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EVALUATION OF SOME PLANT ESSENTIAL OILS AGAINST THE BLACK CUTWORM AGROTIS IPSILON

Aziza Sharaby
Pests & Plant Protection Department,
Agriculture Division, National Research Center, Cairo,
Egypt.

Asma El-Nojiban
Biology Depatment, College of Science and Arts,
Unizah, Qassim University,
Kingdum of Saude Arabia

Abstract

The black cutworm, *A.ipsilon* (Lepidoptera: Noctudae) is one of the most destructive insect pest attacking different field crops. The effect of different concentrations of some natural plant essential oils were evaluated on third larval instars' of the insect. The results clearly demonstrated that the tested oils(Garlic, Mint, Cumin, Caraway and Parsley) had a stomach and contact toxicity through the larval feeding on treated diet, also all the tested oils exhibited antifeedant and starvation effects. The LC_{50} of different oils varied from one to other on the different stages (eggs- larvae- pupae) the best treatment among all the tested oils was Garlic oil with LC_{50} ranged from 0.006 – 0.019%, it was more toxic as contact than stomach poison. The combination of the oils exhibited potentiating effect between them and increasing their toxicity. The promising toxic mixture was(Garlic + Mint). The sub lethal concentrations of the tested oils achieved remarkable significant increase in larval and pupal duration with retardation in their development and increase percentage of mortality, decrease in larval and pupal weight, increase in the percent of malformation for both the resulting pupae and adults. From this point of view, and so could be recommending usage of the mentioned plant essential oils for controlling the black cutworm on their hosts by spraying it as emulsion or as a toxic baits alternatives to chemical pesticides, it can also mixing oils in the mentioned concentrations range for increasing their toxicity and decreasing insect resistant buildup as a biological control method throughout the integrated pest control program

Key word: *Agrotis ipsilon,* Essential oils, Garlic (*Illium sativum).*, Parsley (*Petroselinum crispum).*, Carawaya (*Carum carvi).*, Cumin (*Cuminum cyminum).*, Mint(*Mentha piperita*.)

1. INTRODUCTION:

The black cutworm, *A. ipsilon* is one of the .most destructive insect pest attacking different field crops, such as cotton, soybean, corn, potatoes and tomatoes not only in Egypt but also in several countries of the throughout the year. Great

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losses occurred in yield due to *A. ipsilon* infestation especially at seedling stage(Ladhari et.al, 2013)..The black cutworm control is currently based on heavy use of many insecticides, which damage the environment and/or pose a threat to public health via food residues, ground water or accidental exposure. The problems caused by pesticides and their residues have amplified the need for effective and biodegradable pesticides with great selectivity(Hazaa &Alam EL-Din, 2011). Alternative strategies have included the investigation for new type of insecticides, and re-evaluation and use of traditional pest control agents. The adverse special effects of synthetic pesticides have enlarged the requisite for effective and bio-degradable pesticides. Because of the power of plant-insect interactions, the plant have well-developed defense mechanism against herbivores and are excellent sources of new toxic substances for pests(Pickett et.al., 2006). Among various classes of natural substances that introduced as natural biopesticides are essential oils from aromatic plants (Isman & Grieneisen, 2014; Prakash et al., 2014). There are numerous researches on the pesticidal activity of essential oils from Lamiaceae family (Rajendran & Sriranjini,2008; Isman et al., 2011; Ebadollahi & Jalali, 2011). The advantage of using plant essential oils is that they are easily available and they have been used extensively for medicinal purposes, implying that they have low or no toxicity to humans(Upadhyay 2013). The deleterious effects of plant products on insects can be manifested in several manners including toxicity, mortality, antifeedant growth inhibitor, suppression of reproductive behavior and reduction of fecundity and fertility, growth inhibition, perturbation of reproductive behavior (reduction of fecundity and fertility) (Lambrano et al., 2014). The main goal of the present investigation was to evaluate the toxic activities of some natural plant essential oils on different stages of the black cutworm *A. ipsilon* under controlled laboratory conditions for possible use as a safe biological method and alternative to chemical pesticides within the means of integrated pest control program.

2. MATERIALS AND METHODS:

A **The tested insects:** The tested insects in this study were obtained from a standard laboratory culture reared on artificial diet as that described by Salama & Tolba (1967) at a constant temperature of 25±5C° and R.H 65±5% Under photo period of 14 light and 10 dark (EL-Kady et al.,1990). The toxic and biological effects of five different natural plant essential oils were evaluated ,(Garlic *Illium sativum*., Parsley *Petroselinum crispum*., Carawaya *Carum carvi.*, Cumin *Cuminum cyminum* and Mint *Mentha piperita*.as indicated in Table(1).these oils obtained from (Bahfarat Company in Reyadh ,KSA). Different concentrations were prepared for each oil by dilution with warer (ml.of oil/ 100ml. water) and 0.5% of Triton x was added as emulsifier. Different stages of the black cutworm (eggs, third larval instars and pupae) were treated by the prepared emulations each separately. Eggs one day old were soaked in the oil emulsion for 10 seconds then left for hatching, percentage of egg hatching were calculated after 2-4 day from the treatments. The third larval instars were chosen from the breeding culture , threted with the tested oils following two methods .

Table (1) The plant essential oils .

English name of plant essential oil	Scientific name	Family name	Part of plant used
Garlic	*Allium sativu*m	Liliaceae	bulbs
Parsley	*Petroselinum crispum*	Apiaceae	Herbs
Carawya	*Carum carvi*	Apiaceae	Herbs
Cumin	*Cuminum cyminum*	Apiaceae	Herbs
Mint	*Mentha pipreta*	Lamiaceae	Herbs

B **Stomach effect of the oil emulsion on the 3rd larval nstar**. By mixing the oil concentration with the artificial diet through its preparation (ml. oil/ml. diet) then the larvae left to fed for three days on the treated diet, each larva in a separate jar to prevent cannebalism habits.The remained alive larvae were transferred to continued feeding on

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normal untreated artificial diet, percentage of larval mortality were estimated after 7 days form treatment. Thirty replicate were used for each concentration.

C **Contact effect of the oil emulsion on the 3rd larval nstar**. By spraying the oil emulsion on the larvae using small hand sprayer , larvae left for feeding seven days on untreated diet then percentage of mortality was estimated. Control treatment in each of the two previous methods replaced the oils with water. Corrected mortality calculation using Abbott's formula (1925) LC_{50} concentration was calculated using Sigma plot (2002). **Toxicity of oils on pupal stage**. One day old pupae were used ,pupae were immersed into the oil emulsion for 10 seconds(as in the eggs treatment) . The treated pupae left till moths emergence. Percent of pupal mortality were calculated from the number of emerged adults. Control treatment, pupae immersed in water with Triton only.

D **Effect of different oils on some biological aspect of the black cuworm**t . LC_{50} value of each oil was mixed separately with the diet, 100 larvae two days old were left to fed for 48 hours on the treated diet , then the remained alive larvae were transferred to conteneue their feeding on untreated diet till pupation and adult emergence. Different biological parameters (larval duration, larval weight, pupal duration, pupal weigh, pupal deformation, % of moths emergence, % of adults malformation, sex ratio , moths fertility and % of moths strility) were calculated. Moth sterility was calculated from Toppozada et al.,(1966).

E **Combined effect of different oils.** Third larval instar were obtained from the standared laboratory culture that reared on artificial diet , LC_{50} of each two oils (that previously estimated), were mixed in one diet , then the larvae left to fed on the oil combination diet for one day, the treated larvae after feeding were transferred for continues feeding on un treated diet for other 7 days . % of larval mortality was calculated at the end of the seven days, at the same % of mortality of the larvae on each oil mixed with diet separately was calculated , this for Co toxicity factors obtained from Mansour et al. (1965).All experiments contained 5 replicates, Dancan(1955) was used for all tests

Statistical analysis:-

The average percent mortality of the tested larvae was calculated and corrected using Abbott's formula **(Abbott,1925)**. The corrected percentage of mortalities were statistically computed according to the method of **Finney (1971).**Computed percentage of mortality was plotted versus the corresponding concentrations on logarithmic probability paper to obtain the corresponding Log-concentration probit lines. The lethal concentrations 50 % were determined for established regression lines.All data obtained for (biological studies) were statistically analyzed and the variance ratios were calculated. The method of ANOVA by using (SPSS) computer program calculated at 5% level.

3. RESULTS& DISCUSSION

A Toxicity of the tested oils on different stages of. *A. ipsilon*

The toxicity values of the tested oils based on LC_{50} Table (2) may be arranged in descending orders as follows Garlic> Mint> Cumin> Carawaya> Parsley. The data indicated that the highest mortality present was caused by Garlic oil which has the lowest LC_{50} than the other oils for all stages , it was 0.006%. on the eggs, 0.030 and 0.019% as a stomach and contact poison respectively, on the pupal stage it was 0.009%.

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Table(2) Toxicity of the plant essential oils on different developmental stages of the black cut worm *A.ipsilon.*

Plant oil	LC_{50} for different stages(mL oil/100ml.water)			
	Egg	Larva		Pupa
		Contact	Stomach	
Garlic	0.006	0.019	0.030	0.009
Mint	0.019	0.032	0.160	0.148
Cumin	0.318	1.218	2.562	1.505
Carawya	0.797	1.152	2.243	1.967
Pasley	2.942	1.575	3.413	4.017

It is obvious that eggs and pupal stages was the most sensitive to oils treatment LC_{50} was 0.006 and 0.009% respectively., it means that dormant stages more affected than the movable stages., this disagreed with what previously preceded the knowledge that dormant stages more resistant to chemical insecticides. For Mint oil the lowest LC_{50} 0.019% followed by 0.032% as a contact poison on the larvae, LC_{50} for larvae as a stomach poison and on pupal stage nearly equal it was 0.160 and 0.148% respectively. The aforementioned results cleared that the effect of different tested oils was correlated to the degree of oil solubility in water and lipids and the degree of their permeability through the larval and pupal integument or egg chorion.as a contact poison. Cumin and Carawya oils were more effective on eggs and larvae as stomach poisons . The stomach effect of the tested oils was depended on the degree of their acceptability for the larval feeding on the treated diet with oils .Also it was cleared that Garlic and Mint oils have great effect on different stages of the cutworm and as a stomach and contact poisons on the larvae, while Cumin and Parsley oils have acceptable larval tasty for increasing their LC_{50} values as a stomach poisons it was 2.562 and 3.413% for Cumin and Parsley respectively. The all tested oils more effective as contact than stomach poisons, Garlic oil as contact poison with LC_{50}0.019% more effective when comparing with 0.030% as stomach poison, fore Mint 0.032 % comparing with 0.16%, for Cumin 1.218% comparing with 2.562% , fore Carawaya 1.152% comparing with 2.234%, and for Parsley it was 1.575% comparing with 3.413%. Variable in oil toxicity as stomach or contact may be due to the degree of their permeability through the integument and their effect on the insect haemolymph , viscera, nervous system and the neuoroendocryne system (Fallatah, 2003).The results agreed with that recorded by Odeyemi (1991) who found the decreasing of progeny of the insects adult treated with oils related to the physical and chemical characters 'of each oil. he mentioned that the oils effect on insect respiratory system by obstruct breathing and choking. Klingauf e tal., (1982) stated that *Mentha piperita* oils decreased the fertility of female moths of *S.littoralis* , also found that Carawaya and Parsley oils decreased the mating times. Purohit et al.,(1983) stared that *Cuminum cyminum* oil was used for controlling *Musca domestica* , *Aedes aegyptii* and *Dysderus cingulatus.* Chander& Ahmed (1986) recoded that percent of deposited eggs by *Callosobrocus chinenses* on Cowpea seeds significantly decreased after seeds treatment with *Carum carvi* oil. Mahgoub et al., (1998) mentioned that Parsley oil decreased the reproductive potential of *C. maculates* , at 95% concentration of oil the adults was prevented for laid eggs on the treated wheat seeds. Varma & Dubey (2001) stated that Mint *M. arensis* has toxic effect on larvae of *Sitophelus oryzaea, Tribolium castanium.* Also Our results in agreement with reported by Sharaby et al, (2012) that the essential oils such as Garlic *Allium sativum* ,Mint *Mintha pipereta* and Eucalyptus *Eucalyptus globulus* are known for their pest control properties for Controlling the Grasshopper *Heteracris littoralis* . Gurusubramanian & Krishna (1996) found that severe reduction in egg hatchability occurred in *Earias vitalla* (Fabricius) and *Dysderus koenigii* (F.) when their eggs were exposed to the vapour of *Alluim sativum.* They attributed that to some chemical ingredients present in the volatiles of *A. sativum* (bulbs) which probably diffused into eggs and affected the vital physiological and biochemical processes associated with embryonic development. The embryonic development in these eggs was not relatively complete; and the egg color did not change from crystal - transparent to dark color as in the control eggs. Essential oil constituents are primarily lipophilic compounds that act as toxins, feeding detterents and oviposition deterrents to a wide variety of insect pests, it was also effective as a fumigant **(Koul *et al,* 2008). Bhargava & Meena(2002)** tested 6 vegetable oils, i.e. castor, mustard, groundnut, sesame, coconut and sunflower against

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Callasobruchus chinensis in cowpea. All oils caused significant mortality in adults and mortality percent increased as concentration level increased.. **Pavela (2005)** tested 34 essential oils for insecticidal activity against larvae of *spodopetra littoralis* and concluded that they were toxic or highly toxic. In semiller findings **Tripathy & Singh (2005)** in India reported larval mortality in *Helicoverpa armigera* as induced by some vegetable oils (mustard oil, sesame oil, linseed oil, castor oil, cottonseed oil and groundnut oil). Eziah *et al* (2011) found that application of neem oil at 5ML/L were effective dosage in preventing the development of *Ephestia cautell* larvae, mortality ranged from 32.5 – 55 % after 96 hours of exposure period,the observed mortality can be attributed to the inherent properties of neem , mortality was dosage and time dependent . Sharaby et al (2012) reported that there was statistical variable numbers of increased the nymphal periods of *Heteracris littoralis* , life cycle, adults longevity and life span comparing with the control test. Garlic oil inhibited egg lying by the resulting females offspring of the treated1st instar nymphs. High reduction in the deposited eggs and egg fertility caused by Eucalyptus or Mint oil and marked malformation were observed. **Sharaby et al (2014)** found Vapors of *Cymbopogon citratus, Myristica fragrans* (nutmag), *Mentha citrata and a-Ionone* (monoterpene) caused a highly significant reductions in the life span of exposed moths of *Phthorimea operculilla* as well as in new adult offsprings. Other tested oils as *Cinnamonium zeylanicum, Myristica. fragrans* (Mace) and *Pelargonium graveolens* caused a insignificant effect. There was no significant effect of the tested vapors on egg hatchability, except in case of oils of *C. citratus, M. fragrans* (nutmag) and *M. tragrans*(Mace oil) which caused high reduction in egg hatchability. According to the values of damage indices, the most effective oil vapors were arranged ascendingly as follows: *Myristica* (nutmag) < *Cymbopogon* < *Mentha* < *a - Ionone.* They also found that dusting potato tubers with bulb powder of *Allium cepa* (50% cone. mixed with talcum powder) displayed a highly effective role in the reduction of deposited eggs as well as adult emergence there from. *Allium cepa, Pelargonium graveolens* and *Cymbopogon citratus* oils caused high reduction in larval penetration into treated tubers.

B Antifeedant and starvation effect of the oils on the third larva instar of *A. ipsilon.*

The results obtainedin Table (3) indicated that botanical oils tested acted as antifeedants or feeding deterrents against *A. ipsilon* larvae especiallyGarlic oil, where it caused the highest antifeeding activity. (- 18.267%) and starvation was (231.174%) , followed by Mint (67.07% starvation)= Cumin> Parsley (62,37%) > Carawya (58.33%). Many plant extracts and botanical oils manifest antifeeding activity against different insect species. For example, **Rajasekaran & kumaraswami (1985)** found that the addition of sesame oil to an aqueous extract of neem seed kernel enhanced antifeedent activity against larvae of *S. littoralis*; **Khadr *et al.* (1986)** showed that the leaf extract of *Melia azadrach* had a significant antifeedant effect on larvae of *S. littoralis*; **Sabbour & Abd El- Aziz (2002)** reported that *Eucalyptus* oil was effective as an antifeeding deterrent against the 3rd larval instar of *A. ipsilon* and *S. littoralis*; **Shershby *et al.* (2004)** showed that cinquef oil enhanced a repellent activity against *A. ipsilon* larvae; **Erturk(2006)** reported that the extracts derived from different plants *Aesculus hippocastanum , Viscum album, Sambucus nigra, Buxus sempervirens , Diospyros kaki , Artemisia absinthum , Alnus glutiosa Goertn , Origanum vulgare ,Hypericum androsaemum and Ocimum basilicum* had antifeeding effect against the 3rd – 4th instar larvae of the *Thaumetopoae solitaria*. Recently Labrano et al (2014) determined the biological effects of essential oils isolated from *Cymbopogon nardus, C.flexuosus* and *C. martini* against two Lepidoptera larvae , the all tested oils showed antifeedant acticity and dermal contact lethality against *Acharia fusca* and *Euprosterna elaeasa* (Lepidoptera: Emacodidae) at various concentrations. All oils exhibited strong antifeedant and toxicity activity toward the insects.

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Table(3): Antifeedant effect and percentage starvation of the essential oils on 3rd larval instars' of the black cu worm *A.ipsilon.*

Essential oil	% Antifeedant	% Starvation	LC_{50} as stomach poison (ml/100ml.)
Garlic	- 18..267	231.74	0.030
Mint	67.067	186.4	0.160
Carawy	58.33	1.64	2.243
Cumin	67.067	139.3	2.562
Parsley	62.37	130.9	3.413

C Effect of plant oils on some biological aspect of *A. ipsilon*.

The biological activity (larval and pupal mortality, larval and pupal duration, pupal weight, adult emergence and morphogenetic effects) of the tested botanical oils (Garlic, Mint, Cumin, Caraweya and Pasley) at the (Lc50) against the 3rd larval instar of *A. ipsilon* has been studied. Table (4) cleared that the all tested oils have great effect on growth and development *of A. ipsilon* Garlic oil has the greatest effect where all larvae died after 4-5 day from feeding on the treated as a result of starvation and toxic effect of the Garlic oil. All other oils gave highly significant variation comparing with the control untreated test. The results obtained indicated that the (Lc50) of the tested botanical oils caused significant larval and pupal mortality as compared with control. In addition, the (Lc50) of botanical oils prolonged significantly the larval and pupal duration as compared to the control. Also, it significantly reduced the percentage of adult emergence and significantly decreased the weight of the resulted pupae as compared with the untreated control. Moreover, the (Lc50) of tested oils caused malformation percentages among the resulted pupae and adults Malformation included wing folding and failure of ecdysis which indicate that volatile oils can affect chitin synthesis and inhibit the process of ecdysis. However, the abnormal emerged adults were all died within few days. . Similar findings, were also obtained by many authors using different botanical oils (**Das, 1986** on *Callosobruchus chinesis*; **Trivedi, 1986** on *Rhyzopertha dominica* and *Tribolium castaneum*; **Ahmed *et al*. 1999** on *C. chinensis*; **Baskran & Janarthanan, 2000** on *Sitotroga cerealella* and *C.chinensis*; **Rofail *et al*. 2000** on *Pectinophora gossypiella;* **Labinas& Crocomo, 2002** on *Spodoptera frugiperda* ; **Pavela, 2005** on larvae of *Spodoptera littoralis*; **Abdel El-Aziz *et al*. 2007** on *A.ipsilon* and **Moawad & Ebadah, 2007** on *Phthorimaea operculelle).* The biological effect of the botanical oils on insect pests may attributed to their effect on the insect neuroendocyne system and juvenile hormone leading to hormone unbalance occurring malformation , increasing the larval and pupal duration and decreasing moths fecundity and egg fertility resembling the effect of the growth regulators. Rao et al.,(1999) cleared that botanical oils has a great effect on the digestive enzymes and decrease the concentration of the haemolymph protein , also block the ionic neuronal channels (Shafeek et al., 2003). Klingauf et al.,(1982) and Huang et al.,(2002) attributed decreasing of fecundity and fertility to decreasing in periods and time of adults mating which leading to decreasing in ovulation.Some researches have demonstrated that essential oils have neurotoxic, citotoxic, phototoxic and mutagenic action among others in different organism (Bakkali et al, 2008., Isman et al , 2009), and the essential oils act at multiple level in the insects, so the possibility of generating resistance is little probable (Gutierrez et al,2009).

D Effect of oil combination against the third larval instar of *A. ipsilon* .

There were remarkable effect of the combination between the tested oils on increasing the percentages of the larval mortality Table(5). All combinations of the oils gave potentiating effect , most combination in increasing mortality percentage was(Garlic+ Mint) coursing mortality percentage reached(86%) when compared with the mortality caused with each oil separately (23% for Garlic) and (20% for Mint). In each combination that shows in Table (5) it cleared that all combinations gave the highest mortality than if compared for each oil separately. Combination of oils increased their

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activity and toxicity against the larvae. Jember & Hassanali (2002) mentioned the importance of oil combinations or their constituents of terpens in increasing their toxicity for controlling the stored grain pests and attributed that to variable constituents of each oil with variable side effects on the insect ,.this support the explanation that the oils differ in their toxicity according to their constituents. **Vastrad *et al.* (2002)** determined the effect of vegetable oils from (cotton, linseed, safflower, pundi, honge and sesame) as synergists of synthetic Pyrethroids (fenvalerate, deltamethrin, and cypermethrin) against *Plutella xylostella* in India. They recorded the highest larval mortality by sesame oils also, the larval mortality with Honge and Sesame oils in combination with synthetic pyrethroids increased with concentration. Sharaby et al 2014 recorded that mixture of Pelargoniumor Allium mixed with talcum powder gave good protection for the potato tubers from *Phtorimaea operculella* infestation for a long storage period (30-40 days). Labrano et al (2014) found it should be pointed that syniergistic effects of complex mixture such as essential oils are though to be important in plant defence against herbivore predators. Plants usually present defenses as a set of compounds, thus , complex essential oils may be more efficient than individual pure compounds. .For all these reasons, we can infer that the plant essential oils especiallay Garlic and Mint essential oils could be considered as a natural alternative in the control of *A. ipsilon*

Table (4): Effect of essential oils on some biological aspect of the black cut worm *A.ipsilon*.

Essential oils	Larval duration (day) mean±SE	Larval weight(mg.) mean±SE	Pupal duration(day) mean±SE	Pupal weight(mg.) mean±SE	% pupal deformation	% moths emergence	% moths deformation	% Sex ratio		% Strility
								♂	♀	
Garlic	All larvae died	-	-	-	-	-	-	-	-	-
Mint	27.22±50.41	257±529.29	13.16±0.143	2760±51.9	27.5	75	33.33	55.56	44.44	3.23
Cumin	29±50.13	337±258.38	10.40±50.17	337.2±544.9	15.66	96	8.32	69.44	30.56	15.75
Carawya	32.64±50.27	203±524.88	13.53±0.09	289.2±23.6	11.76	93.33	17.14	54.29	45.71	22.83
Parsley	29.29±50.049	395±089.72	9.62±50.71	477.3±52.60	10.53	87.36	6.58	48.68	51.32	25.70
Control	16,27±0.11	478±7,6	14±0.43	282.6±30.20	5	91.11	4.88	31.70	68.29	5

Table (5): Effect of essential oil combination on their type of toxicity against the 3rd larval instar of the black cut worm *A.ipsilon*.

Essential oil	% Mortality	Cotoxicity factor	Type of interaction
Garlic	32	-	-
Mint	20	-	-
Cumin	20	-	-
Carawaya	17	-	-
Parsley	13	-	-
Garlic +Mint	86	65.38	Potentiating
Garlic + Cumin	72	38.46	Potentiating
Garlic + Carawaya	80	63.26	Potentiating
Garlic + Parsley	76	68.89	Potentiating

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Mint+ Cumin	70	75	Potentiating
Mint+ Carawaya	72	94.59	Potentiating
Mint + Parsley	76	130.30	Potentiating
Cumin + Carawaya	70	89.19	Potentiating
Cumin + Prsley	55	66.67	Potentiating
Carawya + Parsley	46	53.33	Potentiating
Control	0.	0	0

4. CONCLUSION:

The use of plant essential oils has considered as an important alternative for pest control because of their environmental and mammals safety properties. From results of the present study , could be concluded that the tested oils(Garlic, Mint, Cumin, Caraway and Parsley) possess toxic effect on all stages of *A. ipsilon* , had a stomach and contact toxicity for the larvae, also all the tested oils exhibited antifeedant and starvation effects. The best treatment among all the tested oils was Garlic oil followed by Mint oil >Cumin>Carawaya>Parsley.. The combination of the oils exhibited potentiating effect between them and increasing their toxicity. The promising toxic mixture was(Garlic + Mint).. From this point of view, and so could be recommending usage of the mentioned plant essential oils for controlling the black cutworm on their hosts by spraying it as emulsion or as a toxic baits alternatives to chemical pesticides, it can also mixing oils for increasing their toxicity and decreasing insect resistant buildup as a biological control method throughout the integrated pest control program . The obtained results suggested an interesting opportunity to develop bioinsecticides based on plant essential oils for the control of this serious lepidopteran pest and other pests. that may affect production. However further work and additional investigations on the field evaluation are needed.

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