

**Joint action of methomyl, carbaryl, esfenvalerate and profenofos and its latent effect on the cotton leafworm, *Spodoptera littoralis***

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**ABSTRACT**

Four insecticides; methomyl, carbaryl, esfenvalerate and profenofos were tested against the cotton leafworm, *Spodoptera littoralis* to evaluate their effectiveness. Different combinations by mixing of these insecticides at the level of LC<sub>25</sub> with the ratios of 1: 2, 1: 1 and 2: 1 were used to evaluate the joint action effects against *S. littoralis*. Eighteen mixtures were investigated and three of them exhibited potentiation, 10 antagonism and 5 additive effect. The latent effect appeared significant changes in the pupae weight compared with the control. Some malformations were recorded in the pupae and moths stages and some of the mixtures showed sterility effect.

**Keywords:** Joint action, insecticides, *Spodoptera littoralis*, latent effect

**INTRODUCTION**

Insecticide mixtures are usually used in the field to enhance the spectrum of control when multiple pests are attacking simultaneously. They are also recommended to increase the efficacy of control against a single pest to delay the development of insecticide resistance or to combat current resistance in a pest species. Using mixtures as a countermeasure for resistance management in insect pests has been advocated by several workers (Ishaaya *et al.*, 1985; Ascher *et al.*, 1986 and Mushtaq, 2004), but without a good experimental evidence (Tabashnik, 1989). In addition, the use of various mixtures of compounds on different target sites has been adopted (Kurtak *et al.*, 1987; Penilla *et al.*, 1988 and Martin *et al.*, 2000). Synergism between pyrethroids and organophosphates (OPs) or carbamates has already been demonstrated in the control of agricultural pests (Ozaki *et al.*, 1984; Bynum *et al.*, 1997 and Martin *et al.*, 2003).

Recently, studies have also demonstrated the existence of synergistic interactions between pyrethroids and carbamates (or organophosphates) against susceptible and pyrethroid-resistant strains of *Culex quinquefasciatus* (Corbel *et al.*, 2003 and 2004) and in *Anopheles gambiae* (Darriet *et al.*, 2003 and Bonnet *et al.*, 2004). Mixtures are available as pre-mixes from the pesticide companies or they are tank-mixed by the farmers. Ideally, the insecticides having different modes of action are mixed on the assumption that they would complement the action of each other for killing the target pest.

The term potentiation has been used to indicate the enhanced toxic effect of mixing two insecticide active compounds. When two compounds are mixed, they can either be potentiating or additive or antagonistic in an insect species. These effects can be varied on different insect species or strains depending upon their physiology and the mechanism(s) of resistance developed. If a mixture is potentiating, it is a useful tool in enhancing control efficacy and combating insecticide resistance. In this case, there may be potential for reducing the application rate of one or both components of the mixture. If a mixture is antagonistic, it should not be used, because it will reduce the efficiency of pest control and aggravate the resistance problem.

Because of their dissimilar modes of action, pyrethroids and organophosphates (OPs) have commonly been mixed since mid 1980s to manage pest complex of cotton and other crops (Mushtaq, 2004). Some authors have shown that synergism between pyrethroids and OPs were caused by an inhibition by OPs of either esterases (Gunning *et al.*, 1999), or oxidases (Kulkrani and Hodgson, 1980).

The present study was undertaken to find out the joint action effects of mixing insecticides namely; methomyl, carbaryl, esfenvalerate and profenofos against susceptible and methomyl-resistant strains of the cotton leafworm, *S. littoralis*. The latent effect of the candidate mixtures against the laboratory strain of cotton leafworm was also studied.

## MATERIALS AND METHODS

**Insects:** Susceptible strain of the cotton leafworm, *S. littoralis* L. (Lepidoptera) was used for larval bioassay. This strain has been colonized for many years in laboratory without any exposure to any

pesticides and reared on castor bean leaves. Methomyl-resistant strain (18.4 fold) of cotton leafworm, *S. littoralis* was taken from the colony cultured in the Economic Entomology and Pesticides Department, Faculty of Agriculture, Cairo University. All experiments and culture were carried out at  $28 \pm 2$  °C, 65 % R.H, with a 14:10 light: dark cycle.

**Insecticides:** Four commercial formulations of insecticides used in bioassays were representing, carbamate, pyrethroid and organophosphates classes of insecticides, Lannate (methomyl 90 % SP, DowAgro sciences), Sevin (carbaryl 85 % WP, Bayer crop science), Sumi-alpha (esfenvalerate 5 % EC, Sumitomo) and Selecron (profenofos 72 % EC, Syngenta).

**Bioassay:**

**1. Toxicity test:** Five serial concentrations (in ppm) of the active ingredient of the test compounds were prepared using water. Leaves of castor bean were treated with each concentration using dipping technique for 10 seconds, then left to dry. One hundred, one - day - old 4<sup>th</sup> instar larvae of *S. littoralis* were exposed to the treated leaves in five replicates (20 larvae each). Each replicate was hold in a glass jar covered with muslin. The same number of leaves per treatment was dipped into water as an untreated check. The mortality percent was recorded after 24 hrs exposure, corrected by the formula of Abbott (1925) if necessary, and data were analyzed by the log-probit method of Finney (1971) using the EPA probit analysis program version 1. 5, Florida, then the LC<sub>25</sub> and LC<sub>50</sub> values were computed.

**2. Binary combinations of the tested insecticides:** In order to assess the joint action, different binary combinations of these insecticides at the level of LC<sub>25</sub> were prepared at the ratios of 1:2, 1:1 and 2:1. The toxicity procedure described above was used. In this experiment, one thousand 4<sup>th</sup> instar larvae were used in each treatment divided into 10 replicates (100 larvae each). The obtained eighteen mixtures used to evaluate the joint action and latent effects on the 4<sup>th</sup> instars of *S. littoralis*. Control was concurrently done in the same manner.

**Data analysis:** The percent mortality of each mixture was recorded after 24 hrs. The combined effect of the different mixtures was expressed as the co-toxicity factor (C.F.) which was estimated according to the equation given by Mansour *et al.* (1966). The percentages of pupae and moths maleformation, weight of one day pupae, adult emergence, adult longevity and fecundity were compared with the untreated check (control). Males and

females from the same treatment were allowed to mate. Sterility percentages were calculated according to the equation given by Tappozada, *et al.*, (1966). The data were analyzed according to the T-test and the standard error of mean was calculated.

## RESULTS AND DISCUSSION

The estimated values of LC<sub>25</sub> and LC<sub>50</sub> for each insecticide under investigation against the 4<sup>th</sup> instar larvae of *S. littoralis* are shown in Table (1). The potency of the tested insecticides can be arranged in decreasing order as follow: esfenvalerate > profenofos > methomyl > carbaryl.

Table (1): Estimated LC<sub>25</sub> and LC<sub>50</sub> values of the tested insecticides using food poison technique against the 4<sup>th</sup> instar larvae of *S. littoralis*.

| Insecticide   | LC <sub>25</sub> (ppm) | LC <sub>50</sub> (ppm) |
|---------------|------------------------|------------------------|
| esfenvalerate | 2.00                   | 5.00                   |
| Profenofos    | 5.76                   | 28.8                   |
| Methomyl      | 90                     | 207                    |
| Carbaryl      | 178.5                  | 343                    |

**Joint action:** Table (2) presented the joint action of binary insecticide mixtures on susceptible and methomyl-resistant (18.4 fold) strains of the cotton leafworm, *S. littoralis*. The mixture of methomyl and esfenvalerate showed a good potentiation when used at a ratio of 1:1 on both tested strains. The co-toxicity factor of methomyl-resistant strain was 2 times higher than the susceptible one, which was accounted for 66.6 and 31, respectively. The same trend was observed with the mixture between esfenvalerate and profenofos at the ratio of 1: 1, but the co-toxicity factor was 35 and 32 for susceptible and resistant strain, respectively. The mixtures of esfenvalerate + profenofos (2:1 and 1:2) produced an additive effect on the susceptible strain, with co-toxicity factor of -20 and -16.7, respectively. On the other hand, this mixture showed an antagonism at a ratio of 1:2 against methomyl-resistant strain, but it produced an additive effect at a ratio of 2:1.

Table (2): The effect of binary insecticides mixtures on susceptible and methomyl-resistant strains of the cotton leafworm, *S. littoralis*.

| Combination                | Mixing ratio | %  | Susceptible strain |       |                    | methomyl – resistant strain |                    |              |
|----------------------------|--------------|----|--------------------|-------|--------------------|-----------------------------|--------------------|--------------|
|                            |              |    | Expected mortality | %     | Co-toxicity factor | Joint action category       | Observed mortality | %            |
| methomyl + esfenvalerate   | 1 : 1        | 50 | 65.8± 4.6          | 31    | Potentiation       | 80.0± 4.9                   | 66.6               | Potentiation |
|                            | 2 : 1        | 75 | 66.7± 5.1          | -11   | Additive           | 56.0± 6.0                   | -25.3              | Inhibition   |
|                            | 1 : 2        | 75 | 52.5± 2.4          | -30   | Inhibition         | 62.9± 4.5                   | -16.1              | Additive     |
| methomyl + profenofos      | 1 : 1        | 50 | 58.8± 3.0          | 17.5  | Additive           | 77.0± 2.0                   | 54                 | Potentiation |
|                            | 2 : 1        | 75 | 48.8± 2.6          | -35   | Inhibition         | 78.0± 2.0                   | 4                  | Additive     |
|                            | 1 : 2        | 75 | 35.0± 4.0          | -53   | Inhibition         | 56.0± 4.0                   | -25.3              | Inhibition   |
| methomyl + carbaryl        | 1 : 1        | 50 | 8.0± 2.1           | -84   | Inhibition         | 0.0± 0.0                    | -100               | Inhibition   |
|                            | 2 : 1        | 75 | 10.0± 2.3          | -86   | Inhibition         | 0.0± 0.0                    | -100               | Inhibition   |
|                            | 1 : 2        | 75 | 14.6± 3.0          | -80   | Inhibition         | 0.0± 0.0                    | -100               | Inhibition   |
| Esfenvalerate + profenofos | 1 : 1        | 50 | 67.5± 5.8          | 35    | Potentiation       | 66.0± 2.5                   | 32                 | Potentiation |
|                            | 2 : 1        | 75 | 60.0± 4.7          | -20   | Additive           | 76.0± 1.9                   | 1.3                | Additive     |
|                            | 1 : 2        | 75 | 62.5± 6.5          | -16.7 | Additive           | 52.0± 2.0                   | -30.7              | Inhibition   |
| esfenvalerate + carbaryl   | 1 : 1        | 50 | 39.0± 3.5          | -22   | Inhibition         | 42.0± 2.0                   | -16                | Additive     |
|                            | 2 : 1        | 75 | 10.0± 2.7          | -86   | Inhibition         | 82.5± 6.3                   | -20                | Additive     |
|                            | 1 : 2        | 75 | 33.3± 3.7          | -55   | Inhibition         | 60.0± 8.4                   | 4                  | Additive     |
| profenofos + carbaryl      | 1 : 1        | 50 | 64.2± 4.8          | 28    | Potentiation       | 36.0± 2.4                   | -28                | Inhibition   |
|                            | 2 : 1        | 75 | 59.2± 6.3          | -21   | Inhibition         | 26.0± 2.4                   | -65                | Inhibition   |
|                            | 1 : 2        | 75 | 70.0± 5.9          | -6    | Additive           | 32.0± 3.7                   | -57.3              | Inhibition   |

A potentiation effect was occurred with the mixture of methomyl and profenofos at the ratio of 1:1 against the methomyl-resistant strain, whereas it exhibited an additive effect against the susceptible strain. In case of methomyl and profenofos (2:1), antagonistic and additive effects were recorded in susceptible and resistant strains, respectively.

An antagonistic effect was observed when methomyl was mixed with carbaryl at the different ratios in both susceptible and methomyl -resistant strains (Table 2). The co-toxicity factors for the mixture of methomyl + carbaryl at the ratios of 1:1, 2:1 and 1:2 were -84, -86 and -80 on the susceptible strain, respectively, and on methomyl- resistant strain were -100.

The mixture of esfenvalerate with carbaryl gave an antagonism at the different ratios in the susceptible strain of *S. littoralis*. On the other hand, this mixture exhibited an additive effect against the methomyl-resistant strain. The lowest additive effect was recorded for the ratio of 1:1 and 2:1, with the co-toxicity factor of -16 and -20, respectively, but at the ratio of 1:2 represent a moderately additive effect with co-toxicity factor of 4. On the other hand, this binary mixture exhibited anatagonistic effect against the susceptible strain when used at the ratio of 2:1 and 1:2, with co-toxicity values of -86 and -55, respectively.

The joint action of profenofos and carbaryl mixture at the ratios of 1:1, 2:1 and 1:2 produced a potentiation, antagonism and additive effects, respectively against the susceptible strain of *S. littoralis*. The same binary combination produced an antagonistic effect in methomyl-resistant strain, at all used mixing ratios. The highest antagonism was observed at the ratio of 2:1 followed by 1:2 and 1:1, with co-toxicity values of -65, -57.3 and -28, respectively (Table 2).

The above results demonstrated that the mixtures of methomyl + esfenvalerate and esfenvalerate + profenofos exhibited potentiation effect at the ratio of 1:1 against both susceptible and resistant strains. This result may due to the effect of pyrethroid insecticides to increase the releasing of the neurotransmitter, acetylcholine at cholinergic synaps. This demonstration agrees with the finding of Corbel *et al.* 2003 and 2006. They found that repetitive firing of nerves induced by pyrethroids stimulate acetylcholine release at cholinergic nerve terminals. Then, the application of pyrethroid and carbamate insecticides may contribute to increase acetylcholine

concentration at a critical level leading to block of cholinergic synaptic transmission.

The unexpected response to the mixtures contains carbaryl was unclear. Interestingly, the negative feedback inhibition of ACh release observed in *Preplanta americana* may also explain unusual toxicological responses previously observed in a carbamate resistant strain (MSE) of *C. quinquefasciatus*. Indeed, these authors have shown that in the MSE strain. The authors suspected that mortality of MSE larvae was not due to AChE inhibition but to the interaction with another target site, known as choline acetyltransferase (ChAT) involved in ACh synthesis (Pitman, 1971).

According to Corbett (1974), the general theory of synergism results from the ability of one molecule to interfere with the metabolic detoxification of the other. Indeed, some authors have shown that synergism between pyrethroids and OPs caused by an inhibition by OPs of either esterases (Gunning et al., 1999), or oxidases (Kulkrani and Hodgson, 1980), thereby preventing degradation of the pyrethroids. In such cases, pyrethroid and OP mixtures provide a level of synergism by competitive substrate inhibition.

**Latent effect:** Although synergism between pesticides has been widely documented, there are another point remains unclear, what are the mechanisms of potentiation/antagonism of a mixture? What will be the environmental fate of the mixture, its joint action on humans, animals, birds, and aquatic life, its latent effect? Similar toxicological data as for individual insecticides should be generated for the mixture. Pest control with mixtures as with individual insecticides must be integrated with non-chemical pest management tactics to avoid impending problems for the future. So, this study carried to investigate the effect of the insecticides mixtures, related to different groups on some biological aspects of the susceptible strain of *S. littoralis*.

The data presented in Table (3) showed that the combination treatments exhibited varied effects to pupal and adult stages. The average pupal weights for all different combination of insecticides were significant except the methomyl with profenofos. The esfenvalerate + profenofos mixture significantly decreased the average pupal weight, where the average pupal weight at the ratios of 1:1, 2:1 and 1:2 were  $200.8 \pm 1.45$ ,  $240.6 \pm 2.07$  and  $260.5 \pm 1.54$ , respectively. On the other hand, the mixture of methomyl and

Table (3): Latent effect of different combinations of pesticides on pupae and adult stages of susceptible strain of *S. littoralis*.

| Combination                | Mixing ratio | Pupae          |                |                | Moths            |                |  |
|----------------------------|--------------|----------------|----------------|----------------|------------------|----------------|--|
|                            |              | Weight (mg)    | % malformation | Male longevity | Female longevity | % malformation |  |
| Control                    | 1:1          | 293.7 ± 2.7    | 2.0 ± 0.3      | 10.9 ± 0.28    | 8.3 ± 2.1        | 3.0 ± 0.2      |  |
| methomyl + esfenvalerate   | 1:1          | 271.8 ± 2.23** | 1.5 ± 0.2      | 9.1 ± 0.23**   | 7.5 ± 0.22       | 2.9 ± 0.7      |  |
|                            | 2:1          | 272.1 ± 1.75** | 1.0 ± 0.04     | 8.8 ± 0.25**   | 7.3 ± 0.15**     | 2 ± 0.6        |  |
|                            | 1:2          | 263.4 ± 1.47** | 2.0 ± 0.3      | 9.0 ± 0.33**   | 7.2 ± 0.24**     | 3 ± 0.9        |  |
| methomyl + profenofos      | 1:1          | 290.6 ± 1.15   | 2.2 ± 0.4      | 8.4 ± 0.22**   | 6.5 ± 0.12**     | 3.9 ± 0.5      |  |
|                            | 2:1          | 295.4 ± 0.85   | 2.5 ± 0.6      | 9.1 ± 0.27**   | 7.8 ± 0.20       | 3.9 ± 0.8      |  |
|                            | 1:2          | 296.1 ± 0.98   | 5.6 ± 0.8      | 8.8 ± 0.36**   | 7.0 ± 0.21**     | 4.1 ± 0.8      |  |
| methomyl + carbaryl        | 1:1          | 273.4 ± 2.04** | 14.5 ± 0.5     | 9.0 ± 0.21**   | 6.4 ± 0.27**     | 4.76 ± 1.25    |  |
|                            | 2:1          | 288.2 ± 3.34** | 4.6 ± 0.4      | 8.0 ± 0.39**   | 5.7 ± 0.36**     | 0.0 ± 0.0      |  |
|                            | 1:2          | 273.4 ± 4.71** | 33.3 ± 0.7     | 8.9 ± 0.28     | 7.2 ± 0.20**     | 1.3 ± 0.1      |  |
| esfenvalerate + profenofos | 1:1          | 200.8 ± 1.45** | 2.0 ± 0.03     | 7.6 ± 0.26     | 8.1 ± 0.28       | 2.7 ± 0.7      |  |
|                            | 2:1          | 240.6 ± 2.07** | 5.6 ± 2.1      | 8.5 ± 0.44     | 7.9 ± 0.22       | 0.0 ± 0.0      |  |
|                            | 1:2          | 260.5 ± 1.54** | 4.4 ± 0.5      | 7.2 ± 0.37     | 8.2 ± 0.24       | 3.1 ± 0.7      |  |
| esfenvalerate + carbaryl   | 1:1          | 243.5 ± 2.11** | 1.1 ± 0.1      | 9.1 ± 0.38**   | 7.3 ± 0.37       | 0.0 ± 0.0      |  |
|                            | 2:1          | 261.8 ± 1.37** | 2.3 ± 0.3      | 8.7 ± 0.21**   | 6.8 ± 0.13**     | 0.0 ± 0.0      |  |
|                            | 1:2          | 262.1 ± 4.13** | 3.4 ± 0.3      | 8.9 ± 0.31**   | 7.2 ± 0.20**     | 5.8 ± 0.7      |  |
| Profenofos + carbaryl      | 1:1          | 267.7 ± 3.02** | 1.6 ± 0.02     | 9.8 ± 0.39     | 7.9 ± 0.23       | 17 ± 0.9       |  |
|                            | 2:1          | 240.0 ± 3.81** | 1.7 ± 0.01     | 10.0 ± 0.42    | 8.1 ± 0.28       | 29.6 ± 1.3     |  |
|                            | 1:2          | 243.4 ± 7.33** | 0.0 ± 0.0      | 9.2 ± 0.36**   | 7.1 ± 0.28**     | 27.3 ± 1.7     |  |

\*\* Significant ( $p \leq 0.01$ )

profenofos increased the pupal weight, where the average pupal weight at the ratios of 2:1 and 1:2 were  $295.4 \pm 0.85$  and  $296.1 \pm 0.98$ , respectively (Table 3).

Malformation percentages of pupa in all treatments varied in some cases within normal level in comparison with the untreated check. The percentage of deformed pupa caused by the mixture of methomyl + carbaryl was high compared with the untreated check. In general, when comparing the malformation percentage of this mixture with those of the rest combinations, the value of this mixture was the highest. Its malformation percentage at the ratios of 1:1 and 1:2 were  $14.5 \pm 0.5$  and  $33.3 \pm 0.7$ , respectively (Fig. 1).



(A)



(B)

Fig (1): The malformation in pupal stage after the treatment with the mixture of methomyl and carbaryl at the ratio of 1:1 (A) and 1:2 (B).

The longevity of females and males seems to be also affected by the most of binary combinations compared with the untreated check. The obtained values of the esfenvalerate + profenofos mixtures were not significant at  $p \leq 0.01$  (Table 3).

The percentage of deformed moths caused by the mixture of profenofos and carbaryl was high when compared with control treatment. The data listed in Table (3) showed the highly significant malformation percentage for the mixture of profenofos and carbaryl when applied at the ratios of 1:1 (Fig. 2 A) and 1:2 (Fig. 2 B) .



(A)



(B)



(C)

Fig. (2): The malformation in pupal stage after treated with the mixture of profenofos and carbaryl at the ratio of 1:1 (A), 1:2 (B) and 2:1 (C).

The data in Table (4) elucidate the latent effects of different insecticide combinations on eggs stage. The mixture of methomyl with either carbaryl or esfenvalerate decreased the number of laids per female at the three

Table (4): Lattent effects of different pesticides combinations on eggs stage and its sterility effect on the cotton leafworm, *S. littoralis*.

| Combination    | Mixing ratio | No. of laids | Non fertilized egg masses |       | No. of eggs/laid | %Hatchability | %Sterility  |
|----------------|--------------|--------------|---------------------------|-------|------------------|---------------|-------------|
|                |              |              | Number                    | %     |                  |               |             |
| Control        | -----        | 8.5 ± 0.45   | 0.6 ± 0.22                | 7.06  | 284.8 ± 10.78    | 98.5 ± 0.44   | 0.0 ± 0.0   |
| methomyl       | 1 : 1        | 6.2 ± 0.29** | 1.2 ± 0.20                | 19.35 | 159.4 ± 3.08**   | 64.1 ± 1.12** | 63.6 ± 1.83 |
| +esfenvalerate | 2 : 1        | 6.7 ± 0.26** | 1.2 ± 0.33                | 17.91 | 170.2 ± 2.77**   | 76.2 ± 1.13** | 53.8 ± 2.17 |
|                | 1 : 2        | 6.4 ± 0.26** | 1.5 ± 0.22                | 23.44 | 156.4 ± 1.67**   | 50.8 ± 1.02** | 71.7 ± 1.84 |
| methomyl       | 1 : 1        | 7.2 ± 0.39   | 0.8 ± 0.20                | 11.11 | 236.4 ± 4.30**   | 83.6 ± 0.85** | 29.6 ± 3.78 |
| + profenofos   | 2 : 1        | 7.0 ± 0.26   | 0.8 ± 0.29                | 11.43 | 286.4 ± 2.51     | 87.2 ± 1.11** | 11.0 ± 3.74 |
|                | 1 : 2        | 8.0 ± 0.30   | 0.4 ± 0.16                | 5.00  | 293.0 ± 1.60     | 92.5 ± 0.97** | 3.4 ± 2.88  |
| methomyl       | 1 : 1        | 5.5 ± 0.45** | 1.6 ± 0.22**              | 29.09 | 177.0 ± 10.17**  | 41.6 ± 2.80** | 73.6 ± 5.47 |
| + carbaryl     | 2 : 1        | 5.3 ± 0.45** | 1.3 ± 0.26                | 24.53 | 192.8 ± 4.65**   | 55.8 ± 1.74** | 61.6 ± 4.57 |
|                | 1 : 2        | 5.4 ± 0.34** | 1.2 ± 0.13                | 22.22 | 199.8 ± 7.09**   | 70.9 ± 1.77** | 49.4 ± 6.29 |
| esfenvalerate  | 1 : 1        | 5.6 ± 0.37** | 5.6 ± 0.12                | 100   | 312.5 ± 13.45    | 0.0 ± 0.0**   | 100.0 ± 0.0 |
| + profenofos   | 2 : 1        | 6.3 ± 0.65** | 3.0 ± 0.05**              | 47.62 | 370.3 ± 11.23    | 60.6 ± 3.67** | 20.0 ± 1.05 |
|                | 1 : 2        | 7.1 ± 0.45   | 1.6 ± 0.03**              | 2.54  | 256.7 ± 12.34    | 55.9 ± 2.37** | 48.8 ± 3.78 |
| esfenvalerate  | 1 : 1        | 8.9 ± 0.41   | 1.4 ± 0.76                | 15.73 | 242.2 ± 5.65**   | 92.5 ± 0.97** | 20.2 ± 4.93 |
| + carbaryl     | 2 : 1        | 7.0 ± 0.26   | 1.2 ± 0.25                | 17.14 | 266.1 ± 11.50    | 72.6 ± 0.65** | 31.1 ± 7.05 |
|                | 1 : 2        | 8.4 ± 0.31   | 0.5 ± 0.22                | 5.95  | 273.9 ± 12.64    | 92.8 ± 0.57** | 10.0 ± 9.98 |
| profenofos     | 1 : 1        | 7.4 ± 0.37   | 2.2 ± 0.29**              | 25.68 | 244.1 ± 5.98     | 85.8 ± 1.45** | 25.5 ± 4.69 |
| + carbaryl     | 2 : 1        | 7.8 ± 0.57   | 1.9 ± 0.41**              | 24.36 | 279.3 ± 11.79    | 82.8 ± 0.84** | 17.7 ± 8.49 |
|                | 1 : 2        | 7.0 ± 0.47   | 1.9 ± 0.23                | 27.14 | 272.2 ± 12.80    | 91.1 ± 1.00** | 12.6 ± 9.91 |

\*\* Significant (p≤0.01)

different ratios. The mean number of egg-masses per female (methomyl + carbaryl) at the ratios of 1:1, 2:1 and 1:2 were  $5.5 \pm 0.45$ ,  $5.3 \pm 0.45$  and  $5.4 \pm 0.34$ , respectively. The mean number of egg-masses per female (methomyl + esfenvalerate) at the ratios of 1:1, 2:1 and 1:2 were  $6.2 \pm 0.45$ ,  $6.2 \pm 0.29$  and  $6.7 \pm 0.26$ , respectively. The ratios of 1:1 and 2:1 for the mixture of esfenvalerate with profenofos were affected the number of laid per female, with the values of  $5.4 \pm 0.34$  and  $5.6 \pm 0.37$ , respectively.

The percentage of non fertilized egg-masses was highly affected by the different insecticide combinations. The data in Table (4) showed that the mixture of esfenvalerate with profenofos increased the percentage of non fertilized egg-masses at a ratio of 1:1. The percentage of non fertilized egg-masses values at the ratios of 1:1, 2:1 and 1:2 were 100, 47.62 and 22.54, respectively. Followed by the mixtures of profenofos + carbaryl and methomyl + carbaryl, their percentages of non fertilized egg-masses values at the ratios of 1:1, 2:1 and 1:2 were (25.68, 24.36 and 27.14) and (29.09, 24.53 and 22.22), respectively (Table 4).

The mixture of methomyl with esfenvalerate decreased the number of eggs per laid at the ratios of 1:1, 2:1 and 1:2. These values were  $159.4 \pm 3.08$ ,  $170.2 \pm 2.77$  and  $156.4 \pm 1.67$ , respectively. In contrast, the mixture of esfenvalerate with profenofos increased the number of eggs per laid at the ratios of 1:1 and 2:1. The obtained values were  $312.5 \pm 13.45$  and  $370.3 \pm 11.23$ , respectively.

The percentage of hatchability was highly significant affected by all the tested combinations except the mixture of esfenvalerate with profenofos at the ratio of 1:1, which appeared zero percentage of hatchability. The efficiency of the different combinations as chemosterilants can be descendingly arranged as follow: esfenvalerate with profenofos, methomyl with carbaryl and methomyl with esfenvalerate (Table 4).

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