar heating affected some of the biochemical analyses of two insects after exposure. Under thermal stress, oxidative enzymes might be up-regulated or down-regulated. To fully understand the enzymatic activity in the thermotolerance mechanism of insects, different times and temperature combinations should be investigated. Another important factor that should be considered is using different developmental stages of the insect as the enzymatic activity is different between different insect life stages.

REFERENCES

Aalfs, M. (2011). Principles of solar box cooker design. Solar Box Cooker Northwest–Seattle-USA. Solar Cookers International. Internatura. Energía Renovable. Seattle USA. *Consulta electrónica realizada*, 8(10).

Abotaleb, A. O., Badr, N. F., and Rashed, U. M. (2021). Assessment of the potential of non-thermal atmospheric pressure plasma discharge and microwave energy against

Tribolium castaneum and *Trogoderma granarium*. *Bulletin of Entomological Research*, 111(5), 528-543.

Abbott W. S. (1925) A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, 18:265–267.

Abdelghany, A.Y., Awadalla, S.S., Abdel-Baky, N.F., EL-Syrafi, H.A., and Fields, P.G. (2010). Stored-product insects in botanical warehouses. *Journal of Stored Product Research*, 46: 93-97.

Abdullahi, G., Muhamad, R., Dzolkhifli, O., and Sinniah, U.R. (2019). Efficiency of cardboard solar heater boxes for disinfestations of stored grains against arthropod pest. *Agricultural Science and Technolgy*,11: 247–256.

Adler, C. (2002). Efficacy of high temperatures to control *Lasioderma serricorne* and *Rhyzopertha dominica*, pp. 199-203. *In* C. Adler, S. Navarro, M. Scho¨ller, and L. Stengard-Hansen (eds.), Proceedings, of the Integrated Protection of Stored Products, IOBC/WPRC Bulletin 25, 3-5 September 2001. IOBC, Lisbon, Portugal.

Ahmedani, M.S., Haque, M.I., Afzal, S.N., Naeem, M., Hussain, T., and Naz, S. (2011). Quantitative losses and physical damage caused to wheat kernel (*Triticum aestivum* L.) by khapra beetle infestation. *Pakistan Journal of Botany*, 43(1): 659-668.

Ajamhassani, M. (2015). Study of cytology of hemocytes in the Spurge hawkmoth, *Hyles euphorbiae* L. (Lepidoptera: Sphingidae). Plant Protection. (*Agricultural Science Journal*), 38: 49-62. (In Persian).

Ajayi, F. A., Peter, E., Okrikata, E., Emmanuel, R. A. L., Dattijo, S. A., and Kayode, E. A. (2021). Impact of solar heat enhanced by the use of black polypropylene sheets on the development of *Callosobruchus maculatus* Fabricius (Coleoptera: Chrysomelidae) eggs and germinability of cowpea seeds. *International Journal of Tropical Insect Science.* 41, 2867–2872.

An, M. I. and Choi, C. Y. (2010). Activity of antioxidant enzymes and physiological responses in ark shell, *Scapharcabroughtonii*, exposed to thermal and osmotic stress: effects on hemolymph and biochemical parameters. *Comparative Biochemistry and physiology. Part B, Biochemistry and Molecular Biology*, 155: 34–42

Balakrishnan, B., Su, S., Wang, K., Tian, R., and Chen, M. (2018). Identification, Expression, and Regulation of an Omega Class Glutathione S-transferase in *Rhopalosiphum padi* (L.) (Hemiptera: Aphididae) Under Insecticide Stress. *Frontiers in Physiology*: 9, 427.

Baoua, I. B., Amadou, L., Margam, V., Murdock, L. L. (2012a). Comparative evaluation of six storage methods for postharvest preservation of cowpea grain. *Journal of Stored Product Research*, 49:171–175.

Bradford, M. M. (I976). A rapid and sensitive method for the quantitation of microgram quantities of proteins utilizing the principle of protein-dye binding. *Analytical Biochemistry*, 72:248-254.

Brokerhof, A.W. (2003). The solar tent—cheap and effective pest control in museums. *AICCM Bulletin*, 28, 93–97.

Cabrera, B. J. (2001). Drugstore beetle, *Stegobium paniceum* (L.) (Insecta:Coleoptera: Anobiidae). https://edis.ifas.ufl.edu/in385.

Chauhan, Y. S., and Ghaffar, M. A. (2002). Solar heating of seeds—a low-cost method to control bruchid (*Callosobruchus* spp.) attack during storage of pigeonpea. *Journal of Stored Products Research*, 38(1), 87-91.

Collins, P.J. (2017). Relative tolerance and expression of resistance to phosphine in life stages of the rusty grain beetle, *Cryptolestes ferrugineus*. *Journal of Pest Science*, 91: 277–286.

Demis, E., and Yenewa, W. (2022). Review on major storage insect pests of cereals and pulses. *Asian Journal of Advances in Research*, 41-56.

Duarte, J. P., Silva, C. E., Ribeiro, P. B., and Carcamo, M. C. (2020). Do dietary stresses affect the immune system of *Periplaneta americana* (Blattaria: Blattidae)? *Brazilian Journal of Biology*, 80: 73-80.

Duncan, D. B. (1955). Multiple ranges and multiple F test. *Biometrics*, 11:1–42.

El-Samad, L. M., El-Ashram, S., Kheirallah, D. A., Abdul-Aziz, K. K., Toto, N. A., and Mokhamer, E. M. (2021). Relative gene expression, micronuclei formation, and ultrastructure alterations induced by heavy metal contamination in *Pimelia latreillei* (Coleoptera: Tenebrionidae) in an urban-industrial area of Alexandria, Egypt. *PLOS ONE*, 16(6): 1-20.

Enayati, A.A., Ranson, H., and Hemingway, J., (2005). Insect glutathione transferases and insecticide resistance. *Insect Molecular Biology*: 14: 3-8.

EPPO (2011). European and Mediterranean plant protection organization Standards; EPPO A1 and A2 lists of pests recommended for regulation as quarantine pests. Pharm. Manag. PM1/2 (20). Paris, France.

FAO (2022). Crop Prospects and Food Situation – Quarterly Global Report No. 4, December 2022. Rome.

FAO (2023). Crop Prospects and Food Situation – Quarterly Global Report No. 1, March 2023. Rome.

Fawki, S., Abdel Fattah, H., Hussein, M., Ibrahim, M., Soliman, A., Salem, D. (2014). The use of solar energy and citrus peel powder to control cowpea beetle *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae), *In 11th International Working Conference on Stored Product Protection (pp. 1022-1033).*

Fawki, S., Fields, P. G, Jian, F., Yousery, A. (2022). Control of *Sitophilus oryzae* (Coleoptera: Curculionidae) in bags of wheat using solar radiation. *Journal of Stored Products Research*, 96 :101941

Fields, P. G. (1992). The control of stored-product insects and mites with extremes temperatures. *Journal of Stored Products Research*, 28: 89–111.

Gbaye, O. A., Millard, J. C., Holloway, G. J. (2011). Legume type and temperature effects on the toxicity of insecticide to the genus *Callosobruchus* (Coleoptera: Bruchidae). *Journal of Stored Products Research*, 47 (1), 8–12.

Ghasemi, V., Yazdi, A. Y., Tavallaie, F. Z., and Sendi, J. J. (2014). Effect of essential oils from *Callistemon viminalis* and *Ferulagummosa* on toxicity and on the hemocyte profile of *Ephestia kuehniella* (Lep.: Pyralidae). *Archives of Phytopathology and Plant Protection*, 47: 268-278.

Gunewardena, K.N.C. (2002). Effect of solar heating on Bruchid (Coleoptera: Bruchidae) infestation and seed viability in pigeonpea. Research News. In: *Annals of the Sri-Lanka Department of Agriculture* 4, p. 432.

Habig, W. H., Pabst, M. J., and Jakoby, W. B. (I974). Glutathione S-transferase. the first enzymatic step in mercapturic acid formation. *Journal of Biological Chemistry*, 249:7130-7139.

Hagstrum, D. W. and Subramanyam, B. H. (2009). Stored-Product Insect Resource. AACC International, Inc., St. Paul, Minnesota, USA.

Hajam, Y. A., and Kumar, R. (2022). Management of stored grain pest with special reference to *Callosobruchus maculatus*, a major pest of cowpea: A review. *Heliyon*, 8(2): e08703.

Hammerschmidt, R., Nuckles, F., and Kuc, J. (1982). Association of enhanced peroxidase activity with induced systemic resistance of cucumber to *Colletotrchum lagenarium*. *Physiologial Plant Pathology*, 20:73-82.

Hermes-Lima, M. (2004). Oxygen in biology and biochemistry: role of free radicals. Functional metabolism: regulation and adaptation, John Wiley & Sons, Inc., Hoboken, 319-368.

Holmstrup, M., Sørensen, J.G., Heckmann, L.-H., Slotsbo, S., Hansen, P., and Hansen, L.S., (2011). Effects of ozone on gene expression and lipid peroxidation in adults and larvae of the red flour beetle (*Tribolium castaneum*). *Journal of Stored Products Research*, 47:378-384.

Jia, X. F., Dou, W., Hu, F., and Wang, J. J. (2011). Effects of thermal stress on lipid peroxidation and antioxidant enzyme activities of oriental fruit fly, *Bactrocera dorsalis* (Diptera: Tephritidae). *Florida Entomologist* ,94, 956–963.

Johnson, J.A., Wang, S., and Tang, J. (2010). Radio frequency treatments for insect disinfestation of dried legumes. In: Carvalho, O.M., Fields, P.G., Adler, C.S., Arthur, F.H., Athanassiou, C.G., Campbell, J.F., Fleurat-Lessard, F., Flinn, P.W., Hodges, R.J., Isikber, A.A., Navarro, S., Noyes, R.T., Riudavets, J., Sinha, K.K., Thorpe, G.R., Timlick, B.H., Trematerra, P., White, N.D.G. (Eds), Proceedings of the10th Inter- national Working Conference on Stored Product Protection, , Estoril, Protugal, Julius-Kühn-Archiv, Berlin, Germany, pp. 688-694.

Ju, R. T., Gao, L., Zhou, X. H., and Li, B. (2014). Physiological responses of *Corythuchaciliata* adults to high temperatures under laboratory and field conditions. *Journal of Thermal Biology* ,45, 15–21

Kavallieratos, N.G., Karagianni, E.S., and Papanikolaou, N.E. (2019). Life history of *Trogoderma granarium* Everts (Coleoptera: Dermestidae) on peeled barley, peeled oats and triticale. *Journal of Stored Products Research*, 84, 101515.

Kalsa, K. K., Subramanyam, B., Demissie, G., Worku, A. F., and Habtu, N. G. (2019). Major Insect Pests and their Associated Losses in Quantity and Quality of Farm-Stored Wheat Seed. *Ethiopian Journal of Agricultural Sciences*, 29(2)71-82.

Koirala, B.K., Moural, T., and Zhu, F. (2022). Functional and structural diversity of insect Glutathione S-transferases in xenobiotic adaptation. *International Journal of Biological Sciences*, 18(15), 5713-5723.

Korsloot, A., van Gestel, C. A., and Van Straalen, N. M. (2004). Environmental stress and cellular response in arthropods. CRC press. P 208.

Krishnan, N., Davis, A. J. and Giebultowicz, J. M. (2008). Circadian regulation of response to oxidative stress in *Drosophila melanogaster*. *Biochemical and Biophysical Research Communications*,374, 299–303.

Kumar Anuj, Randhir Singh, Gyanendra Singh, R. K. Sharma, M. S. Saharan, R. S. Chhokar, B. S. Tyagi, Sendhil, R., Ramesh Chand and Indu Sharma (2014). Wheat cultivation in India (Pocket Guide), Directorate of Wheat Research Karnal-132 001, *Extension Bulletin*, (52) 34.

Lale, N.E.S. and Vidal, S. (2003). Effect of constant temperature and humidity on oviposition and development of *Callosobruchus maculatus* (F.) and *Callosobruchus subinnotatus* (Pic) on bambara groundnut, *Vigna subterranean* (L.) Verdcourt. *Journal of Stored Products Research*, 39: 459-470.

Lalouette, L., Williams, C. M., Hervant, F., Sinclair, B. J., and Renault, D. (2011). Metabolic rate and oxidative stress in insects exposed to low temperature thermal fluctuations. *Comparative Biochemistry and Physiology*, A. 158, 229–234.

Lee, K. P., Simpson, S. J., and Wilson, K. (2008) Dietary protein-quality influences melanization and immune function in an insect. *Functional Ecology*, 22: 1052-1061.

Liu, C., Masri, J., Perez, V., Maya, C., and Zhao, J. (2020). Growth performance and nutrient composition of mealworms (*Tenebrio molitor*) fed on fresh plant materials-supplemented diets. *Foods,* 9(2), 151.

Loganathan, M., Jayas, D. S., Fields, P. G., and White, N. D. G. (2011). Low and high temperatures for the control of cowpea beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in chickpeas. *Journal of Stored Products Research,* 47(3), 244-248.

Lü, J. (2017). Effects of high temperatures on the mortality of *Stegobium paniceum* (L.) (Coleoptera: Anobiidae). *Journal of food protection*, 80(9): 1557-1561.

Manjula, P., Lalitha, K., Vengateswari, G., Patil, J., Nathan, S. S., and Shivakumar, M. S. (2020). Effect of *Manihot esculenta* (Crantz) leaf extracts on antioxidant and immune system of *Spodoptera litura* (Lepidoptera: Noctuidae). *Biocatalysis and Agricultural Biotechnology*, 23, 101476.

Mahmoudzadeh, M. (2020). Cellular defense responses of 5th instar larvae of the Apple Ermine Moth, *Yponomeutamalinellus* (Lepidoptera: Yponomeutidae) against starvation, thermal stresses and entomopathogenic bacteria *Bacillus thuringiensis*. *Journal of Animal Researches*, 33 (1) 68 - 81

Maina, Y. T., and Lale, N. E. S. (2004). Efficacy of integrating varietal resistance and neem (*Azadirachta indica*) seed oil for the management of *Callosobruchus maculatus* infesting Bambara Groundnut in storage in storage. *Nigerian Journal of Entomological Society*, *2*, 94-103.

Mbata, G. N., Johnson, M., Phillips, T. W., and Payton, M. (2005). Mortality of life stages of cowpea weevil (Coleoptera: Bruchidae) exposed to low pressure at different temperatures. *Journal of Economic Entomology,* 98 (3), 1070–1075.

Mekasha C., Dzolkifli O., Yusuf, S., Rita, M., and Noorma, O. (2006). Short communication-development of efficient solar heaters for storage insect pest management. *African Crop Science Journal*, 14, 253-261.

Miao, Z.Q., Tu, Y.Q., Guo, P.Y., He, W., Jing, T.X., Wang, J.J., and Wei, D.D., (2020). Antioxidant enzymes and heat shock protein genes from *Liposcelis bostrychophila* Are Involved in stress defense upon heat shock. *Insects*: 11, 839.

Moumouni, D. A., Doumma, A., and Seyni, I. S. (2014). Effect of solar drying on the biological parameters of the cowpea weevil, *Callosobruchus maculatus* Fab. (Coleoptera: Bruchinae), in Sahelian area. *Journal of Applied Biosciences*, 84, 7723–7729.

Mowlds, P., and Kavanagh, K. (2020). Effect of pre-incubation temperature on susceptibility of *Galleria mellonella* larvae to infection by *Candida albicans*. *Mycopathologia*, 165: 5-12.

Papanikolaou, N. E., Kavallieratos, N. G., Kondakis, M., Boukouvala, M. C., Nika, E. P., and Demiris, N. (2019) Elucidating fitness components of the invasive dermestid beetle *Trogoderma granarium* combining deterministic and stochastic demography. *PLOS ONE*, 14, e0212182.

Pourali, Z., and Ajamhassani, M. (2018). The effect of thermal stresses on the immune system of the potato tuber moth, *Phthorimaeaoperculella* (Lepidoptera: Gelechiidae). *Journal of Entomological Society of Iran*,*Supplementary*. 37(4): 515-525.

Sahadia, E. and Aziz, A. E. (2011). Control strategies of stored product pests. *Journal of Entomology,* 8 (2), 101–122.

Strang, T. J. K. (2014). The use of thermal control against insect pests of cultural property, In: Arthur, F.H.K., R.; Chayaprasert, W.; Suthisut, D. (Eds), The 11th International Working Conference on Stored Product Protection, Chiang Mai, Thailand, pp. 690-

723.

Toxopeus, J., and Sinclair, B. J. (2018). Mechanisms underlying insect freeze tolerance. *Biological Reviews*, 93(4), 1891-1914.

USDA (2022). United Stated Department of Agriculture Grain and Feed Annual, Import Challenges and High Prices Reduces Egypt's Wheat and Corn Imports. Report Number: EG2022-0009.

Venkidusamy, M., Jagadeesan, R., Nayak, M. K., Subbarayalu, M., Subramaniam, C., and Collins, P.J. (2017). Relative tolerance and expression of resistance to phosphine in life stages of the rusty grain beetle, *Cryptolestes ferrugineus*. *Journal of Pest Science*, 91: 277–286.

Wang, J., Yu, Y., and Tian, X. (2012). Effect of γ-Ray irradiation on the germinating characteristics of wheat seed. *Radiation Physics and Chemistry*, 81(4):463– 465.

Yigezu, Y. A., Moustafa, M. A., Mohiy, M. M., Ibrahim, S. E., Ghanem, W. M., Niane, A. A., Abbas, E., Sabry, S.R.S., and Halila, H. (2021). Food losses and wastage along the wheat value chain in Egypt and their implications on food and energy security, natural resources, and the environment. *Sustainability*, 13(18), 10011; https:// doi.org/10.3390/su131810011

Zhang, L. J., Wu, Z.L., Wang, K.F., Liu, Q., Zhuang, H.M. and Wu, G. (2015). Trade-off between thermal tolerance and insecticide resistance in *Plutella xylostella*. *Ecology and Evolution*, 5: 515–530.

Zhang, S., Fu, W., Li, N., Zhang, F., Liu, T. X. (2015). Antioxidant responses of *Propylaea japonica* (Coleoptera: Coccinellidae) exposed to high temperature stress. *Journal of Insect Physiology*, 73: 47–52.

Zhu, G., Xue, M., Luo, Y., Ji, G., Liu, F., Zhao, H., and Sun, X. (2017). Effects of short-term heat shock and physiological responses to heat stress in two *Bradysia* adults, *Bradysiaodoriphaga* and *Bradysiadifformis*. *Scientific Reports*, *7*(1), 1-11.

ARABIC SUMMARY

فعالية نظام التسخين الشمسي في النفوق والتكاثر والإنزيمات المضادة للأكسدة في خنفساء الصعيد وخنفساء العقاقير

رشا أحمد زينهم[١]، عبير عمر أبو طالب[١]، نيللي أحمد حسن عبد الفتاح [١]، شمس فوقي [٢*]

١- قسم أفات الحبوب والمواد المخزونة، معهد بحوث وقاية النباتات، مركز البحوث الزراعية ١٢٦١٩ الدقي، الجيزة، مصر

٢-قسم علم الحشرات، كلية العلوم، جامعة عين شمس، ١١٥٦٦ العباسية، القاهرة، مصر

التسخين الشمسي يعتبر وسيلة واعدة لمكافحة أفات الحبوب والمواد المخزونة. من خلال هذه الدراسة قمنا بدراسة تأثير التسخين الشمسي باستخدام صندوق معدني على فترات تعريض مختلفة (30،20،15،10،5،0 دقيقة) على الاطوار المختلفة لخنفساء الصعيد وخنفساء العقاقير على محصول القمح. وقد كانت نسبة الموت 100% في الحشرات البالغة في النوعين بعد 20 دقيقة. وكذلك في الجيل الناتج من الاطوار غير الكاملة بعد 15 بعد 15، 20 دقيقة في النوعين. وهذه النتائج تؤكد ان طور العذراء هو أكثر الاطوار تحملا. وقد وجد أن محتوى البروتين في يرقات خنفساء الصعيد والحشرة الكاملة لخنفساء العقاقير تأثر معنويا بالسالب عند التعريض للتسخين الشمسي عن المجموعة الضابطة. علاوة على ذلك كان هناك فرق معنوي كبير في نشاط العامل الحفاز جلاثيون ترانسفراز ولإنزيم البيروكيداز بين العينة المعاملة وغير المعاملة لكلا الحشرتين لإنزيم بالإضافة الى ذلك لم تتأثر حبوب القمح بالتعرض لحرارة الشمس وبالتالي يمكن ان يوصى بالتسخين الشمسي كطريقة بديلة فعالة لمكافحة حشرات الحبوب المخزونة ذات الرتبة غمديه الاجنحة.