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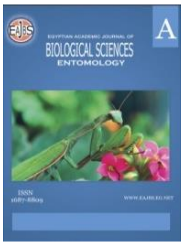

Impact of Malathion and Lufenuron Alone and Their Mixtures against *Trogoderma granarium* Larvae

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ABSTRACT

The effectiveness of Malathion and Lufenuron alone and their mixtures against *Trogoderma granarium* larvae was investigated. The obtained results showed that Malathion was more toxic to the tested insect larvae than Lufenuron and the mixtures of Malathion with Lufenuron concentrations were more effective than each compound alone. Malathion at the highest concentration gave 65.5% larval mortality after 14 days, while the corresponding value of Lufenuron was only 33.3%.

In addition, the presence of larvae in grain treated with Lufenuron extends the larval stage for a long time that increases the toxic effect of Malathion and should reduce adult emergence. An additive effect on the larval mortality and reduction rates in *T. granarium* adult emergence was achieved when Malathion at 4ppm mixed with each concentration of Lufenuron.

INTRODUCTION

The Khapra beetle, *Trogoderma granarium* (Eversts) is the most destructive insect of stored grain and products. It is widespread in tropical and subtropical countries like Upper Egypt. It infests either whole or broken wheat, oilseeds and other cereal grains causing a huge loss in weight, germination and quality (Masolkar *et al.*, 2018). Insect larvae can resist starvation for up to 3 years and live on food with low moisture content **(**Banks 1977; Hill 1983). Furthermore, larvae wander in and out sacked materials and weakening the sacks which may ultimately tear (Howe, 1952). Eradication of khapra beetle has been reported as difficult, which may reduce its susceptibility to some control methods, so control methods must be able to penetrate throughout the infested material or facilities (Pasek, 2004).

Malathion is an organophosphorus (OP) insecticide that is being used to protect stored grains against stored product insects till now. The repeated use of these insecticides like Malathion changes the susceptibility of stored-product insects and several insects now are resistant, the lesser grain borer *Rhizopertha dominica* (F.) adults were resistant to both Malathion and Pirimiphos- methyl (El-Lakwah et *al*., 2004). Therefore, there is an urgent need for new alternative pest control agents and reduced-risk insecticides such as insect growth regulators (IGRs), Lufenuron 5% is an acylurea insect growth regulator which inhibits chitin synthesis and thereby prevents Lepidoptera larvae from molting from one stage to another (Oberlander and Silhacek, 2000; Arthur, 2007).

Synergism was shown between (OP) and Pyrothriods and combinations of insecticides with other substances were evaluated against stored product insects (Bengston *et. al*, 1987; Nasr, 2017 and Yasir 2019).

The aim of the present study the effect of Malathion and Lufenuron alone and their mixtures on larval mortality and percent reduction in adult emergence of *Trogoderma granarium*.

MATERIALS AND METHODS

Insects:

The tested insect *Trogoderma granarium* (Eversts) (Coleoptra: Dermestidae) were reared for several generations in the laboratory at 28 ± 2°C and 60 ± 5% RH. About 600 adults of insect (0-24 hrs. old) were introduced into Jar 1kg capacity containing half-filled with sterilized and conditioned wheat kernels with 14% moisture content. A roll of paper placed on the grain top to serve as a suitable premise for the diapausing larvae and covered with double folded muslin clothes held tight with rubber bands. Three days later, all insects were separated from the food and the Jars were kept again at the experimental conditions. This procedure was repeated several times in order to obtain larger numbers of larvae needed to carry out the experiments. The food renewed when it was necessary.

Insecticides:

Malathion 1% dust: 0,0 dimethyl-s-(1-2dicarboxyethyl) phosphodithioate, produced by Kafr El-Zayat chemical and Pesticides company, Egypt.

Match® (Lufenuron5%) EC: produced by Syngenta crop protection limited.

Grain treatment:

The amount of Malathion insecticide was mixed with 50 g of wheat in jars about 125 ml volume to obtain Malathion concentrations 8, 4, 2, 1 and 0.5 ppm (toxicity of Malathion alone), five ml from each concentration of Lufenuron solution in water were added to 50g wheat to give 10, 5, 2.5, 1.25 and 0.625ppm, (toxicity of Lufenuron alone) and treated wheat left for 24 hrs to evaporate the solvent.

In the case of mixtures, at first, the amount of Lufenuron was added to wheat kernels and left for 24 hrs to evaporate the solvent then mixed well with the amount of Malathion.

Bioassay:

Batches of 30 *T. granarium* larvae were introduced to the jars, the jars were covered with muslin cloth and fixed with a rubber band. Three replicates for each concentration were used and kept at 28 ± 2°C and 60 ± 5% RH. Mortalities were recorded after 2, 3, 5, 7, and 14 days from treatment and corrected using Abbot's formula (1925). Replicates were kept in the experimental conditions and inspected daily for 3 months to count the emerged adults and the reduction percentages in an adult emergency were calculated according to the following equation:

$$\text{Reduction \%} = N_0 - N_1 / N_0 * 100$$

N_0 = No. of adults emerged in control. N_1 = No. of adults emerged in each treatment.

The joint action after14days from exposure caused by adding different concentrations of Lufenuron to 4ppm of Malathion insecticide was determined according to the equation adopted by Mansour *et. al.* (1966):

Co-toxicity factor = [(observed mortality % - expected mortality %) / expected mortality%] *100

This factor was used to classify the results into three categories, an appositive factor of 20 or more mean a synergistic effect, a negative factor of -20 or more meant antagonism, and any value intermediate between +20 and -20 was considered only an additive effect.

RESULTS AND DISCUSSION

Effect of Malathion:

The effect of Malathion alone at different concentrations on mortalities of *T. granarium* larvae and reduction % of adult emergency are given in Table (1).

Larval mortality was increased with an increase of concentrations and exposure time, these percentages were 31.1, 25.6, 18.9, 13.3and 6.7% after 5days of treatment of 8, 4, 2, 1, and 0.5 ppm, respectively. Mortality values increased gradually with prolonging the exposure time to reach 65.5, 46. 7, 31.1, 30.0 and16.7% after 14days of aforementioned concentrations, respectively. Meanwhile, the effect of Malathion on the adult emergency was higher than larval mortality. No adults emerged from larvae exposed to treated wheat with 8ppm of Malathion. While the reduction percentages in adult emergence were ranged from 40.1-80.1% at the lower concentrations.

The obtained results are in harmony with the findings of other investigators (Haubruge *et al.*, 1988; Kljajic et *al.* 2004; Husain and Hasan 2006 and Goran *et al.*, 2015).

Table 1: Effect of Malathion on mortalities and reduction in adult emergency of *T. granarium* larvae.

Conc. (ppm)	% Adult mortalities after various periods (days) ± S.E.					No. of emerged adults	% Reduction in adult emergency
	2	3	5	7	14		
0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	26.7±0.9	-
0.5	1.1 ± 0.33	2.2 ± 0.33	6.7 ± 0.00	13.3 ± 0.58	16.7±.0.00	16.0 ± 0.0	40.1
1.0	6.7 ± 0.0	10.0 ±0.58	13.3 ± 0.58	17.8 ±0.33	30.0 ±0.00	14.0 ± 0.0	47.6
2.0	11.1± 0.33	14.4± 0.67	18.9± 0.33	23.3± 0.58	31.1± 0.88	8.3 ± 0.9	68.9
4.0	13.3± 0.58	15. 6±0.88	25.6± 0.67	32.2± 0.33	46. 7±0.58	5.3 ± 0.9	80.1
8.0	18.9± 0.33	23.3±0.58	31.1± 0.33	45.6± 0.88	65.5± 0.67	0.0 ± 0.0	100.0

Effect of Lufenuron:

Response of *T. granarium* larvae after exposure to Lufenuron at 10, 5, 2.5, 1.25, and 0.625ppm, (Table 2).

Results showed that the effect of Lufenuron on larval mortality was lower than Malathion with no larval mortality till 5days after treatment at different concentrations of Lufenuron. Only 33.3% larval mortality was observed at the highest concentrations (10ppm) and the lowest concentrations gave the lower mortalities (less than 20%). While Reduction rates of adult emergency at all tested concentrations were higher than mortality percentages. All larvae failed to emerge adults after exposed to wheat treated with the highest concentration of Lufenuron. Meanwhile, the corresponding values were 92.5, 72.5, 46.4, and 31.5% of the lower concentrations, respectively.

Mahanthi (2006) tested Lufenuron and Diflubenzuron as stored-maize Protectants, results showed that they inhibited completely the adult emergence of *Sitophilus oryzae* (L.) and controlled completely *Corcyra cephalonica* (Stainton). Chitin synthesis inhibitors (diflubenzuron, flufenoxuron, lufenuron and triflumuron) at doses of ≥5 ppm gave (>88.5% suppression of *Prostephanus truncatus* and *Rhyzopertha dominica* progeny), while diflubenzuron at 25^{0}C in the case of *P. truncatus* or lufenuron in the case of *R. dominica* completely suppressed of progeny production when they were applied at 1 ppm (Kavallieratos, 2012).

Table 2: Effect of Lufenuron on mortalities and reduction in adult emergency of *T. granarium* larvae.

Conc. (ppm)	% Adult mortalities after various periods (days) ± S.E.					No. of emerged adults after 90 days	% Reduction in adult emergency
	2	3	5	7	14		
0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	26.7±0.9	-
0.625	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.1 ± 0.33	18.3± 0.9	31.5
1.25	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	5.6± 0.33	14.3 ±0.3	46.4
2.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.1 ± 0.33	6.7 ± 0.58	7.3 ±0.9	72.5
5.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	2.2 ± 0.33	15.6 ±0.67	2.0 ± 0.6	92.5
10.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	4.4± 0.33	33.3± 0.58	0.0 ± 0.0	100.0

The combined action of 4ppm of Malathion and different concentrations of Lufenuron:

The toxic effect of 4ppm of Malathion and different concentrations of Lufenuron mixtures is given in Table (3).

Data revealed that all tested mixtures were more effective on larval mortality and emergency % than each compound alone at various periods after treatment.

At 14 days, the larval mortality percentages were 75.6, 71.1, 58.9, 53.3and 51.1% of mixtures, respectively. Furthermore, a complete inhibition in adult emergence was obtained at the two highest concentrations of Lufenuron mixed with 4ppm of Malathion. Meanwhile, the other mixtures reduced adult emergence by 91.4, 85.0, and 78.7%, respectively.

Table 3: The combined effect of 4ppm of Malathion and different concentrations of Lufenuron on mortalities and reduction in adult emergency of *T. granarium* larvae.

Conc. (ppm)	% Adult mortalities after various periods (days) ± S.E.					No. of emerged adults	% Reduction in adult emergency
	2	3	5	7	14		
0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	26.7±0.9	-
4+0.625	13.3 ± 0.0	15.6 ± 0.67	25.6 ± 0.88	32.2 ± 0.67	51.1± 0.33	5.7± 0.9	78.7
4+1.25	13.3 ± 0.58	15.6 ±0.33	26.7 ± 0.00	32.2 ± 0.33	53.3 ±0.58	4.0 ±0.6	85.0
4+2.50	14.4 ± 0.33	16.7± 0.58	26.7 ± 0.58	34.4± 0.67	58.9 ±0.88	2.3 ±0.3	91.4
4+5	14.4 ± 0.88	17.8± 0.33	27.8± 0.67	35.6± 0.33	71.1 ±0.88	0.0 ± 0.0	100.0
4+10	15.6 ±0.33	18.9± 0.67	28.9 ± 0.88	36.7± 0.67	75.6± 0.33	0.0 ± 0.0	100.0

In addition, the Co-toxicity values resulted from mixing 4ppm of Malathion with different concentrations gave an additive effect on *T. granarium* larvae except at the highest mixture which gave an antagonistic effect (Table 4). The combination of chlorpyrifos-methyl at 5ppm with s- methoprene at 0.6ppm in wheat increased significantly the mortality of the parental adults of a Malathion-Pyrethroid–resistant strain of *T. castaneum* compared with the mortality obtained by treatments with chlorpyrifos-methyl or s-methoprene alone. In addition, the combination of these compounds inhibited completely the progeny production as in the case of the application of chlorpyrifos-methyl alone (Daglish, 2008).

The obtained data revealed clearly that Malathion was more toxic to the tested insect larvae than Lufenuron and the mixtures of Malathion and Lufenuron were more effective than each compound alone. The presence of larvae in grain treated with Lufenuron extends the larval stage for a long time that increases the toxic effect of Malathion and should reduce adult emergence.

Table 4: Co-toxicity factor of 4ppm of Malathion combined with different concentrations of Lufenuron against of *T. granarium* larvae

Conc. ppm	% Adult mortalities after 14 days ± S.E.		
	Lufenuron alone	4ppm of Malathion + Lufenuron	Co-toxicity factor
0.625	1.1 ± 0.33	51.1± 0.33	-2.1 d
1.25	5.6± 0.33	53.3 ±0.58	-9.5 d
2.5	6.7 ± 0.58	58.9 ±0.88	-10.2 d
5.0	15.6 ±0.67	71.1 ±0.88	-18.0 d
10.0	33.3± 0.58	75.6± 0.33	-30.6 a

Numbers followed by a= antagonistic, d=additive and s=synergistic

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ARABIC SUMMARY

تأثيرمبيد الملاثيون ومنظم النمو الليوفنيورون منفردين ومخاليطهما على يرقات خنفساء الصعيد

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معهد بحوث وقاية النباتات – مركز البحوث الزراعية – الدقى - مصر

تم دراسة تأثيرمبيد الملاثيون ومنظم النمو الليوفنيورون منفردين وكذلك مخاليطهما على يرقات خنفساء الصعيد. وأظهرت النتائج المتحصل عليها أن مبيد الملاثيون كان أكثر سمية من الليوفنيورون على يرقات خنفساء الصعيد، كما كانت المخاليط أكثرتأثيراً من كل مركب منفرداً. حيث أعطى أعلى تركيزللملاثيون نسبة موت لليرقات ٦٥,٥ % بعد ١٤ يوم من المعاملة بينما نسبة الموت المتحصل عليها من الليوفنيورون هى ٣٣,٣ % فقط. بالإضافة الى ذلك فإن وجود اليرقات على حبوب معاملة يطيل مدة العمر اليرقى والذي يزيد من فعالية الملاثيون عليها ويقلل نسبة خروج الحشرات الكاملة. وتم الحصول على تأثير إضافى على نسبة الموت لليرقات ونسبة خروج الحشرات الكاملة عند خلط الملاثيون بتركيز ٤ جزء فى المليون الى أى من تركيزات الليوفنيورون.