# Efficacy of Lufenuron (CGA-184699) and Diofenolan (CGA-59205) on survival, growth and development of the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae)

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## ABSTRACT

Seven doses (500, 100, 50, 10, 1.0, 0.1 and 0.01 µg/insect) of Lufenuron (CGA-184699) and Diofenolan (CGA-59205) were topically applied onto the prepupae of *Rhynchophorus ferrugineus.* Survival of the prepupae had not been affected except at the higher two doses of Lufenuron or only at the highest dose of Diofenolan. Increasing water loss may explain the increasing mortality % in pupae. Depleting effect of both IGRs had been exhibited on the prepupal maximal body weights especially at the higher two dose-levels. Pupal development was hastened and duration was shortened as the dose-level of each IGR increased. Reduction of the body weights in pupae were observed by the action of each IGR, irrespective of the age. The higher two doses of Lufenuron , but only the highest dose of Diofenolan, remarkably reduced the pupation percent. Also, the pupation program was impaired variously by different dose-levels. The adult eclosion was completely blocked by increasing the dose-level of Lufenuron and by the higher two doses of Diofenolan. Different dose-levels of Lufenuron affected the adult morphogenesis but only the lower two doses of Diofenolan deranged it in 12%.

Keywords: Rhynchophorus ferrugineus, Lufenuron, Diofenolan, mortality, growth, development, morphogenesis, pupation, emergence, deformation.

## INTRODUCTION

Insect growth regulators (IGRs) have received a great deal of attention as so-called "Third-generation insecticides" (Williams, 1976). These compounds including insect juvenile hormone mimics and other compounds controlling the insect development have mode of action disports from other insecticides and low toxicity against non-target organisms. The use of IGRs is increasing of controlling various insects of

agricultural, horticultural, stored product and public health pests (Retnakarn *et al.*, 1985).

On the other hand. diflubenzuron (with its commercial name: Dimilin) was the pioneer of benzoylphenyl urea exhibiting a chitin. synthesis inhibition (Verloop and Ferrell, 1977) in various insect species (Hajjar and Casida, 1978, 1979, Mitsui *et al.*, 1984; Neumann and Guyer, 1983). In addition to this group, chitin synthesis inhibition have been caused by several groups, extracts and compounds such as polyoxins, nikkomycines, avermectin, ... etc. (*cf*. Cohen, 1987).

Lufenuron (Match or CGA -184699) and Diofenolan (Aware or CGA-59205) are assorted in a group among chitin biosynthesis inhibitors, or IGR, in general. The present study extends our previous studies (Bream *et al.* 2001) assessing some extracts and IGRs on the red palm weevil *Rhynchophorus ferrugineus* which was recorded at 1992 in Egypt as a destructive pest for the date palms *Phoenix dactylifera* (Cox, 1993). This paper deals with the toxicological, developmental and morphogenic effects of Lufenuron and Diofenolan on this weevil.

## MATERIALS AND METHODS

### 1) The Experimental Insect:

The red palm weevil *Rhynchophorus ferrugineus* is a serious pest of coconut causing damage and often killing the palm in its prime of life The hatched grubs burrow into the trunk and feed on tissue of the stem. The pupation and adult emergence within the same stem allow successive generations within the same stem. In the present study, prepupae were collected for every experiment from large cavities of infested date trees specialized for this purpose, i.e. received no chemicals such as insecticides. No laboratory culture of *Rh. ferrugineus* could be established because of the legislative regulation preventing the transfer of it outside the infestation region (Ismailia and Sharqia Governorates, during the period of the practical work of the present study, 2000).

### 2) Administration of Insect Growth Regulators:

Two acylureas were used in the present study. Lufenuron (CGA 184699) and Diofenolan (CGA 59205). The first compound has the chemical name: N {[2,5-dichloro-4- (1, 1, 2, 3, 3, 3 - hexafluora-propoxyl)phenyl]amino]carboryl}-2,6-difluoro-benzamide (CA). The second compound has the chemical name: cis, trans-(±)-2-Ethyl-(4-

phenoxy-methyl,1,3-dioxolone(mixture of the four configurationally isomers).

Seven dose-levels of each compound were prepared: 500.00, 100.00, 50.00, 1.00, 0.10, 0.01 μg/insect and topically applied onto the pronotum of prepupae in 1 μl acetone. Eight replicates for each treatment were treated. Twelve replicates of controls were topically applied with acetone only. All treated and control insects were kept at 27 ± 2 °C and 70 ± 5% RH.

**3) Criteria and calculations:**

Pupal mortalities were observed during the pupal period, especially of the early-, mid- and late-aged pupae. Also, adult mortalities were calculated basing on the successfully emerged individuals All mortalities were counted and expressed in percentages.

In addition, pupation and adult emergence percentages were calculated as suggested by Jimenez-Peydro *et al.* (1995). Morphogenic aberrations were recorded and expressed in %s. For calculating the developmental duration Dempster's equation (1957) was used, and for calculating the developmental rate, Richard's equation (1957) was used. Growth index was determined according to Saxena and Sumittra (1985). Water loss % was calculated basing on the data of initial and final weights of pupae.

**4) Statistical analysis of data:**

Data obtained were analyzed by the Student's *t*-distribution and refined by Bessel correction (Moroney, 1956).

## RESULTS

The two IGRs, Lufenuron (CGA-184699) and Diofenolan (CGA-59205), were bioassayed against the red palm weevil, *Rh. ferrugineus* and the obtained results can be assorted as follows.

**1) Lethal effects:**

Survival potential of the prepupae did not affect except by the higher two doses of Lufenuron (Table 1). In the light of data in the same table, it is easily seen that the insecticidal action of this compound run parallel to the dose level. Moreover, the lowest dose level could not cause a pupal mortality, irrespective of the pupal age. Total mortality consecutively correlated to the dose value. The increasing water loss may

explain the increasing mortality % with ascending level of dose (38.17% at the highest level vs. 13.52% of controls, Table 1). As similar trend of the effect on the pupal survival, the adult had been undergone to the action of Lufenuron (Table 1).

Depending on the data of Table (2), the survival potential of prepupae had not been affected except by the highest dose of Diofenolan. Otherwise, pupal survival was remarkably affected. This adverse effect run parallel to the rising level of the compound. As mentioned in Table (1), Table (2) shows a dose - depending water loss %. This course of drought may interpret the increasing deaths of pupae.

**2) Effects on growth and development:**

The data presented in Table (3) revealed the reducing effect of Lufenuron on the prepupal body weights. This effect elegantly observed after the use of two higher dose-levels (3.38±0.37 and 3.45±0.50 mg by using 500.0 and 100.0 μg/insect, respectively, vs. 4.54±0.90 mg of control congeners). This effect was substantiated by the calculation of growth index, which decreases in no certain trend (Table 3).

The development was hastened and the durations were shortened. This shortening was more exiguously detected by increasing dose-level. The results of the same Table (3) revealed that this shortness was statistically significant by the higher four doses of Lufenuron (5.55±0.45, 5.88±0.87, 6.00±0.67 and 6.15±1.28 days vs 7.45±0.93 days of control corresponding).

Dealing with the pupae, data arranged in the same table showed the shortening action of Lufenuron on the pupal stage in the meaning of accelerated development of pupae. This effect appeared significantly by the use of two higher doses (4.31±0.46, 4.57±0.81 days vs 6.16±1.58 days of controls). This effect was explored by the great values of the developmental rate (23.20 at 500.00 μg/insect vs. 16.23 of controls).

On the other hand, the topical application of Lufenuron in its higher four doses considerably suppressed the body weights of the pupae (both the newly- and late-aged, for more details, see Table 3). It is noteworthy to mention that the mean body weights of the newly formed pupae were 0.64 of the control body weight (after treatment of the prepupae with the highest dose 500.00 μg/insect). Also, the late-aged pupae weighed 0.53 of the control weight (after treatment with the same dose-level).

As it is distributed in Table (4), only the higher two doses of Diofenolan caused significant depletion of prepupal body weights (3.38±0.37 and 3.45±0.50 mg vs. 4.54±0.90 mg of controls). This compound, in other dose-levels, did not stimulate the prepupae to attain similar significantly recorded body weights or growth index.

Results of the same table indicated the shortening effect of Diofenolan on prepupae before the transformation into pupae. Pronouncedly shortened durations were measured for the prepupae after treatment with the higher four doses (5.55±0.45, 5.88±0.87, 6.00±0.67 and 6.15±1.28 days vs 7.45±0.93 days of control congeners). In other words, they had fast developmental rates as a response to the action of Diofenolan at higher dose levels. Moving to the right half of the same Table (4), it is quite clear that the pupal durations were shortened and the developmental rate increased consecutively to the dose level. This compound at its three high dose-levels, led to the faster developmental rates (23.81, 20.49 and 19.96 vs. 16.23 of controls).

In view of data presented at the same half of the table, different degrees of the reduction in pupal body weights were observed, irrespective of the age. This decreasing effect was a dose-dependent. Also, it is noticed that the resulted pupae from the treated prepupae with the highest dose weighed 0.75 of their controls at the beginning and weighed 0.53 of their controls at the end of the stage.

**3) Metamorphic and morphogenic effects:**

Data given in Table (5) revealed the metamorphosing action of Lufenuron. The topical application onto prepupae with 500.00 and 100.00 μg Lufenuron/insect resulted in the hindering of pupation process. On the other hand, the pupation program was impaired in different degrees by various dose levels. This effect was approximately a dose-dependent, with few exceptions. In addition, the capability of pupae to metamorphose into adults was deranged in different degrees. The rate of adult emergence decreased by increasing the dose-level, which could not be observed for the adult morphogenesis. Unexpectedly, the present IGR, at its higher two dose levels did not induce adult deformities but caused only 87.5 and 63.0% adult blockage (at 500 and 100 μg/insect, respectively).

Only the highest dose level of Diofenolan caused a decreasing of pupation, but slightly, and defused the pupation program in only 25% (see Table 6). Some degrees of such effect could be appreciated except at the two lower dose levels which could not disturb the adult morphogenesis.

The same table showed a complete blockage of adult eclosion by Diofenolan at its two higher dose-levels. Such effect gradually decreased as the dose-level decreased (75 and 12% emergence blockage by 50.00 and 0.01 μg/insect, respectively). Table (6), also, indicated that only the two lower dose-levels deranged the adult morphogenesis in 12%.

The majority of pupal deformities produced by the action of Lufenuron can easily be observed in Fig. (1). These deformities varied between charred body, collapsed appendages and atrophied elytron pads.

Diofenolan treatments resulted in similar degrees of pupal deformation in addition to dorso-ventrally compressed body, failure of complete escape from the prepupal skin, tubercle thorax and dwarf wing pad (Fig. 3).

Lufenuron exerted some action on adult morphogenesis. Fig. (2) demonstrates some photos of pupal-adult intermediates, adults with remains of pupal skin, adult with atrophied wings and legs. Diofenolan caused similar adult malformations beside to some other features such as permanently expanded membranous wings, collapsed appendages and evaginated elytre (Fig. 4).

## DISCUSSION

Benzoylphenyl urea are known to be highly effective IGRs against many agricultural pests with a relatively low toxicity to mammals and natural enemies (Degheele, 1990; Ishaaya, 1990). Diflubenzuron (Dimilin), the most thoroughly investigated compound of this group, has been reported to have no appreciable effect on hymenopterous and dipterous parasites; (Granett and Weseloh, 1975; Ravensberg, 1981). On the other hand, Westigard (1979) found that application of Dimilin was harmful to natural enemies of *Laspeyresia pomonella*, although only at relatively high concentrations. Also, detrimental effects of Dimilin on beneficial insects were reported by (McWhorther and Shepard, (1977) and Zungoli, *et al.*, (1983). Thus, it was necessary for derivatives of Dimilin have been synthesized along several years ago.

Lufenuron (Fluphenacur or Match or CGA-184699) and Diofenolan (Aware or CGA-59205) are chitin synthesis inhibitors or IGRs, in general, manufactured by Ciba Gaigi, Basel, Switzerland. The first was assessed against several insect pests, such as summer fruit tortix, *Adoxophyes orana* (Charmillot *et al.*, 1991; Ioriatti *et al.*, 1993); cat flea, *Ctenocephalides felis* (Hink *et al.*, 1991). The second compound was assessed against some species, such as scale insects: *Hemiberlesia rapax*

(Tomkins *et al.*, 1994), *Quadraspidiotus pyri* and *Q. ostreaeformis* (Hippe *et al.*, 1995); lepidopterous pests (Sechser *et al.*, 1994; Streibert *et al.*, 1994) and some citrus pests (Grout *et al.*, 1997).

However, different results had been obtained about the effects of these acylureas on survival, growth and development of those insects. The promising results, of the aforementioned works and others, encouraged to carry out the present study for investigating the possible effects of these two IGRs on the weevil *Rh. ferrugineus* through the following criteria.

**1) Survival responses of *Rh. ferrugineus*:**

Lethality of Lufenuron and Diofenolan was studied, both in laboratory and in the field, against some insect pests and parasites. Shortly reviewing the available information may be useful. At 50 ppm Lufenuron had little effect on newly hatched larvae of the lepidopteran *A. orana* but was effective as larvicide against 8- to 20-days old larvae (Charmillot *et al.*, 1991). Feeding of cat fleas on orally administered cats with Lufenuron resulted in prevented development of the progeny. Most deaths of progeny occurred in the egg stage and the hatched eggs provided larvae which failed to develop into adults because they died. In addition, Diofenolan has demonstrated excellent selectivity at rates of between 50 and 200 ppm against the predators of scale insects: *Orius majusculus* and *Aphytis melinus* under laboratory conditions (Sechser *et al.*, 1994). On citrus trees in Egypt, Diofenolan caused only a low reduction of larvae of *Aphytis* spp. attacking the citrus purple scale (*Lepidosaphes backii*) and showed no significant effect on the predatory mite *Typhlodromus pyri* in an Italian apple orchard in a control Programme against the codling moth, C*ydia pomella* (Sechser, 1994).

In the present study, the action of Lufenuron and Diofenolan (at dose levels: 500.0, 100.0, 50.0, 10.0, 1.0, 0.1 and 0.01 μg/prepupa) was investigated on the survival potential of prepupae which had not been pronouncedly affected except at the higher two dose levels of Lufenuron. The mortal potency of the latter IGR was obviously observed as run parallel to the dose-level. Also, survival potential of prepupae had not been affected, except at the highest dose-level of Diofenolan. Otherwise, pupal survival was remarkably affected and such effect increased by the increasing dose-level of these IGRs.

A lot of research works showed various degrees of mortal potency or lethal action of different chitin inhibitors within which our Lufenuron and Diofenolan are assorted. Dimilin had been exhibited high activity as a

larvicide, pupicide and adulticide against *Spodoptera littoralis* (Radwan *et al.*, 1978; Sobeiha *et al.*, 1981; Ishaaya *et al.*, 1984; Osman, 1984; Watson *et al.*, 1984; Radwan *et al.*, 1986). Several dimiloids were, also, reported to have high toxicity against several insects such as mosquito species by Chlorfluazuron (IKI-7899), Teflubenzuron (CME-134) and Hexaflumuron (XRD-473) (Mulla and Darwazch, 1988; Bakr *et al.*, 1989; Mulla *et al.*, 1988; Vasuki, 1992a,b; Montada *et al.*, 1994; Mohapatra *et al.*, 1996); lepidopterous species by IKI-7899, XRD-473, CME-143, DPX and Triflumuron (Bay SIR-8514) Granett and Hejazi, 1983; Moustafa and El-Attal, 1984; Osman, 1984; Watson *et al.*, 1984; Atkins and Wright, 1985; Radwan *et al.*, 1986; Horowitz *et al.*, 1992; Furlong and Wright, 1994; Naguib *et al.*, 1994); muscoid flies by IKI-7899 or Bay SIR-8514 (Ghoneim *et al.*, 1992; Ghoneim and Ismail, 1995; Nassar, 1995); subterranean termites by XRD-473 (Su, 1994; Forschler and Ryder, 1996; Su and Scheffrahn, 1996 a,b; Su *et al.*, 1997). Also, larval feeding of *Muscina stabulans* on dietary concentrations either of Dimilin, CME-134 or by larval topical application with IKI-7899 or XRD-473, caused remarkable larval and adult mortalities (Basiouny, 2000). Also, Wright and Harris (1976) recorded non considerable effect for TH-6040 on the adult stage of stable fly *Stomoxys calcitrans*. Furthermore, Dimilin showed very low toxicity against *S. exigua* larvae owing to its rapid elimination from the larva and rapid metabolism of the materials remained in the body (Van Laeck and Degheele, 1993 a,b). Also, young *Spodoptera exigua* larvae owing to its rapid elimination from the larva and rapid metabolism of the materials remained in the body (Van Laeck and Degheele, 1993 a,b). Also, young *S exigua* larvae have shown a tolerance to Dimilin and CME-134.

The toxicity differences among different species may be due to innate differences in the degradative metabolism, absorption and excretion (Wellinga *et al.*, 1973 and Granett *et al.*, 1980). In addition, lethal action of several juvenoids, antijuvenoids, ecdysteroids, antiecdysteroids, and other IGRs are available in the literature but a few references may be suffice for saving effort, area, and time (Ghoneim *et al.*, 1992, 1998; Sundaram *et al.*, 1998; Dedos and Fugo, 1999; Bakr *et al.*, 2000).

However, these different results of toxic effects and lethal action exhibited in various mortalities by several chitin inhibitors, as well as Lufenuron and Diofenolan in the present study on *Rh. ferrugineus*, may be ascribed to a direct inhibition of chitin synthesis within the integument rather than to any indirect extracuticular effects on hormone levels (Hunter and Vincent, 1974; Ishaaya and Casida, 1974; Sowa and Marks,

1975; Hajjar and Casida, 1978; Sundaramurthy and Balsubmanian, 1978). Also, the actual cause of insect death by chitin inhibitors may be attributed to either a rupture of the newly formed cuticle (Beenakkers and Brock, 1974; Salama *et al.*, 1976; Sundaramurthy, 1977; Abid *et al.*, 1978; Fytizus and Mourikis, 1979).

There is an appreciated suggestion for explicating the death or mortality of different insect stages by the action of IGRs, general. According to this suggestion, mortalities are not directly related to the hormonal activity of the IGR, but to other factors or causes, such as: suffocation, bleeding and desiccation due to imperfect exuvation, starvation due to morphological defects, failure of vital homeostatic mechanisms, etc.. (Sehnal, 1983; Smagghe and Degheele, 1994). The latter suggestion is, at least, partially conceived in the present study upon *Rh. ferrugineus* since water loss of pupae increased parallel to the increasing mortality % with ascending dose-level of Lufenuron of Diofenolan which indicated an adverse condition of the water body content.

**2) Influence on growth and development of *Rh. ferrugineus.***

Diflubenzuran the pioneer of benzoylphenyl urea, affects the development, among other vital criteria, of several insect species (El-Sayed *et al.*, 1984; Osman, 1984, Soltani-Mazouni and Soltani, 1994; Soltani *et al.*, 1996; Basiouny, 2000; Chebira *et al.*, 2000).

In the present study on *Rh. ferrugineus*, prepupal treatment with Lufenuron or Diofenolan resulted in significant depletion of body weights, especially at the two higher dose-levels. Also, the produced pupae had reduced body weights especially at the beginning and end of the stage (in the case of Lufenuron application) or along the age (in the case of Diofenolan application). Reduction of body weights, or the weight gain, by some other chitin inhibitors, and IGRs in general, had been reported for several insect species, such as *M. domestica Spodoptera exempta, S. exigua, Mamestra brassicae* and *Galleria mellonella* (Smagghe and Degheele, 1994), as well as *S. littoralis* (Ghoneim *et al.*, 1998). Likewise, no effect on the body weights was recorded by some IGRs against *Leptinotarsa decemlineata, Diabrotica virgifera, Podisus sagitta* and *Locusta migratoria* (Smagghe and Degheele, 1994); *M. domestica* (Ghoneim *et al.*, 1991); *Periplaneta americana* and *Oncopeltus fasciatus* (Darvas *et al.*, 1992).

However, the suppressing action of Lufenuron and Diofenolan, in the present study, may be due to an ecdysonergic activity as suggested by

Smagghe and Degheele (1994) after using an ecdysone agonist, tebufenozide (RH-5992). With regard to the effect on the developmental durations and rates, results of the present study clearly showed remarkably hastened development of pupae which lasted a short duration, irrespective of the dose-level of both IGRs. On the contrary, many authors measured a suppressing action of several chitin inhibitors on the development during prolonged durations of immature stages (see, as for examples, Osman, 1984; Bakr *et al.*, 1989; Soltani *et al.*, 1989; Ghoneim *et al.*, 1992; Vasuki and Rajavel, 1992; Van Laeck and Degheele, 1993 a,b; Ghoneim and Ismail, 1995; Mohapatra *et al.*, 1996, etc.). However, the presence of variation in developmental effects of chitin inhibitors may be largely due to the large species - variation in respect to relative potency of these various compounds. This variation may, also, be resulted from the different mechanisms of ecdysteroid metabolism existing in different insects (Whisenton *et al.*, 1989).

The shortening effect of Lufenuron and Diofenolan in the present study on the weevil *Rh. ferrugineus*, or the lengthening effect of other chitin inhibitors on various insect species, may be explicated by causing an imbalance in the hormone titers at critical times of moulting because the proper balance in the hormone titers is necessary for normal growth, transformation into the pupal stage (Richards, 1981; Retnakaran *et al.*, 1985; Sehnal and Bryant, 1993). That relationships between chitin inhibitors, especially Dimilin and ecdysteroids were investigated in several species (Soltani *et al.*, 1993, 1996; Rehimi and Soltani, 1998; Chebira *et al.*, 2000). Moreover, shortening or elongating the developmental periods by IGRs, other than the chitin inhibitors, may be attributed to their effect on the release of ecdysteroids indirectly, by interfering with the neuroendocrine sites responsible for the release of tropic hormones (espcially the prothoracicotropic hormone) (1985; Schmutterer, 1989; Subrahmanyam *et al.*, 1989).

**3) Morphogenic effects on *Rh. ferrugineus*:**

Topical application of Lufenuron onto the prepupae of *Rh. ferrugineus*, in the present study, at dose-levels: 500.0 and 100.0 μg/insect resulted in pronouncedly prohibition of the pupation. In respect to Diofenolan, only the highest dose caused only a slight prohibition of this process. Similar results had been obtained by using Dimilin and its analogues (or chitin inhibitors) against *S. littoralis* (Gamal *et al.*, 1994), *Tribolium confusum* (El-Sayed *et al.*, 1984), *M. domestica* (El-Kordy *et al.*, 1989), *C. tarsalis* (Mulla *et al.*, 1989), some mosquito species (Montada *et al.*, 1994), some muscoids (Ghoneim *et al.*, 1992; Ghoneim and Ismail, 1995; Basiouny, 2000). Also, Diofenolan inhibited the

pupation in *Coccinella septempunctata* and *Chrysoperla carnea* (Sechser *et al.*, 1994) and *Hemiberlesia rapex* (Tomkins *et al.*, 1994). It is noteworthy to remember here that Lufenuron and Diofenolan are classified in the category of chitin inhibitors, so various works concerning only with it have been referred for saving time and effort because there are a big lot of data and results about the effects of IGRs - other than chitin inhibitors - on the pupation rate of a great variety of insect species, as well as on the adult emergence beside the affected pupal and adult morphogenesis.

Dealing with the action of Lufenuron and Diofenolan on the adult emergence of *Rh. ferrugineus*, in the present study, prepupal treatments reduced it in an effect reversibly correlated with the dose-level. The two higher dose-levels of Diofenolan completely prevented the adult eclosion but some adult weevils enclosed at other dose-levels. Similar effect was reported for various insects by Dimilin and Dimiloids (Salama *et al.*, 1976; Abo Elgar *et al.*, 1978; Bakr *et al.*, 1989; El-Kordy *et al.*, 1989; Ghoneim *et al.*, 1992; Ghoneim and Ismail, 1995; Basiouny, 2000). On the contrary, no effect of some dimiloids on adult emergence was reported by some authors, such as: Schmidt *et al.*, (1993).

However, inhibition of pupation and blockage of adult eclosion, as distinctly found in the present study by the action of Lufenuron and Diofenolan, may be considered as a result either to the haemolymph ecdysteroids or to a delay in the appearance of the last ecdysteroid peak, with or without a reduction in peak height and a slow abnormal decline in the peak (Handler, 1982; Redfern *et al.*, 1982; Sieber and Rembold, 1983). In other words, inhibition of pupation and blockage of adult emergence may be explained by the reduction of eclosion hormone production release, since this hormone is responsible for some prerequisite processes of the completion of moulting (Ghoneim *et al.*, 1998).

To clarify the possible morphogenic action of Lufenuron and Diofenolan on the pupation and adult eclosion programs, available data in the present study unambiguously prevailed increased pupal deformity, approximately, by the increasing dose-level of Lufenuron; while at the highest dose-level, the compound defused this pupal program in 25% only. The pupal malformation varied between charred body color, collapsed appendages, dorso-ventrally compressed body and presence of some prepupal skin remains, irrespective of the used IGR. No effect of Lufenuron on the adult morphogenesis was observed while Diofenolan, at its two lower doses, only, of Diofenolan impaired this phenomenon in 12%. Whether the used IGR, Lufenuron or Diofenolan, deformities of

adult weevils comprised pupal-adult intermediates, remains of the pupal exuvia and abnormal wings.

Various pupal and adult deformities were observed by several authors for different insect species, belonging to several orders by many chitin inhibitors such as: Dimilin against *Glossina morsitans* (Jordan *et al.*, 1979), *Simulium vittatum* (Lacy and Mulla, 1979), *Culex pipiens* (Bakr *et al.*, 1989), and *M. stabulans* (Basiouny, 2000); Bay SIR-8514 against *T. confusum* (El-Sayed *et al.*, 1984), *M. domestica* (Miller and Schmidtman, 1985), *C. pipiens* (Bakr *et al.*, 1989), *M. stabulans* (Ghoneim *et al.*, 1992); IKI-7899 against *C. pipiens* (Bakr *et al.*, 1989), *P. argyrostoma* (Ghoneim and Ismail, 1995), *M. stabulans* (Basiouny, 2000); .... etc. As well as, Diofenolan disrupted the insect transformation of the lepidopterans *Cydia pomonella* and *C. molesta* (Streibert *et al.*, 1994).

Several hypotheses have been made to explain the mode of action of the IGRs including direct inhibition and/or interference with chitin synthesis (Grosscut *et al.)*, effect on the chitinase levels comprising that chitin is being digested faster than deposited (Soltani *et al.*, 1993), interference with juvenile hormone and ecdysteroid metabolism causing a disruption in the chitin metabolic system (Yu and Terriere, 1975), inhibition of chitin synthase by metabolites of chitin synthesis inhibitors (Cohen and Casida, 1980), inhibition of protease (s) that activate the chitin synthase zymogen (Leighton *et al.*, 1981), inhibition of DNA synthesis (Mitlin *et al.*, 1977), inhibition of glycosyl transferases that are involved with synthesis of lipid linked oligosaccharids in cell membranes which possibly provide primer molecules for chitin synthase (Marks and Sowa, 1979; Mayer *et al.*, 1980 a,b), and/or inhibition of facilitated diffusion and active transport across cell membranes of nucleosides and amino acids (Deloach *et al.*, 1981; Mayer *et al.*, 1988). However, and whatever the degree of pupal or adult deformation, it is suggested that chitin inhibitor (including Lufenuron and Diofenolan, in the present study) suppressed the chitin synthesis and prevented the normal deposition of new cuticle during apolysis, hence moulting abnormalities during larval-pupal or pupal-adult transformation may occur (*cf.* Yu and Terriere, 1975; Retnakaran *et al.*, 1985; Degheele, 1990). Finally, the exact mode of action of most IGRs almost remains poorly understood (Doannio *et al.*, 1993).

## REFERENCES


Abid, M.K.; Chobrial, A.; El-Haideri, H.S. and Abbas, S.A. (1978): Dimilin (TH-6040) effect on the spiny bollworm, *Earias insulana* Boisd. (Lepi., Phalaenidae). Z. Angew Ent. 85:321-324.

Abo El-Gar, M.R.; Radwan, H.S.A. and Ammar, I.M.A. (1978): Morphogenetic activity of an IGR disrupting chitin biosynthesis against pupae of the cotton leafworm *Spodoptera littoralis* (Boisd). J. App. Ent., 86:308-311.

Aikins, J.A. and Wright, D.J. (1985): Toxicity of DDT and malathion to various larval stages of *Mamestra brassicae* L. Pestic. Sci., 16:73-80.

Bakr, R.F.A.; Abo Gabal, N.M. and Hussein, M.A. (1989): Biological activity of some IGRs against the susceptible and resistant strains of *Culex pipiens* pattern of cross resistance to IGRs in carbonyl-resistant strain. J. Egypt. Soc. Parasitol., 19(2):589-597.

Bakr, R.F.A.; Abdel Razik, N.A.; Ahmed, N.S. and Guneidy, N.M. (1991): Physiological effects of some insect growth regulators on the respirometric measurements, total protein, and free amino acids of the house fly *Musca domestica.* Ain shams Sci. Bull., 28(B): 169-183.

Bakr, R.F.A.; Guneidy, N.A.; El Bermawy, S.M.; Helmy, N. and Abul-Yazid, I. (2000): Toxicological effect and ultrastructural changes in *Musca domestica* larvae (Diptera : Muscidae) induced by the insect growth regulator (Admiral) combined with the new pyrethroid insecticide (Goklaht). J. Union Arab Biol., Cairo, 13A : 177-191.

Basiouny, A.L. (2000): Some physiological effects of certain insect growth regulators (IGRs) on the false stable fly, *Muscina stabulans* (Fallen.) (Diptera : Muscidae). Ph.D. Thesis, Fac. Sci., Al-Azhar Univ., Cairo.

Beenakkers, A.M.T. and Brock, A.T.H. (1974): Influence of juvenile hormone on growth and digestion in fifth instar larvae and adults of *Locusta migratoria*. J. Insect. Physiol., 20:1131-1142.

Berreur, P.; Porcheron, P., Berreur-Bonnenfan, J. and Simpson, P. (1979): Ecdysteroid levels and pupariation in *Drosophila melanogaster.* J. Exp. Zool., 210:347-352.

Bream, A.S.; Ghoneim, K.S. Tanani, M.A. and Nassar, M.M. (2001): Evaluation of plant extracts, Azadirachtin and Jojoba oil, on the red palm weevil *Rhynchophorus ferrugineous* (Olivier) (Coleoptera: Curulionidae). Sec. Int. Conf. Date Palms, Fac. Agric. Al-Ain, UAEU. 25-27 March.

Briers, T. and De Loof, A. (1980): The moulting hormone activity in *Sarcophaga bullata* in relation to metamorphosis and reproduction. Int. J. Invert. Reprod., 2:263-372.

Charmillot, P.J.; Pasquier, D.; Schneider, D. (1991): Ovicidal and Larvicidal activity of three insect growth inhibitors (IGI) against the summer fruit tortix Adoxophyes orana F.V.R. (Lep. Tortricidae), J. Appl. Ent., 1(1) : 35-49:5.

Chebira, N.; Soltani-Mazouni and Soltani, N. (2000): Evaluation of two insect growth regulators, Flucycloxuron and Diflubenzuron, affecting *in vivo* and *in vitro* the ecdysteroid production in *Tenebri molitor* (Coleoptera). J. Egypt Ger. Soc. Zool., 32(E) : 75-89.

Cohen, E. (1987): Chitin biochemistry : synthesis and inhibition. Anu. Rev. Ent., 32:71-93.

Choen, E. and Casida, J.E. (1980): Inhibition of *Tribolium* gut synthetase. Pestic. Biochem. Physiol., 13:129.

Coppen, G.D. and Jepson, P.C. (1996a): Comparative laboratory evaluation of acute and chronic toxicology of Diflubenzuron, Hexaflumuron and Teflubenzuron (Orthoptera : Acrididae). Pestic. Sci., 46:183-190.

(1996b): The effects of the duration of exposure on the toxicity of Difluabenzuron, hexaflumuron and Teflubenzuron to various stages of instar *Schistocerca gergaria*. Pestic. Sci., 46:191-197.

Cox, M.L. (1993): Red palm weevil, *Rhynchophorus ferrugineus* in Egypt. FAO-Plant, Prot. Bull., 41 (1):30-31.

Darvas, B.; Polgar, L.; Tag El-Din, M.H. Katalin, E. and Wing, D. (1992): Developmental disturbances in different insect orders caused by an ecdysteroid against, RH-5849. J. Econ. Ent., 85:2107-2112.

Dedos, G. and Fugo, H. (1999): Disturbance of adult eclosion by fenoxycarb in the silk worm, *Bombyx mori*. J. Insect Physiol. 45:257-264.

Deloach, J.R.; Meola, S.M. and Mayer, R.T. (1981): Effect of Diflubenzuron on thymidine in corporation in *Stomoxys calcitrans* Pupae S.W. Entomol., 6:123-125.

Dempster, C. (1957): The population dynamic of Moroccan locust *Dociostarus murcocamus* In Cyprus. Anti Locust Bull., 27.

Doannio, J.M.; Dossou, Y.J.; Duval, J.; Hougard, J.M. and Guillet, P. (1993): Factors affecting the efficecy of two growth regulator compounds OMS 3010 (Phenoxycarb) and OMS 3019 (ethoxypridine), on larvae of the *Simulium damnosum* complex. Ann. Soc. Belg. Med. Trop., 73:119-125.

El-Kordy, M.W.; Metwally, M.M.; El Khouly, A.S. and Hamdy, A.M. (1989): Bioloigical activity of the insect growth regulators. Chlorfluazuron and Teflubenzuron on *Musca domestica* L. Proc. 1*st* Int. Conf. Econ. Ent. 1:349-357.

El-Sayed, M.A.; Abdel Razik, F. and Kandil, M.A. (1984): Biological activity of insect growth regulator Triflumuron against *Tribolium confusum*. Bull. Ent. Soc. Egypt, 14:171-175.

Forscher, B.T. and Ryder, J.C. (1996): Subterramean termite, Reticulitermes spp. (Isoptera : Rhinotermitidae), Colony response to biting with Hexaflumuron using a prototype commercial termite baiting system. J. Entomol. Sci., 31(1):143-151.

Furlong, M.J. and Wright, D.J. (1994): Examination of stability resistance and cross resistance patterns to acylurea insect growth - regulators in field populations of the Diamond back moths, *Platella xylostella*, from Malaysia. Pestic. Sci., 42 (4):315-326.

Fytizus, E. and Mourikis, P.A. (1979): Some aspects of the action of a juvenoid on the growth of *Heliothis armigera* Hbn. (Lepidoptera : Noctuidae), Body weight, feeding and utilization of food. Z. Angew. Ent., 88: 542-547.

Gamal, E.S.; Abo Elghar, Radwan, S.A.; El-Bermawy, Z.A. and Zidan, L.T.M. (1994): Biological activity of nvermctin $B_1$, β-Exotoxin of *bacillus thuringiensis* and Difluabenzuron against cotton leaf worm (Lepidoptera : Noctuidae). Bull. Ent. Soc. Egypt, 21:11-23.

Ghoneim, K.S.; and Ismail, I.E. (1995a): Assessment of the Juvenile hormone activity of Pyriproxyfen against *Schistocerca gregaria* (Forsk.) (Orthoptera : Acrididae) after treating the two late nymphal instars. J. Egypt. Ger. Soc. Zool., 17(E) 55-90.

Ghoneim, K.S.; and Ismail, I.E. (1995b): Survival, developmental and morphogenic deficiencies of *Parasarcaphaga argyrostoma* (Diptera : Sarcophagidae) induced by the biosynthesis inhibitor, chlorfluazuron (IKI-8799). J. Egypt Soc. Parasitol., 25(2):561-581.

Ghoneim, K.S.; Bream, A.S. and Mohamed H.A. (1998): Bioactivity of the ecdysteroid against Tebufenozide (RH-5992) on the Egyptian cotton leaf worm *Spodoptera littoralis* (Boisd). (Noctuidae : Lepidoptera). Al-Azhar Bull. Sci., 9 (2): 947-963.

Ghoneim, K.S.; Essa, N.; Abul-Ela, R.G.; Al-Morsy A.A. and Nassar, M.I. (1992): Efficacy of Triflumuron, Bay Sir. 8514. for remedial control of the false stable fly *Muscina stabulans* (Fallen) (Diptra Muscidae). Al-Azhar Bull. Sci., 3, (2):687-693.

Ghoneim, K.S.; Fouda, M.A. and Bream, A.S. (1991): Effectiveness of the nonsteroidal mimic, RH-5849, for the control of *Musca domestica vicina*. J. Egypt. Soc. Parasit., 21(2): 723-733.

Granett, J. and Hejazi, M.J. (1983): Synergism of two Benzoylphenylurea insect growth regulators. J. Econ. Ent., 76:403-406.

Granett, J. and Weseloh, R.M. (1975): Dimilin toxicity to the gypsy moth larval parasitoid. *Apanteles melamoscelus*. J. Econ. Ent., 68:577-580.

Granett, J.; Robertson, J. and Retnakaran, A. (1980): Metabolic basis of differential susceptibility of two forest lepidopterans to Diflubenzuron. Ent. Exp. Appl., 28:295.

Greenberg, S.H.; Ishaaya, I.; Ishaaya, F.; Silhacek, D.L. and Oberlander, H. (1995): Hydrolase activity in *Ploida interpunctella* use of Difluabenzuron and P-Nitroacetanilide as substrates. Pestic. Biochem. Physiol., 52 (3):157-169.

Griffith, B.; Michael, B.M. and Perry, A.S. (1996): Effects of aerial application of Diflubenzuron on emergence and flight of adult aquatic insects. J. Econ. Entomol., 89(2):442-446.

Grosscut, A.C.; Haar, M.T.; Logsma, B. and Stocker, A. (1988): A new acaricide and insecticide interfering with chitin deposition. Pestic. Sci., 22: 51-55.

Grout, T.G.; Richards, G.I. and Stephen, P.R. (1997): Further non-target effects of citrus pesticides on *Euseius addoensis* and *Euseius citri* (Acari : Phytoseiidae). Exp. Appl. Acarol., 21:171-177.

Hajjar, N.P. and Casida, J.E. (1978): Insecticidal benzoylpyridly ureas : structure - activity relationships as chitin synthesis inhibitors. Sci. 200:1499-1500.

Handler, A.M. (1982): Ecdysteroid titers during pupal and adult development in *Drosophila melanogaster*. Devel. Biol., 93:73-82.

Hink, W.F.; Draught, D.C.; Barnett, S. (1991): Effect of an experimental systemic compound CGA-184699, on life stages of the cat flea (Siphonaptera : Pulicidae). J. Med. Ent., 28:3, 424-427.

Hippe, C.; Schwaller, F.; Mani, E.; Kull, H.; Kozar, F. (1995): Control of native oyster scale insects, Obst - Und Weinbau 131:4, 84-85.

Horwitz, A.R.; Klien, M.; Yablonski, S. and Ishaaya, I. (1992): Evaluation of benzoylphenyl ureas for controlling the spiny Boll Worm *Earias insulana* (Boisd), in cotton. Crop Prot., 11(5):465-469.

Hunter, E. and Vincent, J.F. (1974): The effects of a novel insecticide on insect cuticle. Experientia, 30(12):1432-1433.

Ioriatti, G.; Delaiti, M.; Angeli, G. and Mattedi, L. (1993): The activity of 3 insect growth regulators for the control of tortricides present in the Tortino region. Informatore-Fitopatologico, 43(10):45-49.

Ishaaya, I. (1990): Benzoylphenyl ureas and other selective insect control agents - mechanism and application. In “Pesticides and Alternatives”. (Casida, J. ed.). Elseiver Sci. Publ. (Biomid. Divi.), Amesterdam 365-376.

Ishaaya, I. and Casida, J.E. (1974): Dietry TH-604- alters Composition and enzyme activity of house fly larval cuticle. Pestic. Biochem. Physiol., 4:484-490.

Ishaaya, I.; Nemny, N.E.; Ascher, K.R.S. (1984): The effect of IKI-7899, a new chitin synthesis inhibitor, on larvae of *Tribolium castaneum* and *Spodoptera littoralis*. Phytoparasitica, 12:193-197.

Jimenez-Peydro, P.R.; Gimeno, M.C.; Lopez, F.J.; Serrano, D.C. and Moreno, M. (1995): Effects of the insect growth regutors cyromazine on the fecundity, fertility and offspring development of Mediterranean fruit fly, *Ceratitis capitata* Wied Dip, Tephritidae. J. Appl. Ent., 119:435-438.

Jordan, A.M.; Trewern, M.A.; Borkcovec, A.B. and De Milo, A.B. (1979): Laboratory studies on the potential of three insect growth regulators for control of tse tse fly, *Glossina morsitans* west wood (Dipt. Glossinidae). Bull. Ent., 69:55-64.

Lacy, L.A. and Mulla, M.S. (1979): Field evaluation of diflubenzuron against *Simulium* larvae. Mosq. News., 39:86-90.

Leighton, T.E.; Marks, E. and Leighton, F. (1981): Pesticides : Insecticides and Fungicides are chitin synthesis inhibitors. Sci., 213:905-907.

McWhorther, R. and Shepard (1977): Response of Mexican bean beetle larvae and the parasitoid Pediobius foveolatus to Dimilin. Fla. Entomol., 60:55-56.

Marks, E.P. and Sowa, B.A. (1979): Cuticle formation *in vitro*. In "The Insect Integument". Pp. 338-357., Elsevier, New York.

Mayer, R.T.; Chen, A.C. and De Loach, J.R. (1980b): Characterization of chitin synthase from the stable fly, *Stomoxys calcitrans*. Insect Biochem. 10:549-556.

Mayer, R.T.; Chen, A.C. and Loach, J.R. (1980a): Chitin synthesis inhibiting insect growth regulators do not inhibit chitin synthase. Experintia 37, 337.

Mayer, R.T.; Witt, W.; Klitschka, G.E. and Chen, A.C. (1988): Evidence that chitin synthesis inhibitors affect cell membrane transport. In : "Endocrinological Frontiers in physiol. Insect Ecol. (Eds. Sehnal, F.; Zabza, A. and Denlinger, D.L.,) Wroclow Tech. Univ. Press, Wroclaw.

Miller, R.W. and Schmidtman, E.T. (1985): Feeding cyromazine (Larvadex) to dairy claves for the control of house flies. J. Agric. Ent., 2:31-36.

Mitlin, N.; Wiygul, G. and Haynes, J.W. (1977): Inhibition of DNA synthesis in boll weevil *Anthonomus grandis* (Boheman) sterilized by Dimilin. Pestic. Biochem. Physiol., 7:559-563.

Mitsui, T.; Nobusawa, C. and Fukami, T. (1984): Mode of inhibition of chitin synthesis by diflubenzuron in the cabbage armyworme Mamestra brassicae L. J. Pestic. Sci. 9: 19-27.

Mohapatra, ARE.; Ranjit, M.R. and Dash, A.R. (1996): The effect of chitin synthesis inhibitors on the development of *Brugia malayia* in *Aedes aegypti*. J. Helminth., 70:269-270.

Montada, D.; Rajavel, A.R. and Vasuki, V. (1994): Use of Hexaflumuron on insect growth regulator in the control of *Aedes albopictus* (skuse). Southeast - Asian. J. Trop. Med. Public. Health, 25(2):374-377.

Moroney, M.J. (1956): Facts from Figures. (3*rd* ed.), Penguin Books Ltd., Harmonds Worth Middlesex.

Moustafa, K.O. and El-Attal, Z.M. (1984): The joint action of Triflumuron and some insecticides against the cotton leaf worm, *Spodoptera littoralis* (Boisd). Bull. Ent. Soc. Egypt, 14;161-164.

Mulla, M.S. and Darwazeh, H.A. (1988): Efficacy of new insect growth regulators against mosquito larvae in dairy waste water lagoons. J. Am. Mosq. Control. Assoc., 4(3):322-325.

Mulla, M.S.; Darwazeh, H.A. and Schreiber, E.T. (1989): Impact of new insect growth regulators and their formulations on Mosquito larval development and food water habitats. J. Am. Mosq. Control Assoc., 5(1):15-20.

Naguib, S.M.; Rashad, A.M.; Wahaba, M.E. and Elgemeiy, H.M. (1994): Responses of *Pectinophora gossypiella* (Saunders) and *Earias insulana* (Boisd). Bull. Ent. Soec. Egypt, 21:25-32.

Nassar, M.I. (1995): The potaniceles of some juvenoids precocenes and botanical extracts for the control of *Muscina stabulans* (Falken) (Diptera Muscidae). Ph.D. Thesis, Fac. Sci. Cairo Univ.

Neumann, R. and Guyer, W. (1983): A new chitin synthesis inhibitor, CGA 112913: its biochemical mode of action compared to diflubenzuron proc.10th Int. Congr. Pl. Protec., 1: 445-451 .

Osman, S.E. (1984): Effect of antimoulting agent “Dimilin” on the blood picture and cuticle formation in *Spodoptera littoralis* Boisd Larvae. Bull. Ent. Soc. Egypt, 14:37-46.

Post, L.C. de Jong, B.J. and Vin Cent, W.R. (1974): 1-(4,6-Disubstituted benzoyl)-3-phenyl-urea insecticides : inhibitors of chitin synthesis. Pestic. Biochem. Physiol., 4:473-483.

Radwan, H.S.A.; Abo El-Ghar, H.P. and Ammar, I.M. (1978): Reproductive parformance of *Spodoptera littoralis* (Bosid.) treated topically with sublethal doses of an antimoulting IGR (Dimilin). J. Appl. Entomol., 86:414-419.

Radwan, H.S.A.; Assal, O.M.; Abo El-Ghar, G.E.; Riskallah, M.R. and Ahmad, M.T. (1986): Some aspects of the action of Diflubenzuron and Trifluron by *Spodoptera littoralis.* J. Insect Physiol., 32(2):103-107.

Ravensberg, W.J. (1981): The natural enemies of the woolly apple aphid *Eriosoma lanigerum* (Hausm.) (Homopt. : Aphididae), and their susceptibility to diflubenzuron. Meded. Fac. Landbouwwet. Rijksuniv. Gent, 46:437-441.

Redfern, R.E.; Kelly, T.J. and Hayes, D.K. (1982): Ecdysteroid titres and moulting aberrations in last stage on copettus nymphs treated with insect growth regulators. Pestic. Biochem. Physiol., 18:351-356.

Rehimi, N. and Soltani, N. (1998): Laboratory evaluation of Alsystin, a chitin synthesis inhibitor, against *Culex pipiens* (Dip., Culicidae): effects on development and cuticle secretion. J. Appl. Ent., 123:437-441.

Richards, A.G. (1957): Cumulative effects of optimum and suboptimum temperatures on insect development. In “Influence of Temperature on Biological System” (ed. Johnson, F.H.). Amer. Physiol. Soc., 15:35-38.

Richards, G. (1981): Insect hormones. Develop. Rev. 56:501-509.

Salama, H.S.; Motagally, Z.A. and Skatulla, U. (1976): On the mode of action of Dimilin as a moulting inhibitor in some Lepidopterous insects. Z. Ang. Ent., 80:396-407.

Saxena, S.C. and Sumittra, L. (1985): Laboratory evaluation of leaf extract of a new plant to suppress the population of malaria vector *Anopheles stephensi*. Liston, Curr. Sci. 54:201.

Schluter, U.; Bidmon, H.J. and Growe, S. (1985): Azadirachtin affects growth and endocrine events in larvae of the tobacco horn worm *Manduca sexta*. J. Insect Physiol., 31:773-777.

Schmidt, G.H.; Ascher, K.R.S. and Schulz, W. (1993): Effect of Teflubenzuron [Nomolt (R)] on the reproductive capacity of the grasshopper *Aiolopus thalassinus* (Fabr.) and *Eyprepocnemis plorans* (Charp.) (Saltatoria, Acridoidea). J. Plant. Dise. Prot., 100(3):225-238.

Schmutterer, H. (1989): Potential of azadirachtin - containing Pesticides for integrated pest control in developing and industrialized countries. J. Insect. Physiol., 34:713-719.

Sechser, B.; Reber, B.and Wesiak, H. (1994): Selectivity of diofenolan (CGA 59205) and its potential for integrated scale control. Proc. Brighton Crop Protection Conf. Pests and Dis., 3 : 1193-1198.

Sehnal, F. (1983): Juvenile hormone analogues. In “Endocrinology of Insects”. Alan R. Liss inc., Ny., pp. 657-672.

Sehnal, F. and Bryant, P. (1993): Delayed pupariation in *Drosophila imaginal* disc. Over growth mutants in associated with reduced ecdysteroid titer. J. Insect physiol., 39(12):1051-1059.

Sieber, K.P. and Rembold, H. (1983): The effects of azadirachtin on the endocrine control of moulting in *Locusta migratoria.* J. Insect. Physiol., 29:523-527.

Smaggh, G.; Degheele, D. (1994): Action of a novel nonsteroidal ecdysteroid mimic, tebufenozide (RH-5992), on insects of different orders. Pestic. Sci., 42(2):85-92.

Sobeiha, A.M.K.; Zidan, Z.H.; Mohmoud, F.A. and Tantawy, S. (1991): Residual influence of Dimilin and Bactospaine on the bio-efficacy of certain synthetic pyrthroids against the cotton leaf worm *Spodoptera littoralis*. Bull. Ent. Soc. Egypt., 12:165-170.

Soltani, N. and Soltani, M.N.; Queendey, B. and Delachambre, J. (1996): Protein synthesis in developing ovaries of meal worm under *in vivo*

and *in vitro* conditions : effects of diflubenzuron. J. Stored Prod. Res. 32(3):205-212.

Soltani, N.; Besson, M.T. and Delachambre, J. (1984): Effects of Tenebrio molitor L. (Coleo. : Tenebrionidae) : Growth and development, Cuticle secretion, epidarmal cell density and DNA synthesis. Pestic. Biochm. Physiol., 21:256.

Soltani, N.; Chebira, S.; Delbecque, J.P. and Delachambre, J. (1993): Biological activity of flucycloxuron, a novel benzoylphenylurea derivative, on *Tenebrio molitor*. Comparison with diflubenzuron and triflumuron. Experintia 49(12):1088-1091.

Soltani, N.; Delachambre, J. and Delbecque, J.P. (1989): Stage-specific effects of diflubenzuron on ecdysteroidtiter during the development of Tenebrio molitor : evidence for a change in hormonal source. Ger. Comp. Endocrinal., 76 (3):350-356.

Soltani, N.; Quennedey, A.; Delbeque, J.P. and Delachambre, J. (1987): Diflubenzuron induced alterations during in vitro development of Tenebrio molitor pupal integument. Arch. Insect. Biochem. Physiol., 5:210-219.

Soltani-Mozouni, M.N. and Soltani, N. (1994): Diflubenzuron affected DNA synthesis in the ovaries of *Tenebrio molitor*. J. Invert. Reprod. Devel., 25(1):19-21.

Sowa, B.A. and Marks, E.P. (1975): An *in vitro* system for the quantitative measurement of chitin synthesis in the cockroach : inhibition by TH-6040 and Polyaxin D. Insect Biochem., 5:855-859.

Streibert, H.P.; Frischknecht, M.L.; Karrer, F. (1994): Diofenalan - a new insect growth regulator for the control of scale insects and important lepidopteraus pests in deciduceus fruit and citrus. Proc. - Brighton Crop Prot. Conf. Pests and Dis., 1 : 23-30.

Su, N.Y. (1994): Field evaluation of Hexaflumuron bait for population suppression of subterranean tremites (Isoptera : Rhinotermitidae). J. Econ. Ent., 87(2):389-397.

Su, N.Y. and Scheffrah, R.H. (1996b): Fate of subterranean termite colonies (Isoptera) after bait applications. An update and Rev. Sociobiology, 27(3):253-275.

Su, N.Y. and Scheffrahn, R.H. (1996a): Comparative effects of two chitin synthesis inhibitors, Hexaflumuron and Lufenuron in a bait matrix against subteranean termites (Isop. - rhinotermitidae). J. Econ. Entomol., 89(5):1156-1160.

Su, N.Y.; Ban, P.M. and Scheffrohen, R.H. (1997): Remedial baiting with Hexaflumuron in above - ground stations to control structure - infesting populations of the formosan substerranean termite (Isop. : Rhinotermitidae). J. Econ. Ent., 90(3):809-817.

Subrahmanyam, B.; Muller, T. and Rembold, H. (1989): Inhibition of turnover of neurosecretion by azadirachtin in *Locusta migratoria*. J. Insect. Physiol., 35:493-500.

Sundaram, P.S.R.; Krell, P.J.; Sohi, S.S.; Dhadialla, T.S.; Retnakaran, A. (1998): Basis for selective action of a synthetic molting hormone against, RH-5992 on Lepidopteran insects. Ins. Biochem. Molec. Biol., 28:693-704.

Sundaramurthy, V.T. (1977): Effect of inhibitor of chitin deposition on the growth differentiation of *Tobacco caterpilla Spodoptera litura* Fb. (Lepi. Noctuidae). Z. Krankh. Path. Schut., 84:597-601.

Sundaramurthy, V.T. and Balasubramanian, M. (1978): Effect of an inhibitor of chitin deposition in tobacco caterpillar (*Spodoptera litura* Fb.) under induced hyper hormone condition. Z. Agn. Ent., 317-321.

Takahashi, R.M. and Ohtaki, T. (1976): A laboratory evaluation of the insect growth regulator, TH-604- against *Culex pipiens* pallens and *Culex tritaeniorhynchus*. J. Saint. Zool., 27:361-367.

Tomkins, A.R.; Follas, G.; Thomson, G.; Wilson, D.J.; Popay, A.J. (1994): A new insect growth regulator, CGA-59205 with promising activity against scale insects. Proc. 47 *th* New Zealand plant Prot. Conf. Waitang. Hotel, New Zealand, 9-11 Augest 337-340.

Van Laecke, K. and Degheele, D. (1993a): Effect of insecticide - synergist combinations on the survival of *Spodoptera exigua* (Hubner). Pestic. Sci., 37:283-288.

Van Laecke, K. and Degheele, D. (1993b): Carboxylamidases in *Spodoptera exigua* : properties and distribution in larval body. Phytoparasitica, 21(1):9-21.

Vasuki, V. and Rajavel, A.R. (1992): Influence of short-time exposure to an insect growth regulator, hexaflumuron, on mortality and adult emergence of vector mosquitos. Mem. Inst. Oswaldo Cruz., Riode Janeiro, 87 (2): 275-283.

Watson, W.M.; El-Dahane, A.A.; Shoeib, A. and Guirguis, M.W. (1984): Different bioassay techniques for evaluating the effeciency of Diflubenzuron and its mixtures with insecticides against *Spodoptera littoralis* (Boisd) Larvae. Agric. Res. Revi., 62(1):1-9.

Wellinga, K.; Mulder, R. and Van Daalen, J.J. (1973): Synthesis and laboratory evaluation of 1-(2,6-disubstituted benzoyl)-3 phenyl urea, a new class of insecticides. Influence of the acyle moiety on insecticidal activity. J. Agric. Food. Chem., 21:993-998.

Wentworth, S.L.; Roberts, B. and O'Connor, J.D. (1981): Ecdysteroid titres during postembryonic development of *Sarcophaga bullata* (Dip. Sarcophagidae). J. Insect. Physiol., 27:435-440.

Whisenton, L.R.; Warren, J.T.; Manning, M.K. and Bollenbacher, W.E. (1989): Ecdysteroid titres during pupal-adult development of *Aedes aegypti* : basis for a sexual dimorphism in the rate of development. J. Insect Physiol., 35 (1) : 67-73.

Williams, C.M. (1976): Juvenile hormone in retrospect and prospect. In ″The Juvenile Hormones " (ed. Gilbert, L.I.). Plenum Press, NY.

Wright, J.E. and Harris, R.L. (1976): Ovicidal activity of Thompson - Hayward TH-6040 In the stable fly and horn fly after surface contact by adult. J. Econ. Ent., 69(6):728-730.

Yu, S.J. and Terriers, L.G. (1975): Activities of hormone metabolizing enzymes in house flies treated with some substituted urea growth regulators. Life Sci., 17:619-626.

Zadrek, J.; Rohlf, are.; Blechl, E. and Frankel, G. (1981): A hormone affecting immobilization in pupariating fly larvae. J. Exp. Biol., 93:51-63.

Zadrek, J.; Salama, K. and Fraenke, G. (1979): Changes in internal pressure during puparium formation in flies. J. Exp. Zool., 207:187-196.

Zungoli, P.A.; Steinhouer, A.L. and Lindusk, J.J. (1983): Evaluation of diflubenzuron for mexican been beetle (Coleo. Coccinellidae) control and impact on *Pediobius foveolatus* (Hymen., Eulophidae). J. Econ. Ent., 76:188-191.

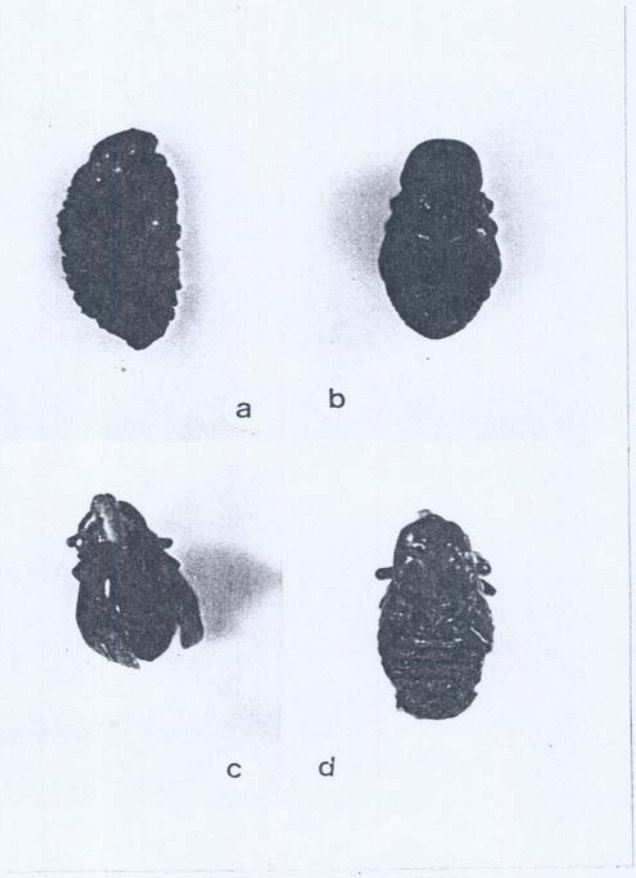


Fig. (1): Topical application of 500.0, 100.0, 50,0, 0.5, 1.0, 0.10 and 0.01 µg/insect of Lufenuron (CGA-184699) onto prepupae of *Rh. ferrugineus* resulted in the following categories of deformed pupae: a) Dead prepupae with charred body. b) Dead pupae with charred body. c) Ventral side of pupae to show collapsed antennae, mouth parts and legs, d) Atrophied elytral pads and arched legs.

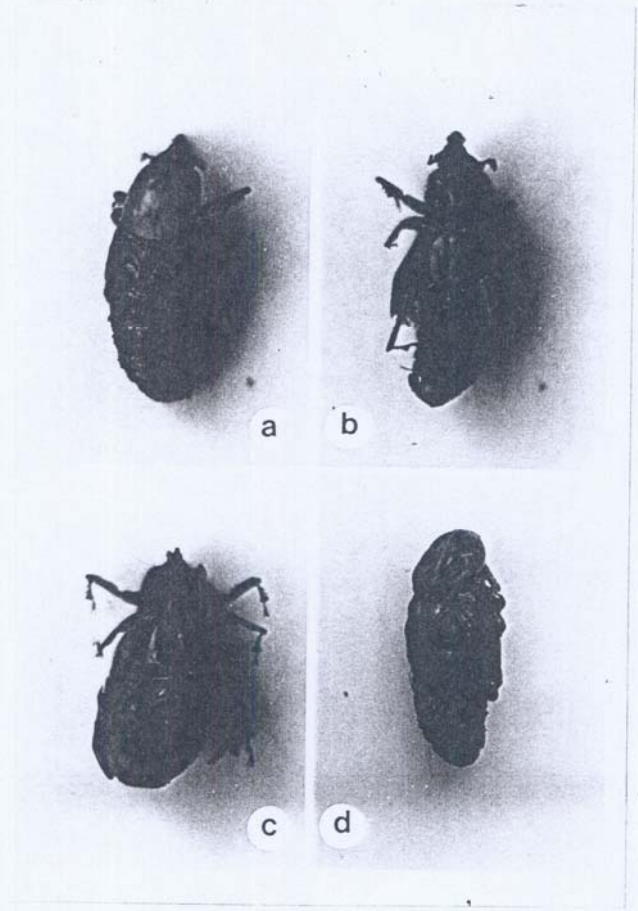


Fig. (2): Topical application of 50.0, 5.0, 1.0, and 0.01 µg/insect of Lufenuron (CGA-184699) onto prepupae of *Rh. ferrugineus* resulted in the following categories of deformed adult weevils: a) Pupal-adult intermediate with posterior pupal portion and anterior adult portion. b) and c) Ventral side of adults which could not to emerge from the pupal exuvia. d) Lateral side of deformed adult weevil with atrophied wings and legs.



271

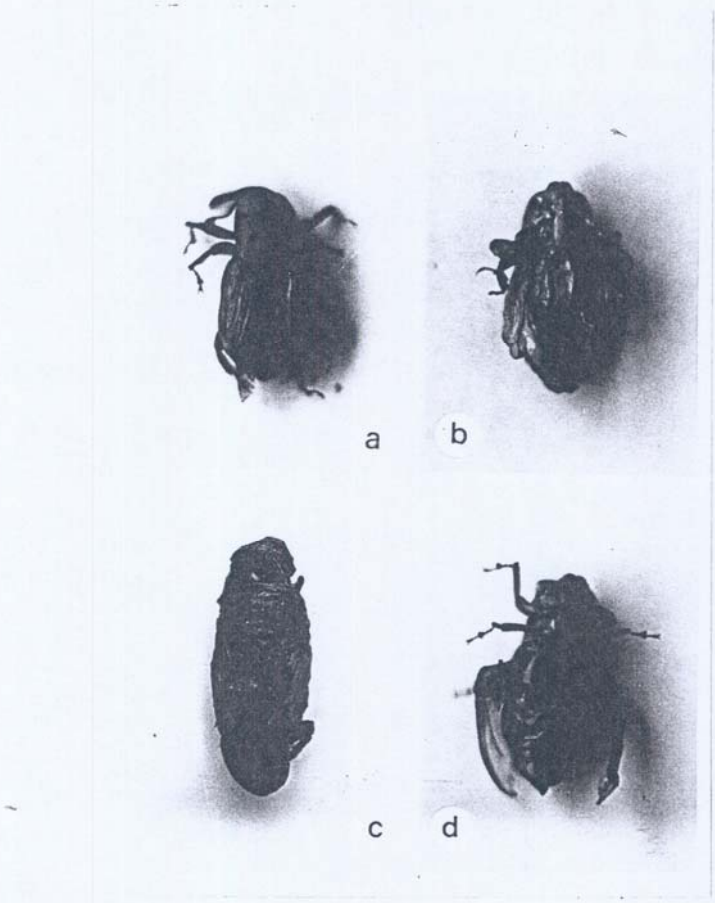


Fig. (3): Topical application of 500.0, 100.0, 50,0, 5.0 and 1.0 µg/insect of Diofenolan (CGA-59052) onto prepupae of *Rh. ferrugineus* resulted in the following categories of deformed pupae: a) Dorso-ventrally compressed pupa. b) Assymetrically formed pupa with zigzaged wing pad. c) Dorsal side of a pupa partially enveloped in the prepupal skin. d) Dorsal side of deformed pupa with a tubercled thorax and a dwarf wing pad.

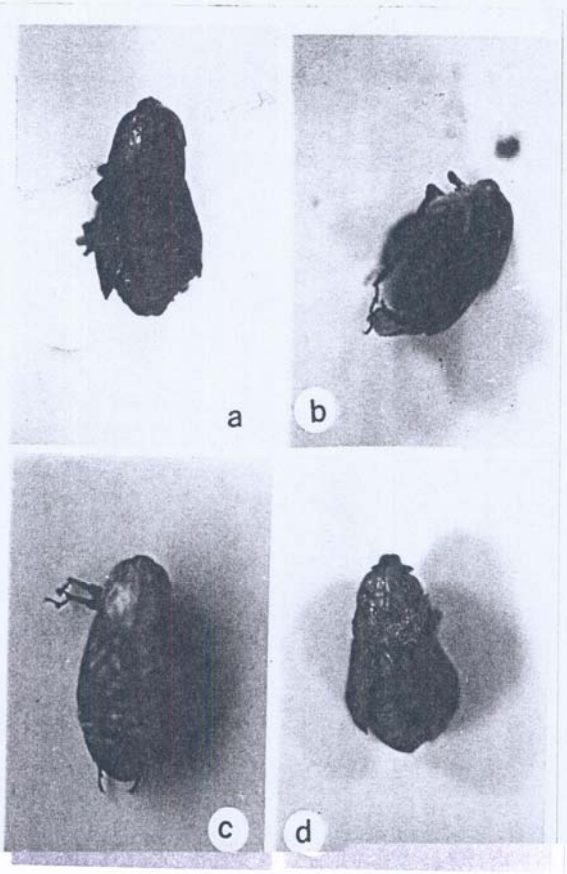


Fig. (4): Topical application of 1.00 and 0.10 µg/insect of Diofenolan (CGA-59052) onto prepupae of *Rh. ferrugineus* resulted in the following categories of deformed adult weevils: a) Adult with permanently expanded membranous wings and evaginated elytra. b) Ventral side of a deformed adult with collapsed antennae and mouth parts, as well as with remains of pupal exuvium. c) Adult with splitted abdomen. d) Adult with permenantly expanded membranous wings.



273

**Table (1): Prepupal pupal and adult mortalities (%) caused by Lufenuron (CGA –184699) applied topically onto prepupae of the red palm weevil *Rhynchophorus ferrugineus.***

| Dose (µg / insect) | Prepupal mortality | Pupal mortalities | | | | | Adult mortality |
|---|---|---|---|---|---|---|---|
| | | Early–age | Mid-age | Late–age | General mortality | Water loss (%) | |
| 500.00 | 12.5 | 25.0 | 25.0 | 25.0 | 87.5 | 38.17 | 12.5 |
| 100.00 | 12.5 | 12.5 | 12.5 | 25.0 | 62.5 | 21.73 | 37.5 |
| 50.00 | 00.0 | 12.5 | 12.5 | 12.5 | 37.5 | 16.88 | 37.5 |
| 5.00 | 00.0 | 00.0 | 12.5 | 12.5 | 25.0 | 15.77 | 25.0 |
| 1.00 | 00.0 | 00.0 | 12.5 | 12.5 | 25.0 | 16.82 | 12.5 |
| 0.10 | 00.0 | 00.0 | 12.5 | 00.0 | 12.5 | 16.32 | 12.5 |
| 0.01 | 00.0 | 00.0 | 00.0 | 00.0 | 12.5 | 15.67 | 00.0 |
| Control | 00.0 | 00.0 | 00.0 | 8.3 | 8.3 | 13.52 | 00.0 |

Early–aged: 1-day old pupae, Mid-aged: 4-day old pupae, Late–aged: 7-day old pupae. Eight prepupae were used as replicates

for treatment, but 12 corresponding prepupae were used as controls.

**Table (2): Prepupal pupal and adult mortalities (%) caused by the Diofenolan (CGA-59205) applied topically onto the prepupae of red palm weevil *Rhynchophorus ferrugineus***

| Dose (µg / insect) | Prepupal mortality | Pupal mortalities | | | | | Adult mortality |
|---|---|---|---|---|---|---|---|
| | | Early–age | Mid-age | Late–age | General mortality | Water loss (%) | |
| 500.00 | 12.5 | 50.0 | 12.5 | 25.0 | 87.5 | 40.3 | 12.5 |
| 100.00 | 00.0 | 37.5 | 25.0 | 12.5 | 75.0 | 38.7 | 12.5 |
| 50.00 | 00.0 | 25.0 | 25.0 | 12.5 | 62.5 | 33.6 | 12.5 |
| 5.00 | 00.0 | 12.5 | 12.5 | 12.5 | 25.0 | 34.5 | 12.5 |
| 1.00 | 00.0 | 00.0 | 00.0 | 12.5 | 12.5 | 27.2 | 12.5 |
| 0.10 | 00.0 | 00.0 | 00.0 | 12.5 | 12.5 | 28.7 | 00.0 |
| 0.01 | 00.0 | 00.0 | 00.0 | 12.5 | 12.5 | 26.8 | 00.0 |
| Control | 00.0 | 00.0 | 00.0 | 00.0 | 8.3 | 24.28 | 00.0 |

Early–aged, Mid-aged and Late–aged: see the footnote of table (1). Eight prepupae were used as replicates for treatment,

but 12 corresponding prepupae were used as controls.

**Table (3): Effects of Lufenuron (CGA-184699) applied topically onto the prepupae on growth and development of red palm weevil *Rhynchophorus ferrugineus***

| Dose (µg / insect) | Prepupae | | | | Pupae | | | |
|---|---|---|---|---|---|---|---|---|
| | Duration (days ± S.D) | Develop. rate | Weights (mg ± S.D ) | Growth index | Duration (days ± S.D ) | Develop. rate | Weights (mg ± S.D ) | |
| | | | | | | | Newly-formed | Late-aged |
| 500.00 | 5.55 ± 0.45d | 29.59 | 3.38 ± 0.37c | 5.00 | 4.31 ± 0.46c | 23.20 | 2.63 ± 0.32d | 1.83 ± 0.29d |
| 100.00 | 5.88 ± 0.87c | 28.99 | 3.45 ± 0.50c | 1.56 | 4.57 ± 0.81b | 21.88 | 3.26 ± 0.29c | 2.18 ± 0.35c |
| 50.00 | 6.00 ± 0.67c | 25.91 | 3.86 ± 0.56a | 5.24 | 5.68 ± 0.35a | 17.61 | 3.32 ± 0.25c | 2.38 ± 0.36c |
| 5.00 | 6.15 ± 1.28b | 26.04 | 3.84 ± 0.75a | 5.08 | 6.00 ± 1.26a | 16.67 | 3.38 ± 0.39b | 2.75 ± 0.27b |
| 1.00 | 6.38 ± 1.48a | 25.19 | 3.96 ± 0.66a | 4.98 | 6.08 ± 0.99a | 16.45 | 3.57 ± 0.47a | 2.77 ± 0.37b |
| 0.10 | 6.75 ± 0.70a | 25.19 | 3.97 ± 0.77a | 4.93 | 6.10 ± 1.77a | 16.39 | 3.68 ± 0.77a | 2.88 ± 0.68a |
| 0.01 | 7.33 ± 1.03a | 24.94 | 4.01 ± 0.40a | 8.64 | 6.12 ± 1.28a | 16.34 | 3.99 ± 0.63a | 3.10 ± 0.56a |
| Control | 7.45 ± 0.93a | 22.03 | 4.54 ± 0.90a | 8.57 | 6.16 ± 1.58a | 16.23 | 4.10 ± 0.85a | 3.46 ± 0.77a |

Means ± SD followed with the same letter (a) are not significantly different (P> 0.05), (b): significantly different (P<0.05), (c): highly significantly different (P<0.01) (d): very highly significantly different (P<0.001). Develop. rate : Developmental rate.Eight prepupae were used as replicates for treatment, but 12 corresponding prepupae were used as controls.

**Table (4): Effects of Diofenolan (CGA-259205) applied topically onto the prepupae on growth and development of the red palm weevil *Rhynchophorous ferrugineus***

| Dose (µg / insect) | Prepupae | | | | Pupae | | | |
|---|---|---|---|---|---|---|---|---|
| | Duration (days ± S.D) | Develop. rate | Weights (mg ± S.D ) | Growth index | Duration (days ± S.D ) | Develop. rate | Weights (mg ± S.D ) | |
| | | | | | | | Newly-formed | Late-aged |
| 500.00 | 5.25 ± 0.55d | 19.05 | 3.51 ± 0.33c | 00.0 | 4.20 ± 0.13d | 23.81 | 2.58 ± 0.37c | 2.32 ± 0.28d |
| 100.00 | 5.88 ± 0.88d | 17.01 | 3.77 ± 0.50b | 00.0 | 4.88 ± 0.27b | 20.49 | 2.65 ± 0.36c | 2.62 ± 0.56d |
| 50.00 | 6.16 ± 0.64d | 16.23 | 3.95 ± 0.65a | 2.23 | 5.01 ± 0.23b | 19.96 | 2.73 ± 0.30b | 3.25 ± 0.39c |
| 5.00 | 6.25 ± 0.70c | 19.05 | 3.93 ± 0.56a | 3.26 | 5.25 ± 0.88a | 19.05 | 3.11 ± 0.88a | 3.41 ± 0.65b |
| 1.00 | 6.55 ± 0.98a | 15.27 | 3.30 ± 0.52a | 3.98 | 6.00 ± 1.41a | 16.67 | 3.23 ± 0.58a | 3.59 ± 0.72a |
| 0.10 | 6.43 ± 1.32a | 15.55 | 4.20 ± 0.45a | 6.63 | 6.75 ± 1.03a | 14.81 | 3.28 ± 1.11a | 3.90 ± 0.83a |
| 0.01 | 6.80 ± 1.41a | 14.71 | 4.50 ± 0.99a | 6.83 | 6.00 ± 1.51a | 16.67 | 3.32 ± 0.25a | 4.25 ± 1.58a |
| Control | 7.45 ± 0.93a | 13.42 | 4.54 ± 0.90a | 6.74 | 6.16 ± 1.58a | 16.23 | 3.46 ± 0.76a | 4.35 ± 0.86a |

a, b, c and d, Develop. rate : See the footnote of Table (3). Eight prepupae were used as replicates for treatment, but 12 corresponding prepupae were used as controls.

**Table (5): Morphogenic and Metamorphic effects (%) of Lufenuron (CGA–184699) applied topically onto the prepupae of the red palm weevil *Rhynchophorus ferrugineus.***

| Dose (µg / insect) | Pupal stage | | Adult stage | |
|---|---|---|---|---|
| | Pupation | Deformities | Emergence | Deformities |
| 500.00 | 87.5 | 50.0 | 37.0 | -- |
| 100.00 | 87.5 | 37.5 | 12.5 | -- |
| 50.00 | 100.0 | 37.5 | 50.0 | 37.50 |
| 5.00 | 100.0 | 25.0 | 50.0 | 25.0 |
| 1.00 | 100.0 | 12.5 | 50.0 | 12.5 |
| 0.10 | 100.0 | 25.0 | 50.0 | 00.0 |
| 0.01 | 100.0 | 12.5 | 87.5 | 12.5 |
| Control | 100.0 | 8.3 | 91.7 | -- |

Eight prepupae were used as replicates for treatment, but 12 corresponding prepupae were used as controls.

**Table (6): Morphogenic and Metamorphic effects (%) of Diofenolan (CGA-59205) applied topically onto the prepupae of red palm weevil *Rhynchophorus ferrugineus.***

| Dose (µg / insect) | Pupal stage | | Adult stage | |
|---|---|---|---|---|
| | Pupation | Deformities | Emergence | Deformities |
| 500.00 | 87.5 | 25.0 | 00.0 | -- |
| 100.00 | 100.0 | 37.5 | 00.0 | -- |
| 50.00 | 100.0 | 25.0 | 25.0 | -- |
| 5.00 | 100.0 | 25.0 | 37.5 | -- |
| 1.00 | 100.0 | 25.0 | 50.0 | -- |
| 0.10 | 100.0 | -- | 87.5 | 12.5 |
| 0.01 | 100.0 | -- | 87.5 | 12.5 |
| Control | 100.0 | -- | 91.7 | -- |

Eight prepupae were used as replicates for treatment, but 12 corresponding prepupae were used as controls.