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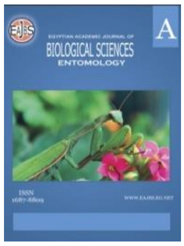

Sublethal Effects of Malathion on Biology and Population Growth of Khapra Beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae)

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ABSTRACT

Khapra beetle, *Trogoderma granarium* Everts is a serious pest that affects stored grains and oilseeds. The current work was carried out to investigate the effect of malathion sublethal concentrations (LC_{10} and LC_{40}) exposed to first and fourth larval instars on biological aspects and population growth of *T. granarium*. Results indicated that exposure of 1^{-st} instar to either LC_{10} or LC_{40} had a destructive effect and treated larvae failed to complete their larval stage. While 4^{-th} instar exposed to the same sublethal concentrations completed their life cycle with considerable impacts on biological aspects and life table parameters. Treatments increased the number of instars molting reaching seven or eight instars. In contrast, larval, pre-adult, and total longevity periods were decreased in treatments compared with control. Concerning life table parameters such as net reproductive rate (*R*0), intrinsic rates of increase (r), finite rate (λ), fecundity and mean generation time (*T*) were decreased compared to control. The current study clarified that sublethal concentrations of malathion induce strong adverse effects and suppress the population growth of *T. granarium*. Our results would be useful to assess the overall effects of malathion on *T. granarium* and can contribute effectively in pest management.

INTRODUCTION

Wheat, (*Triticum aestivum*.) is a key cereal crop that represents a major source of carbohydrate, proteins, minerals, and vitamins for a human's diet. Several pests attack stored wheat such as the khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae) which classified among the most dangerous species worldwide (Lowe et al., 2000). Khapra beetle infests either whole or broken wheat, oilseeds, and other cereal grains, causing a huge loss in weight, germination, and quality (Masolkar et al., 2018; Ahmedani et al., 2009). The beetle has four to five generations per year, lays their eggs loosely scattered on the host material. Larvae can hide in cracks and crevices of shipping containers, bulk cargo holds (Harris, 2006). Larvae of *T. granarium* cause either quantitative damage due to feeding or qualitative damage as a result of the depletion of specific nutrients contents. As well as larvae contamination grains contamination with their faces, skin, bodies of the dead insects, and decomposition which may make it unpalatable or un-marketable (Ahmedani et al., 2009).

Stored grains conservation needs to manage their pests which largely depends on insecticides (Guedes et al., 2011). Stored grain protection can be achieved through the direct mix with insecticides like malathion powder, dusting the outer surfaces of grain bags to prevent new infestations, and fogging around the pile of grains to prevent crawling of insects. Malathion is widely used in empty stores or as a protective insecticide to combat stored grain pests (Mutlu et al., 2019). Malathion is preferred due to its low acute toxicity to humans and other warm-blooded animals (Navarro et al., 1986). In Egypt, malathion is recommended at a concentration of 10 ppm against stored insects. As a result, *T. granarium* exposes to these concentrations or less due to either misapplication or degradation. So, it is important to investigate the influence of the sublethal amount of malathion on population growth and life table parameters of insects.

Up to date, sublethal effects of malathion on *T. granarium* not investigated. Sublethal concentrations of insecticides affect physiology, behavior, development, and population growth of insects (Desneux et al., 2007). The impact of sublethal concentrations of insecticides has great importance to optimize insecticide applications against target insects (Ali et al., 2017; Wang et al., 2018). Sub-lethal responses to insecticides rarely investigated in stored-product insects despite their importance on insect biology (Guedes et al., 2011).

Life table parameters evaluate the multiple effects of certain factors on the mortality and biological potential of the pest (Maroufpoor et al., 2019). And consequently, determine the role of certain factors in mortality rates in each developmental stage (Chi and Getz, 1988). As a result, it can be used to determine the effects of an insecticide on population growth by measuring certain biological parameters such as net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and mean generation time (T) (Rezaei et al.2007). These studies can be used to delay resistance development, combat pest resurgence, and use pesticides in optimal ways (Desneux et al. 2007). On our best knowledge, there were no work investigates the effect of sublethal concentrations of malathion on life table parameters of *T. granarium*. But this aspect has been investigated in other stored pest such as the methoprene and the protectants Storicide (chlorpyrifos-methyl and deltamethrin mixture) against the lesser grain borer, *Rhyzopertha dominica* F. (Arthur, 2012; Daglish and Nayak, 2010)

The objective of this work is to assess the sub-lethal effects of malathion on biological aspects and life table parameters of *T. granarium* infesting stored wheat under laboratory conditions. The results of this study can contribute to pest management programs.

MATERIALS AND METHODS

Insect Rearing:

The khapra beetle, *Trogoderma granarium* (Everts**)** was reared in glass jars (1L. capacity). Each jar contains 500 gm sterilized wheat grains and 30 pairs of newly emerged adults. Insects selected from the stock culture which rearing at Stored Product Insects Department, Plant Protection Research Institute, Agriculture Research Center. The beetles were reared for several generations under controlled conditions (30±2^{o}C and 65±5 R.H.)

Concentration Mortality Response:

Serial of concentrations of malathion were prepared throughout mixing with wheat grains. Each concentration was prepared by mixing 100 gm. of wheat with the estimated amount of malathion and then divides to 5 replicates of about 20 gm. for each. The wheat of each replicate was placed in petri dish 9 cm diameter; ten larvae of the tested instars (1^{-st} and 4^{-th} instar) of *T. granarium* were added into the Petri dishes. Seven concentrations (8, 4, 2, 1, 0.5, 0.25 and 0.125 µg active ingredient/ gm. wheat) were used with 1^{-st} instar,while, five concentrations (16, 8, 4, 2 and 1 µg active ingredient/ gm. wheat) were used against 4^{-th} instar. Petri dishes with untreated wheat conserved as control. All treatments were incubated in the rearing chamber under the aforementioned conditions for 24 hrs, then, mortality percent was scored. Larvae were considered dead if they failed to exhibit coordinate manner movement when probed with a soft hairbrush.

Experiments Procedures:

Sublethal Effects of Malathion on Biological Aspects of *T. granarium:*

Two experiments were conducted to determine the effect of sub-lethal concentrations of malathion (LC_{10} and LC_{40}) on the 1^{-st} and 4^{-th} instar of *T. granarium*.

1. First Instar Larvae Experiment:

Three treatments were carried to evaluate malathion sublethal effects against 1^{-st} instar includes LC_{10}, LC_{40} and untreated (control). Newly hatched larvae (0-24 h old) were placed in 9 cm Petri dishes contain wheat grains treated either with LC_{10} or LC_{40} of malathion. Other larvae were placed in similar Petri dishes contain untreated wheat grains serves as the control. After exposures to sublethal concentrations, fifty survival instars from each treatment were transferred singly to glass tubes contain 2g untreated wheat grains and observed daily until the end of their life span.

2. Fourth Instar Larvae Experiment:

4^{-th} instar of *T. granarium* was used; the experiment was designed as mentioned above in the first experiments. In all experiments, the tubes were incubated at 30 ± 2° C and 65 ± 5 % Rh., and inspected daily to record the number of larval instars, larval, pupa, and adult stages duration.

3. Life Table Construction:

Glass tubes contain single larvae were conserved in the rearing chamber and checked daily to record larval and pupal periods. After adult emergence, pairs of females and males were placed into a glass tube (6 cm diameter and 2 cm depth) and observed daily to record the number of eggs laid for each female until female death. Mortality percent from eggs hatching to the emergence of adults was recorded daily. Development time, immature survival rate, and fecundity were used to calculate life table parameters. Age-specific survival rate (l_x), and fecundity (m_x) were calculated. Age-specific survival and age-specific fecundity, intrinsic rate of natural increase (r_m), net reproductive rate (R_0), mean generation time (T), finite rate of increase (λ) and doubling time were calculated for each concentration and control.

Data Analysis:

To determine the concentration-mortality response, larval mortality corrected according to Abbott's formula (Abbott 1925). Then data subjected to probit analysis (Finney 1971) throughout EPA probit analysis version 1.5. to obtain different LC values. Age-stage two-sex life table analysis was used to derive biological aspects and population growth parameters. Mean values and standard errors were obtained throughout the bootstrap method included in the TWOSEX-MS Chart program (Chi 2012). Graphs of Age-stage specific survival rate (S_{xj}), Age-stage specific reproductive value (V_{xj}), Age-specific survival rate (l_x), age-specific fecundity of the total population (m_x) and age-specific maternity ($l_x m_x$) and age-stage life expectancy (E_{xj}) curves were constructed using GraphPad Prism 7.

RESULTS

Malathion toxicity against the 1^{-st} and 4^{-th} instar larvae of *T. granarium* was evaluated. LC_{50} values recorded 1.38 and 12.78 µg active ingredient (ai) gm $^{-1}$ for the 1^{-st} and 4^{-th} instar larvae, respectively. Also, concentrations that caused 10 and 40 percent mortality were (0.05, 0.72) and (3.14, 9.68) µg active ingredient (ai) gm $^{-1}$ for the 1^{-st} and 4^{-th} instar larvae, resp. (Table 1).

Table 1. Toxicity of malathion to the first and fourth larval instars of *T. germanium*

Instars	Concentration µg (ai) gm _1 (95% CL)			Slope ± SE	X2(df)
	LC_{10}	LC_{40}	LC_{50}		
First instar	0.05 (0.04- 0.15)	0.72 (0.34- 1.22)	1.38 (0.80- 2.62)	0.89 ± 0.16	1.36(3)
Fourth instar	3.14(1.75 – 4.30)	9.68(7.54 – 13.64)	12.78(9.73 – 20.11)	2.10 ±0.39	2.95(2)

Sublethal Effects of Malathion on Larval Instars of *T. granarium:*

The effects of sub-lethal concentrations of malathion on larval instars of *T. granarium* was illustrated in Table 2. Treatment of the first larval instar with LC_{10} or LC_{40} caused a destructive effect. Both LC_{10} and LC_{40} caused complete mortality and not exceed the fourth larval instar with LC_{10} treatment. Similarly, LC_{40} caused stronger effect whereas all larvae were dead without exceeding the third instar larvae. Due to the destructive effect on 1^{-st} instar larvae, treated larvae did not complete their life span, and consequently, the other biological characteristics and life table parameters cannot be estimated. Concerning the effect of 4^{-th} instar exposure to sub-lethal concentrations of malathion (LC_{10} and LC_{40}) on biological aspects and life table parameters. Data present in Table (2) revealed a strong effect for LC_{10} and LC_{40} on mortality and molting of *T. granarium* instars. LC_{10} and LC40 increased larval phases from 6 to either 7 or 8 instars (5 to 7 moultings). Also, exposure of *T. granarium* larvae to LC_{10} and LC_{40} decreased larval instar periods.

Table 2. Mean durations of different larval instars (in days) of *T. gramanium* treated with sublethal concentrations (LC_{10} and LC_{40}) of malathion

Instars	Untreated		1^{st} instar				4^{th} instar			
			LC_{10}		LC_{40}		LC_{10}		LC_{40}	
	N	Mean ± SE (in days)	N	Mean ± SE (in days)	N	Mean ± SE (in days)	N	Mean ± SE (in days)	N	Mean ± SE (in days)
L1	50	4.52± 0.579	50	4.94±0.235	50	3.89±0.351	50	4.52± 0.579	50	4.52± 0.579
L2	50	7.30 ± 0.580	30	5.64±0.244	15	3± 0.00	50	7.30 ± 0.580	50	7.30 ± 0.580
L3	50	7.92 ± 0.274	18	6.38±0.263	3		50	7.92 ± 0.274	50	7.92 ± 0.274
L4	50	10.54 ±0.146	13		0	------	39	7.66 ± 0.192	41	6.024 ±0.183
L5	44	10.09 ± 0.231	0	------	0	------	30	6.70 ± 0.452	39	4.84± 0. 149
L6	44	7.29 ± 0.330	0	------	0	------	28*	5.64 ± 0.270	31*	4.61 ± 0.171
L7	0	------	0	------	0	------	10	3.80 ±0.421	22**	3.40±0.354
L8	0	------	0	------	0	------	0	------	4***	2.75±0.500

N = number of sample individuals

Fourth instar treatments

LC10

*18 members enter directly to the pupae and 10 members entered the 7-th instar

LC_{40}

*4 members enter to pupae after 6-th instar directly

**27 members entered to the 7-th instar and 22 members completed the stage and 15 members entered the pupae

***7members entered the 8-th instar and 4 members completed the stage

Effect of Sublethal Concentrations on Certain Biological Characteristics of *T. granarium*:

Data presented in Table (3) clarified the effect of LC_{10} and LC_{40} of malathion on some biological characteristics of *T. granarium*. Results indicated that total larval development times were significantly influenced by sublethal concentrations. Since, it recorded 48.14, 39.00 and 38.38 days for control, LC_{10} and LC_{40}, respectively. Similar findings were obtained with the pre-adult period (total immature stages periods), and total longevity of female and male. Pre-adult (total immature stages periods) were 51.00 and 45.66 days at LC_{10} and LC_{40} concentrations, respectively and increased to 56.46 days for control. The total longevity of females was 63.71 at control treatment and then decreased to record 54.20 and 50.64 days at LC_{10} and LC_{40} concentrations, respectively. The total longevity of males was recorded 50.99 and 48.33 days at LC_{10} and LC_{40} concentrations compared to 61.11±0.73 days for control.

Table3. Biological characteristics of *T. gramanium* whose 4^{-th} instar were exposed to sublethal concentrations of malathion

parameters	Untreated		LC_{10}		LC_{40}	
	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Total larvae period	50	48.11 ± 0.44a	50	39 ± 1.50b	50	38.38± 0.39b
Pupa	42	5.02 ± 0.11a	29	4.56 ±0.25 a	28	3.26± 0.09 b
Pre-adult	38	56.46± 0.53 a	23	51.00 ±1.44 a	23	45.66 ± 0.57 b
Adult	38	5.18 ± 0.29a	23	4.00 ± 0.31b	23	3.27± 0.32b
Total longevity of female	21	63.71± 0.69a	14	54.20± 1.82b	11	50.64±0.61b
Total longevity of male	17	61.11±0.73a	9	50.99 ± 1.42b	12	48.33±0.57b
Longevity	50	58.51± 1.29a	50	44.26 ± 1.64b	50	42.07±1.25b

Means in the same row followed by the same letter are not significantly different ($P > 0.05$).

Effect of Sublethal Concentrations on Population Growth Parameters:

The population growth parameters of *T. granarium* were given in Table 4. Data demonstrated that differences between control and LC_{10} were insignificant in all parameters except mean generation time (T), total pre-oviposition period (TPOP), and oviposition period. Oppositely LC_{40} treatment exhibited significant differences with the control and LC_{10} in all tested parameters. The net reproductive rate (R_0) was 10.23 and 6.81 (offspring/individual) for control and LC_{10}, respectively. Then, (R_0) sharply decreased to record 1.157± 0.62 (offspring /individual) with LC_{40} treatment. A similar trend observed with the intrinsic rate of increase (r) with values of 0.037 and 0.035 for control and LC10 without significant differences and decreased significantly by LC_{40} to recorded 0.003. Likewise, the Finite rate of increase (λ) was 1.038 and 1.036 for control and LC_{10}, descending significantly by LC_{40} treatment to 0.999. Besides, mean generation time (T) was 61.61 ± 0.73 days for control, descending significantly by LC_{10} and LC_{40} treatment to reach 52.83 and 49.01 days. Furthermore, fecundity was 24.29 and 24.37 eggs/female for control and LC_{10}, descending significantly by LC_{40} treatment to 5.22 eggs /female. The same style observed with GRR which recorded 33.74 and 39.08 female offspring for control and LC_{10}, resp., followed decreased significantly to 6.44 female offspring with LC_{40} treatment. Also, APOP did not affect significantly as a result of exposure for sub-lethal concentrations, While, TPOP was affected significantly and were recorded 60.49, 52.74, and 48.00 days for control, LC_{10}, and LC_{40}, respectively. Furthermore, the oviposition period was recorded at 2.60, 1.91, and 1.25 eggs/female/daily for control, LC_{10}, and LC_{40}, respectively.

Table 4. Population parameters of *T. gramanium* whose 4-th instar were exposed to sublethal concentrations of malathion

Life table parameters	Untreated	LC_{10}	LC_{40}
Net reproductive rate (R0) (offspring/individual)	10.237 ± 1.933a	6.815± 1.951a	1.157±0.620b
Intrinsic rate of increase (r) (d-1)	0.037 ± 0.003a	0.035 ± 0.005a	0.003 ±0.012b
Finite rate of increase (λ) (d-1)	1.038 ± 0.003a	1.036 ± 0.006a	0.999 ± 0.012b
Mean generation time T (d)	61.61 ± 0.73a	52.83 ±0.97b	49.01 ±4.92b
The doubling time (DT)	18.35	19.09	263.17
Fecundity(eggs/female)	24.29 ± 4.36a	24.37 ± 2.22a	5.22 ± 2.56b
GRR	33.74 ± 5.45a	39.08 ± 10.88a	6.44 ± 4.16b
APOP	2.49 ±0.49a	2.54 ± 0.11a	2.00 ± 0.00a
TPOP	60.49 ±0.73a	52.74 ±2.11b	48.00 ± 1.20b
Ovi-days	2.60 ±0.16 a	1.91 ±0.19b	1.25 ± 0.24c
Relative fitness	1	0.66	0.11

APOP, adult pre-ovipositional period
TPOP, total pre-ovipositional period (from egg to first oviposition)
Means in the same row followed by the same letter are not significantly different ($P > 0.05$)

Effect on Survival Rate, Life Expectancy, Reproduction Value, and Fecundity:

The age-stage specific survival rate (S_{xj}) clarifies the effect of the tested factor on mortality. (S_{xj}) clarifies the survival likelihood that laid eggs will survive to age x and stage j. The observed overlaps in the age-stage specific survival rate (S_{xj}) appeared due to variations in developmental rates among individuals. Figure 1 exhibits these differences in developmental rates among individuals. The projected overlapping curves for different developmental stages for LC_{10} and LC_{40} of malathion and control showed a different pattern for every development stage. The curves of all treatments were similar until the end of 3-rd instar larvae. As a result of the treatment of 4-th instar larvae began to differ from beginning the 4-th instar larvae till the end of the life cycle of the pest. The results show that with the treatment of this pest at LC_{40} of malathion, the shortest life span period was 55 days at LC_{40} compared with 70 days in control and LC_{10} (Fig. 1).

Age-stage specific reproductive value ($V_{x,j}$) refers to the future offspring from age x to stage j. Because the contribution of males to the future population was not defined, no curve was included for males. The female reproductive values declined in LC_{10} treatment and decreased sharply with LC_{40} treatment compared with the control group (Fig.2).

The age-specific survival rate (l_x), age-specific fecundity of the total population (m_x) and age-specific maternity ($l_x m_x$) are presented in (Fig.3). Age-specific survival rate (l_x), simply expresses the age-stage survival rate (S_{xj}) and avoids S_{xj} overlapping phenomenon (Fig. 1). The curves of l_x declined significantly in treated larvae especially with LC_{40} compared with control, and consequently illustrates the impact sublethal concentrations of malathion on larval mortality. Age-specific fecundity of the total population (m_x) showed the highest peaks in the control group compared with LC_{10} and the tremendous decrease of LC_{40} groups.

The age-stage-specific life expectancy (exj) is the length of time that an individual of age x and stage j is expected to survive after age x (Fig. 4). The life expectancy (exj) curves indicated that treatment with the sublethal concentration of malathion especially with LC_{40} decreased survival longer than the control (Fig 4).

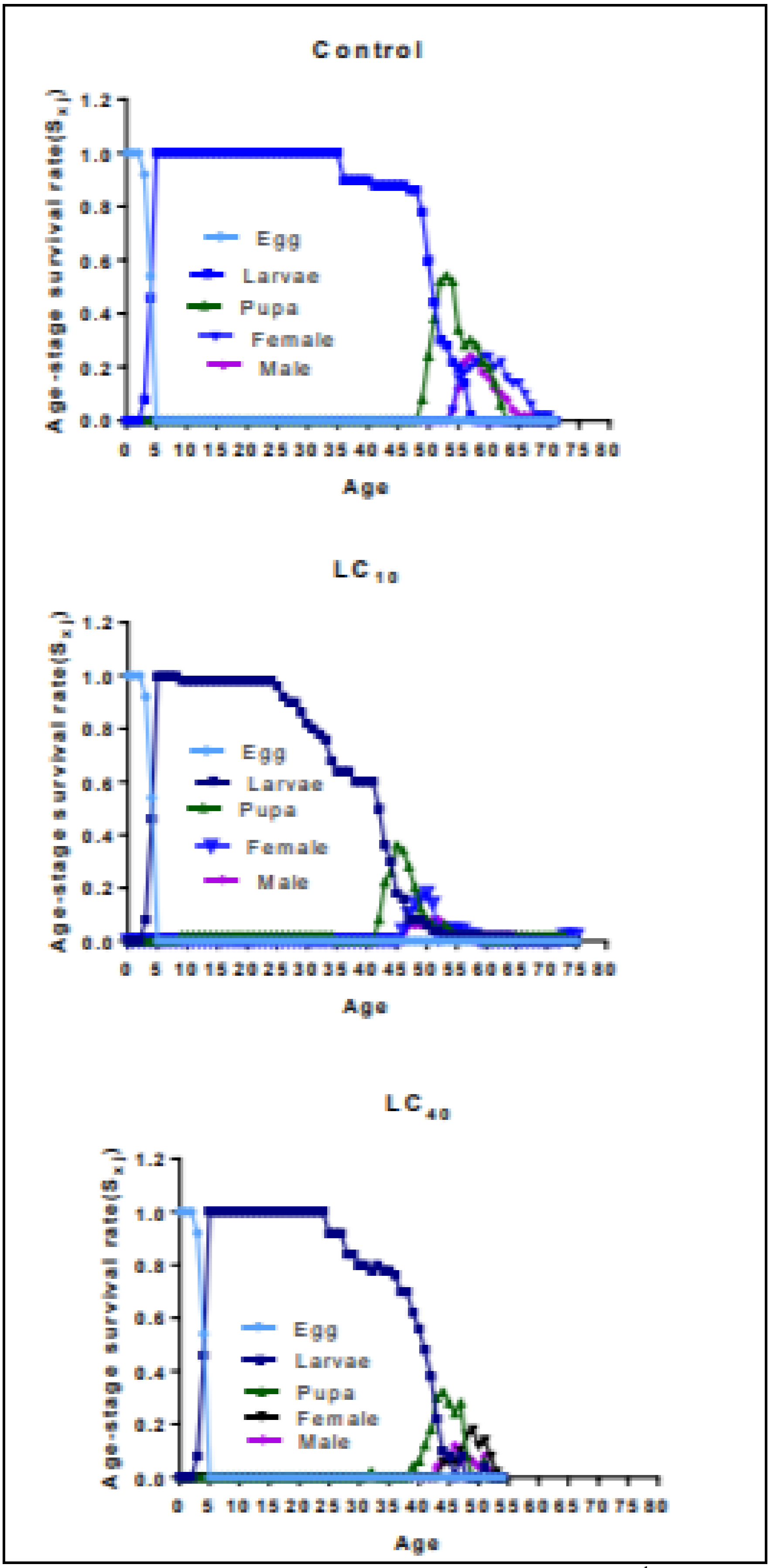

Fig. 1. Age-stage specific survival rate (S_{xj}) of *T. granarium* whose 4-th instar were exposed to sublethal concentrations of malathion

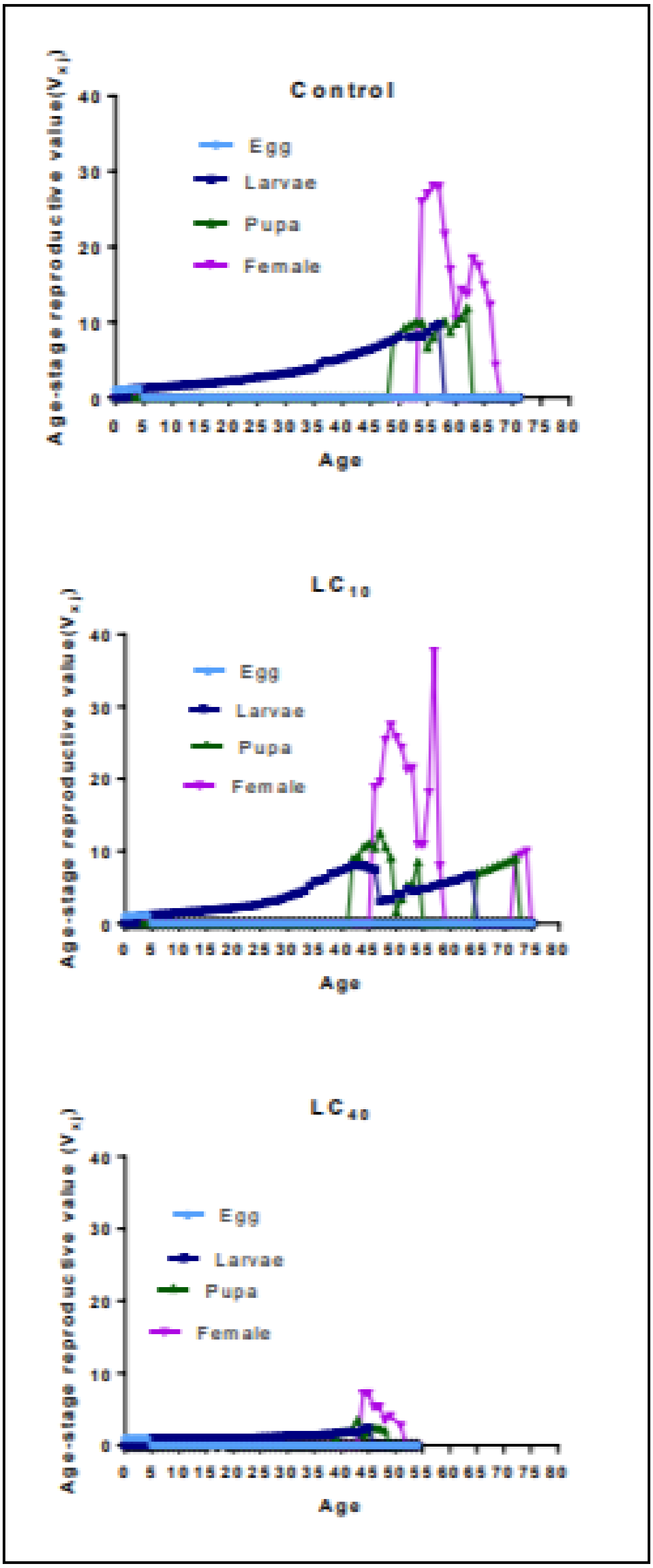

Fig. 2. Age-stage specific reproductive value ($V_{x,j}$) of *T. granarium* of individuals of age x and stage J whose 4-th instar were exposed to sublethal concentrations of malathion

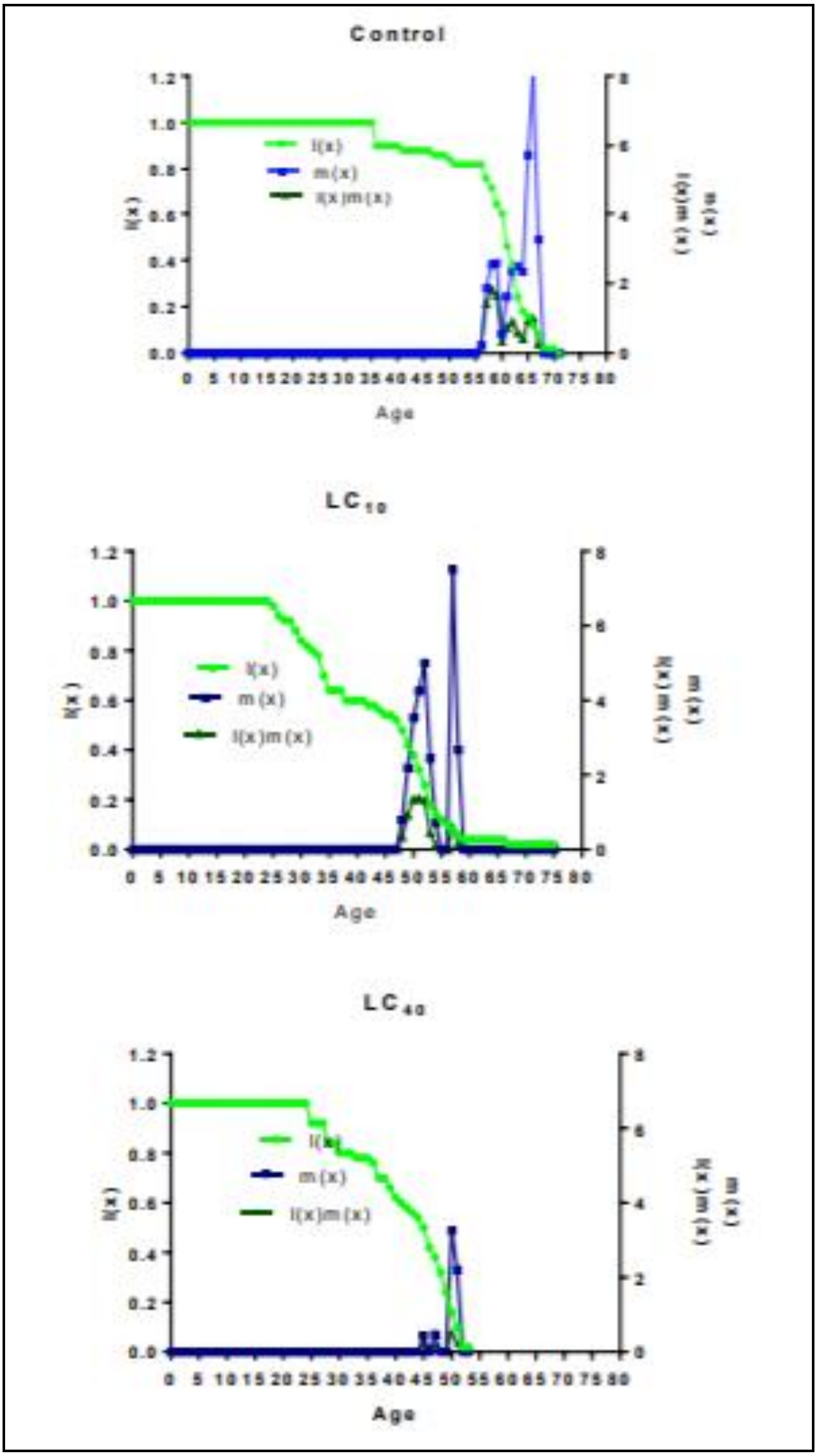

Fig. 3. Age-specific survival rate (l_x), age-specific fecundity of the total population (m_x), and age-specific maternity (l_xm_x) of *T. granarium* whose 4-th instar were exposed to sublethal concentrations of malathion.

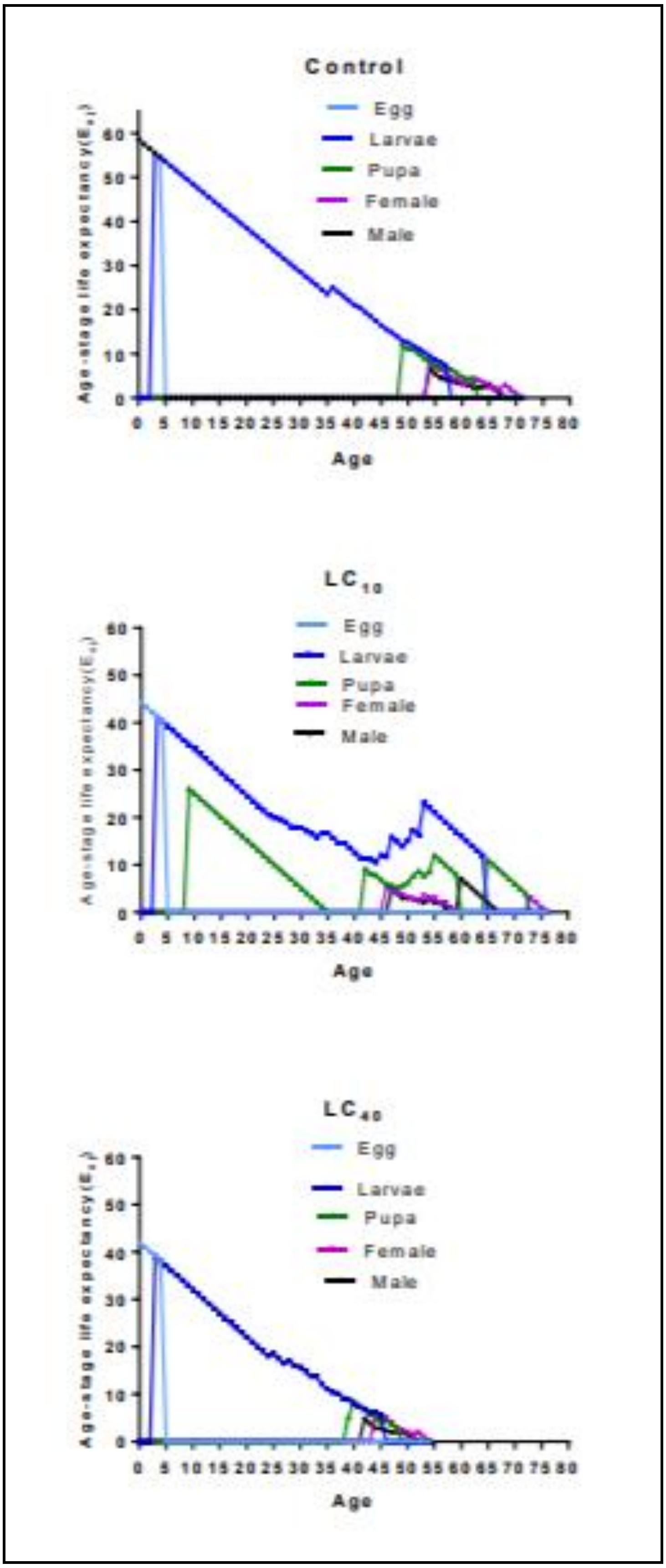

Fig. 4. Age-stage-specific life expectancy (e_{xj}) of *T. granarium* whose 4-th instar were exposed to sublethal concentrations of malathion

DISCUSSION

Effective protection of stored products still relies on various insecticides that belong to many insecticide classes (Daglish, 2006; Riaz *et al.*, 2017). Various insecticides were effective against the Khapra beetle (Riaz *et al.,* 2017). Malathion had become the primary residual insecticide to combat postharvest insect (Haliscak and Beeman, 1983). The current work proved a high probability that *T. granarium* will expose to sub-lethal concentrations of malathion. Whereas malathion recommended concentration (10 ppm) represent about LC_{40} against the 4^{-th} instar larvae. So, it is of great importance to investigate the effect of such concentrations on biological aspects and population growth of *T. granarium*. Sublethal treatments (LC_{10} and LC_{40}) proved a destructive effect against 1^{-st} instar which not exceeds the fourth larval instar. So, it is not possible to conclude life table parameters. These findings in line with Ali et al., 2014 who stated that deltamethrin sublethal concentrations suppress the survival of lesser grain borer, *Rhyzopertha dominica*. Oppositely, the fourth instar treated with LC_{10} and LC_{40} were able to complete their life span with a significant decrease in the larval and pupae period compared with control. These results in agreement with (Kavallieratos *et al.,* 2016; Singh *et al.,* 2000) who found that large larvae of *T. granarium* were more tolerant than small ones in all tested insecticides. In addition, treated larvae showed further molting (supernumerary larvae) and consequently reached to seven or eight larval instars. Supernumerary molts noticed in rice weevils, *Sitophilus oryzae* (L.), as a response to starvation (Jones *et al.,* 1980; Pittendrigh *et al.*, 1997). Also, supernumerary larval molts due to insecticides treatment were observed in other insects such as the red flour beetle, *Tribolium castaneum,* (Parthasarathy and Palli, 2009).

Understanding the overall impacts of insecticides on stored pests need to investigate sub-lethal effect against their life table parameters (Guedes *et al.,* 2011). Exposure insects to a sublethal amount of insecticides, which result from either insecticides misapplication or degradation can generate physiological, behavioral, and survival responses (Biondi *et al.*, 2012; Desneux *et al.*, 2007). Several factors affect Life table parameters of khapra beetle include crop cultivars **(**Majd-Marani *et al.,* 2017; Nemati-Kalkhoran *et al.,* 2018), pressure (Finkelman et al., 2006), irradiation (Sedaghat et al., 2014; Ubaid, 2016), exposure to chemicals (Ali *et al.*, 2018; Shakoori *et al.,* 2016). Sublethal concentrations of tricalcium phosphate prolonged generation time (T), and increased gross reproductive rate (GRR) of *T. granaries,* (Kraszpulski *et al.,* 1987). In contrast, neem oil treatment decreased the percentage of egg hatching (Kteo and Mohammed, 2019). Other stored pests such as the red flour beetle, *Tribolium confusum*, showed a negative effect on life table parameters after exposure to DDT sublethal concentrations (Taher and Cutkomp, 1983). The similar effect observed with the maize stalk borer, *Chilo partellus* (Swinhoe), after exposure to sublethal concentrations of cypermethrin, phosphamidon, quinalphos, and endosulfan (Singh *et al.*, 2000). In addition, low lethal concentration (LC_{20}) of essential oils negatively affected the longevity, fecundity, and fertility of female adults of the cowpea weevil, *Callosobruchus maculatus* F. (Izakmehri *et al.*, 2013). Similarly, essential oil treatments decreased the adult's longevity, oviposition period, the number of eggs laid, and consequently negatively affect population growth of the next generation of *Sitotroga cerealella* (Borzoui and Naseri, 2016; Naseri *et al.*, 2017).

The current study revealed that malathion sublethal concentrations decreased certain life table parameters of *T. granarium*. Intrinsic rates of increase (r), finite rates of increase (λ), net reproduction rate (R_{0}), survival rate, reproductive value, mean generation time (T), total preovipositional period (TPOP), and ovidays were adversely affected. In contrast, doubling time (DT) was prolonged by treatments. The suppression degree of population growth parameters was correlated with the malathion concentration. Previous reports confirmed the impact of several factors on *T. granarium* life table parameters such as the effect of maize hybrid (Majd-Marani *et al.,* 2017), wheat cultivars (Golizadeh and Abedi, 2016), lower temperature (Burges, 2008), and datura alba leaf extracts (Ali *et al.,* 2012). But, investigating pesticides sublethal effects on *T. granarium* were rare.

The adverse effect of malathion on *T. granarium* population growth parameters was shown in the plotted curves of sxj, lx, mx and e_{xj}. These curves clearly illustrate the effect of malathion treatments on mortality, fecundity, stage periods and mean generation times. Malathion sublethal effect on these parameters was interpreted as a result of their impact on survival and reproduction (Amini Jam *et al.,* 2014; Qu *et al.,* 2015) . Age-specific maternity (lxmx), and Age-stage specific reproductive values (vxj) decrease compared to control due to pesticide interaction with nutrient accumulation and inhibiting reproduction's processes (Devine *et al.,* 1996). In certain cases, sublethal concentrations exhibited reproduction stimulation or hormoteic like effect. Certain factors affect this phenomenon including application conditions, pesticide classification, insect species, and physiological states (James and Price, 2002; Wang *et al.,* 2005; Zhang *et al.*, 2014).

The results of the current work revealed that malathion recommendation to combat stored pest (10 ppm) was effective against *T. granarium*. Although this concentration represents a sublethal concentration for the pest, But, exhibiting a pronounced effect in suppressing *T. granarium* population growth. The first instar exposed to sublethal concentrations was destroyed. While the fourth instar exposed to sublethal concentrations were able to complete their life span with pronouncing effects on fecundity and life table parameters. Despite the good indicators about malathion use in stored pest control, there is a need to investigate more details such as the transgenerational effect and the effect on *T. granarium* adults for a comprehensive understanding of the overall effect of malathion on the pest.

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ARABIC SUMMARY

التأثيرات تحت المميتة للمالاثيون على بيولوجية ونمو العشيرة لخنفساء الصعيد
***Trogoderma granarium* Everts (Coleoptera: Dermestidae)**

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خنفساء الصعيد من الآفات الحشرية الرئيسية التى تصيب الحبوب المخزونة وكذلك البذور الزيتية. ويهدف هذا العمل لدراسة تاثير التركيزات تحت المميتة للمالاثيون (LC_{10},LC_{40}) والتى تم معاملة يرقات العمر الأول والرابع بها على الجوانب البيولوجية ومقاييس نمو العشيرة لخنفساء الصعيد.وأوضحت النتائج أن هناك تأثيرمدمر للتركيزات القاتلة لـــ ١٠ و٤٠ % من التعداد على يرقات العمر الأول لحشرة خنفساء الصعيد والتى لم تكمل الطور اليرقى.فى حين أكملت يرقات العمر الرابع المعاملة بالتركيزات القاتلة لـــ ١٠ و٤٠ % من التعداد دورة الحياة مع تأثيرات كبيرة تم ملاحظتها على النواحى البيولوجية ومقاييس نمو-العشيرة حيث زاد عدد الإنسلاخات وبالتالى زاد عدد الأعمار اليرقية إلى ٧ أو ٨ أعمار يرقية بينما قلت فترة العمر اليرقى، ،فترة ماقبل البلوغ وإجمالى طول العمر للحشرة مقارنة بالكنترول.. كذلك إنخفضت مقاييس جداول الحياة مثل معدل التعويض الصافي (R_0)،معدل الزيادة الداخلية (r)،المعدل النهائى للتزايد (λ) ومتوسط فترة الجيل (T) مقارنة بالكنترول. وقد أثبتت الدراسة التأثيرات القوية للتركيزات تحت المميتة للمالاثيون على نمو وبيولوجية خنفساء الصعيد. ويمكن لهذه النتائج أن تساهم فى فهم أفضل لتأثير المالاثيون على الحشرة كما يمكن أن تساهم فى إدارة والسيطرة على الآفة بصورة أفضل.