EGYPTIAN ACADEMIC JOURNAL OF

BIOLOGICAL SCIENCES

TOXICOLOGY & PEST CONTROL

F

ISSN
2090-0791

WWW.EAJBS.EG.NET

Vol. 16 No. 1 (2024)

www.eajbs.eg.net

Citation: *Egypt. Acad. J. Biolog. Sci.* (F. Toxicology& Pest control) *Vol.16(1) pp141-150 (2024)*
DOI: 10.21608/EAJBSF.2024.351925

Egypt. Acad. J. Biology. Sci., 16(1):141-150(2024)

Egyptian Academic Journal of Biological Sciences
F. Toxicology & Pest Control
ISSN: 2090 - 0791
http://eajbsf.journals.ekb.eg/

Some Biological Aspects and an Attempt to Control *Spodoptera frugiperda* (J.E. Smith) Using Some Selected Essential Oils Under Laboratory Conditions

Maha S. El-Ghannam[1], Pansea A. Azzam[1] and Sara.E. El-Deeb[2]
[1]Plant Protection Research Institute, Dokki, Giza, Egypt.
[2]Plant Protection Department, Faculty of Agriculture, Benha University, Egypt.
***E. Mail**: sara.eid8930@gmail.com

REVIEWINFO
Review History
Received:22/3/2024
Accepted:26/4/2024
Available:30/4/2024

***Keywords*:**
Fall armyworm *Spodoptera frugiperda*, biology, host plants, toxicity, essential oils.

ABSTRACT

Fall armyworm (FAW) *Spodoptera frugiperda* is one of the devastating insect pests. It is a polyphagous pest causing economic damage to important cultivated cereal crops such as rice, maize, cotton, sorghum, and various vegetable crops. The first occurrence recorded in Egypt was in 2019. The aim of this study included the study of some biological aspects by using some plant hosts such as maize, sorghum, ricinus and tomato. In general, feeding by maize plants recorded the shortest larval lifespan stage from the 1st to the 6th instar, prepupal stage, pupal stage, adult longevity (♀ & ♂), mean fecundity (no. of eggs and hatchability%). Also, the study included the evaluation of the efficiency of some essential oils against the 2nd and 4th larval instar of *S. frugiperda* under laboratory conditions. Generally, results clearly indicated that tested essential oils (Lemongrass oil, Orange oil, Peppermint oil and Linseed oil) varied considerably in their efficiency against the two tested larval instars (2nd and 4th) and that higher concentration caused a higher reduction in tested larval instars. Generally, it was obvious that the efficiency of the tested essential oils against the 4th instar of S. *frugiperda* remarkably had the same trend as the 2nd instar with variable values. The efficiency of tested oil can be arranged descending according to the length of LC_{50}, LC_{90} and LC_{95} as follows Lemongrass oil > Orange oil > Peppermint oil > Linseed oil to *S. frugiperda* after 10 days post treatments.

INTRODUCTION

Fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith, 1797) is one of the devastating insect pests, (family Noctuidae, order Lepidoptera). It is a polyphagous pest (Baudron *et al.*, 2019) that leads to economic damage for important cultivated cereal crops such as various vegetable crops, cotton, rice, sorghum and maize. *S. frugiperda* had eventually impacts on food security (FAO, 2017 and CABI, 2018). FAW feeds on the stem, leaves and reproductive parts of different plant species (Tefera *et al.*, 2019). Tropical and subtropical regions of America are the original native. FAW was first found in America and is considered one of the most common pests of maize in North and South America (Todd and Poole, 1980). In Africa, (Sisay *et al.*, 2018) had the first report in 2016 about the invasive pest *S. frugiperda*. *S. frugiperda* became one of the major invasive pests reaching over 30 countries across southern and tropical Africa at the end of 2017, later reaching over 44 countries (Sisay *et al.,* 2019). There are 353 plants reported as hosts for this pest (Kansiime *et al.,* 2019).

Symptoms of damage start with the larval stage making different sizes of papery windows in leaves causing extensive defoliation of plants, and the occurrence of faecal materials causing a passive effect on the later growth stage and the development of plants (Reddy, 2019). This insect has marching behavior similar to that of an army leading to havoc loss to crops that come in its way (FAO, 2019). FAW is devastating in nature and CABI (2017) has predicted that pest causes a probable loss of 6.1 billion US dollars only in African countries when the control measures are not utilized.

Control of this pest is challenging due to probable host plants having different phenologies and being grown during successive seasons of the year and proximity to each other, which can facilitate the movement of pests between crops. This availability of various hosts might even result in the selection of insect populations with new food preferences due to different exposure of these insects to a variety of crops (Barros *et al.,* 2010). Some biological studies on the providing and consumption of different food sources, also, host preferences of *S. frugiperda* are serious for addressing the effects of the nutritional composition of different crops on this pest (Barros *et al.,* 2010 and Silva *et al.,* 2017). The extensive and misuse of insecticides against S. *frugiperda* causes reducing in the control efficiency of S. *frugiperda.* Thus, this work focuses on some biological aspects (larvae longevity, pupae longevity, adult longevity, mean fecundity female), and studies food oviposition preference of S. *frugiperda* of maize, sorghum, ricinus and tomato under laboratory conditions with a view to better understand this pest's feeding behavior.

Botanical insecticides used in the control the pests, since ancient times (Viegas Júnior, 2003). These phyto insecticides, in the form of essential oils and plant extracts, are one of the alternative methods for pest management in a diverse flora, and therefore, with elevation potential for the discovery of new insecticides (Krinski *et al.,* 2014). Essential oils of some species may have toxic compounds for insects, but are safe for humans, thus with a high potential to control some agricultural pests (Ebadollahi, 2011). Therefore, this research aimed to evaluate the efficiency of essential oils (Lemongrass oil, Orange oil, Peppermint oil and Linseed oil) against *S. frugiperda*, larvae.

MATERIALS AND METHODS

1.Study Location:

The experiment was conducted in the lab. of the Plant Protection Dept. Fac. of Agriculture, Benha Univ. The objective of this study was to study larvae longevity, pupal longevity, the longevity of adults, mean of the female fecundity), and food oviposition preference of *Spodoptera frugiperda* of different plants (as a food source) under laboratory conditions with a view to better understand feeding behavior and evaluate the effectiveness of some plant oils against the fall armyworm.

2.Rearing of the Fall Armyworm:

FAW eggs and larvae were obtained from a lab. colony maintained at Plant Protection Dep. Fac. of Agriculture at Moshtohor, Benha Univ. This population was initially collected from maize fields Agriculture, Benha University. These insects had been fed on fresh castor leaves for 3 generations. Larvae were reared under controlled conditions of 25 ± 1 °C, 65% ± 5% relative humidity (R.H.), and a photoperiod of 14: 10 h (L: D). Egg masses laid by females were collected and deposited in plastic cups. The males and females were fed on a 10% (w/v) honey-water mixture.

3.Biology of *S. frugiperda* on Different Plants:

Some plants' leaves were collected from the farm of Agriculture, Benha University and provided to *S. frugiperda* for feeding (Table 1).

Table 1. Some plant species provided to fall armyworm feeding:

Scientific name	Common name	Family
Zea mays L.	Maize	Poaceae
Sorghum bicolor (L.) Moench	Sorghum	Poaceae
Ricinus communis L.	Ricinus	Euphorbiaceae
Solanum lycopersicum L	Tomato	Solanaceae

3.1,Biology of FAW on Different Plants:

Development, survival, and reproduction of FAW fed on, sorghum, maize, Ricinus and tomato leaves were investigated and recorded. Newly hatched larvae were placed individually in plastic cups, which were covered with a mesh screen for aeration. Leaf discs (1 cm in diameter) from each tested plant were given as food to larvae. Three replicates were conducted in various treatments. Thirty larvae were put in each replicate.

Each individual larva from 1^{st} to 3^{rd} instars was put with food in a well of plastic cups, and each larva from 4^{th}–6^{th} instars was put in a plastic cup (2.5 cm in diameter, 4 cm in height). The number of leaf discs provided to each larva depended on larval age and type of host plant. Survival and development time of each larval stage were registered daily. Newly emerged females were individually paired with young males recruited from the colony in glass chambers (8 cm in diameter, 12 cm in height) wrapped with a fine mesh for ventilation. These pairs were fed on a mixture of 10% (w/v) honey in sterile water. Glass jars were lined with paper sheets as an oviposition substrate. The number of egg masses laid by each female was registered daily until the females died. Egg masses were individually transferred to plastic cups, and the number of neonates hatched from each egg mass was registered. Survivorship, fecundity, oviposition period, and female longevity were determined. (Guo *et al*., 2021).

4.Essential Oils:

Lemongrass oil (*Cymbopogaon Citratus* L., Fam.: Poaceae), Orange oil (*Citrus sinensis L.*, Fam.: Rutaceae), Peppermint oil (*Mentha spicata* L., Fam.: Lamiaceae) and Linseed oil (*Linum usitatissimum* L. Fam.: Linaceae) were brought from National Research Center. The diluted concentrations of essential oils that were used in this investigation were 2, 1, 0.5 and 0.25 %.

4.1.Bioassay Experiment:

The second and fourth larval instars of *S. frugiperda* were used. Three replicates were conducted in the various treatments. Thirty larvae were placed in each replicate. Series concentrations (2, 1, 0.5 and 0.25%) were prepared using distal water to assess the efficiency of some selected essential oils. A dipping technique was used. Fresh clean caster leaves were immersed in each tested concentration. Then, leaves are allowed to dry at room temperature. Treated leaves were offered to the 2^{nd} and 4^{th} instar of *S. frugiperda* larvae. Larvae were fed on treated leaves for 24 hours. Mortality was recorded after 1, 3, 7, 10, 14 and 21 days.

5. Statistical Analysis:

Mortality percentages were corrected by Abbott's formula (1925) and Duncan's (1955) range test was adapted to variation between treatments. The dosage mortality response was determined by Probit analysis (Finney, 1971) using a computer program of Noack and Reichmuth (1978). Data are presented as the mean ± standard error (SE) and were analyzed using Student's t-test between treatments and control.

RESULTS AND DISCUSSION

1-The Feeding Effect Of Some Tested Plant Leaves On Some Biological Aspects of FAW:

Data in Table (2) illustrates the tested biological aspects under the feeding with maize, sorghum, ricinus and tomato leaves. In general, the feeding with maize plant recorded the shortest larval lifespan stage from the 1^{st} to the 6^{th} instar, prepupal stage, pupal stage, adult longevity (♀ & ♂), mean fecundity (no. of eggs hatchability %). The ascending arrangement of the length of the larval life span stage was obtained as follows (maize < sorghum < ricinus < tomato), with recorded values (18.03, 19.92, 28.2 and 37.2 days), respectively.

The prepupal stage was the shortest for the insects fed on maize (2.29 days) compared with sorghum, Ricinus and tomato (3.94, 4.82 and 5.29 days, respectively). Uniformly, the pupal stage was shorter while insects fed on maize (6.67 days) compared with sorghum, Ricinus and tomato (7.47, 8.67 and 10.58 days, respectively). Also, the same trend was recorded in hatchability %, where the maize had the highest hatchability % (93.21%) and the tomato had the lowest hatchability % (49.87 %).

The longest means of longevities (6.85 days for males and 7.86 days for females) were obtained with adults that emerged from larvae fed on maize. Meanwhile, adults that emerged from larvae fed on tomatoes had the shortest means of longevities registered (3.71 days for males and 5.62 days for females). From data in Table 2, the following descending arrangement of fecundity that resulted from offered nutrient maize > sorghum > ricinus > tomato, respectively the values 560 > 440 > 286 > 176 egg/ female, respectively.

In this study, the effect was evaluated by four plants (maize, sorghum, ricinus and tomato) on the biological of FAW. We detected significant differences in the survival and developmental times of the lab. reared FAW among the four plants. Our results showed that maize is a suitable host for FAW. These results agree with findings by Gamil 2020 and Guo *et al.*, 2021. In general, the development of insects depends on the quality of the food consumed in the first little instars, maybe may vary according to the host (Barros *et al.*, 2010). The components of different plants as food for insect larvae greatly differ among plant species (Awmack and Leather, 2002). Consequently, larval development and survival of insects are strongly affected by the host plant (McCormick *et al.*, 2019).

Table 2: Effect of feeding some plant leaves on some biological aspects of FAW:

Stage		Maize		Sorghum		Ricinus		Tomato	
		n	Mean duration (days) ± S E	n	Mean duration (days) ± S E	n	Mean duration (days) ± S E	n	Mean duration (days)± S E
Larvae	1^{st} instar	90	2.73±0.04	90	2.88±0.58	90	4.22±0.12	90	5.11±0.18
	2^{st} instar	89	2.92±0.15	87	3.06±0.12	86	4.53±1.53	84	5.61±0.04
	3^{st} instar	88	3.28±0.18	83	3.58±0.04	84	4.51±0.19	78	6.22±1.31
	4^{st} instar	87	3.28±0.58	82	4.12±0.18	78	4.82±1.31	70	6.64±0.12
	5^{st} instar	87	2.88±1.53	80	3.22±1.53	75	5.11±0.58	65	6.81±1.53
	6^{st} instar	87	2.94±0.19	78	3.06±1.31	72	5.21±0.12	60	6.81±0.58
Total larvae		18.03		19.92		28.4		37.2	
Prepupa		87	2.29±0.12	70	3.94±0.04	63	4.82±0.04	55	5.29±0.05
Pupa		87	6.67±1.53	68	7.47±0.58	60	8.67±1.31	51	10.58±1.53
Adult longevity	Female	56	7.86±0.58	40	6.63±0.12	41	5.57±1.53	29	5.62±0.58
	Male	31	6.85±1.31	28	5.93±0.05	19	4.42±0.04	22	3.71±0.19
Mean fecundity (female)	N. of eggs	560 ±0.18		440.25±1.53		286 ±1.51		176.45±1.31	
	Hatched eggs	522±18.53		380±22.24		200±12.22		88±6.65	
	Hatchability%	93.21		86.31		69.93		49.87	

2. Laboratory Evaluation of the Efficiency Of Some Selected Essential Oils Against 2nd And 4th Larval Instars of *S. frugiperda*:

Data obtained during the laboratory evaluation of the tested essential oils (Lemongrass oil, Orange oil, Peppermint oil and Linseed oil) against the 2nd & 4th instar larval of *S. frugiperda* are given in Tables (3 & 4).

Generally, results clearly indicated that the tested essential oils varied considerably in their efficiency against the two tested larval instars and that, higher concentration and the prolongation of the exposure period caused a higher reduction in tested larval instars.

2.1. Against the 2nd Instar Larvae of *S. frugiperda*:

The results of the toxicity efficiency of essential oils (Lemongrass oil, Orange oil, Peppermint oil and Linseed oil) on 2nd instar larvae of *S. frugiperda* at 26 ± 1°C and 65 ± 5% R.H are presented in Table (3).

Duncan's analysis grouped the efficiency of testing the four oils into four categories against 2nd instar larvae. The following are descending arrangements, expressed by reduction % where the dissimilar letter indicated a significant difference (73.33 > 54.03 > 53.19> 35.42), of Lemon grass oil > orange oil > peppermint oil > Linseed oil, respectively.

Duncan's analysis categorized the selected concentration of the tested oils (2, 1, 0.5, 0.25 ml/ 100 ml) into four categories. Data indicated that the highest reduction was recorded by the highest conc. 2.0 ml/ 100 ml at all the tested oils.

Table 3: Toxicity of essential oils treatments on 2nd instar larvae mortality of *S. frugiperda*.

Essential oils	Con. % (v/w)	NO. Pre treat	1		3		7		10		14		21		Mean of red. %
			No.	Red. %	No.	Red. %	No.	Red. %	No.	Red. %	No.	Red.%	No.	Red. %	
Lemongrass oil	2	90	42	53.33±2.31	21	76.67±0.58	0	100.00±0.00	0	100.00±0.00	0	100.00±0.00	0	100.00±0.00	73.33 a
	1	90	51	43.33±2.08	33	63.33±0.58	12	86.67±0.58	0	100.00±0.00	0	100.00±0.00	0	100.00±0.00	
	0.5	90	60	33.33±0.58	51	43.33±1.53	36	60.00±1.00	15	83.33±1.31	9	90.00±0.00	0	100.00±0.00	
	0.25	90	63	30.00±0.00	57	36.67±0.58	51	43.33±1.53	33	63.33±0.58	27	70.00±0.58	15	83.33±1.31	
Orange oil	2	90	60	33.33±0.58	51	43.33±2.08	33	63.33±0.58	6	93.33±1.15	0	100.00±0.00	0	100.00±0.00	54.03 b
	1	90	66	26.67±0.58	57	36.67±0.58	45	50.00±0.58	27	70.00±0.58	15	83.33±2.08	0	100.00±0.00	
	0.5	90	75	16.67±0.58	63	30.00±1.00	57	36.67±0.58	42	53.33±0.00	36	60.00±1.00	27	70.00±0.58	
	0.25	90	81	10.00±1.00	75	16.67±0.58	66	26.67±0.58	51	43.33±1..15	45	50.00±0.00	33	63.33±0.58	
Peppermint oil	2	90	45	50.00±0.00	33	63.33±0.58	21	76.67±0.58	6	93.33±1.15	0	100.00±0.00	0	100.00±0.00	53.19 b
	1	90	57	36.67±0.58	51	43.33±2.08	42	53.33±2.31	33	63.33±0.58	27	70.00±0.58	12	86.67±1.15	
	0.5	90	69	23.33±1.15	60	33.33±0.58	54	40.00±1.00	51	43.33±2.08	36	60.00±1.00	27	70.00±1.00	
	0.25	90	84	6.67±0.58	72	20.00±1.00	63	30.00±1.00	57	36.67±0.58	51	43.33±1.53	42	53.33±1.53	
Linseed oil	2	90	57	36.67±0.58	45	50.00±0.00	24	73.33±0.58	18	80.00±0.00	9	90.00±0.00	0	100.00±0.00	35.40c
	1	90	72	20.00±1.00	66	26.67±0.58	60	33.33±0.58	54	40.00±1.00	33	63.33±0.58	27	70.00±0.58	
	0.5	90	87	3.33±0.58	87	3.33±0.58	81	10.00±1.00	76	13.33±0.00	66	26.67±0.58	54	40.00±1.00	
	0.25	90	87	3.33±0.58	87	3.33±0.58	84	6.67±0.58	81	10.00±1.00	75	16.67±0.58	63	30.00±0.00	
Mean of red. %at inspection time				26.66e		36.67d		49.38c		6167 ab		70.21 ab		79.17 a	
Control		90	90		90		90		90		90		90		

L.S.D for treatments =6.665 L.S.D for inspection time = 9.082 red.= reduction

2.2. Against the 4th Larval Instar:

Generally, it was obvious that the efficiency of the tested essential oils against the 4th instar of S. *frugiperda* remarkably had the same trend as the 2nd instar with variable values.Duncan's analysis categorized the four tested essential oils into four categories, descending according to their reduction percentage as follows: Lemongrass oil > orange oil > peppermint oil > Linseed oil.Their efficiency, expressed as reduction %, was recorded at 63.67, 49.33, 38.83 and 32.0%, respectively

With respect to, the efficiency of the tested oils along the time of inspections, Duncan's analysis showed that the following values grouped into five grouped 68.33, 57.71, 48.33, 37.5 and 17.91 % after 14, 10,7,3 and 1 day, respectively.

Also, Duncan's analysis showed a significant difference and grouped the tested concentrations (2, 1, 0.5 and 0.25 %) into four groups against the 4th of S. *frugiperda*.

Table 4: Toxicity of essential oils treatments on 4th instar larvae mortality of *S. frugiperda*.

Essential oils	Con. % (v/w)	NO. Pre treat	1		3		7		10		14		Mean of red. %
			No.	Red. %	No.	Red. %	No.	Red. %	No.	Red. %	No.	Red. %	
Lemongrass oil	2	90	42	53.33± 2.31	15	83.33± 2.08	6	93.33± 1.15	0	100.00 ±0.00	0	100.00 ±0.00	63.67^{a}
	1	90	48	46.67± 0.58	36	60.00± 0.58	24	73.33± 0.58	15	83.33± 2.08	3	96.67± 0.58	
	0.5	90	60	33.3±0 .577	54	40.00± 1.00	48	46.67± 0.58	33	63.33± 1.53	18	80.00± 1.00	
	0.25	90	66	26.67± 0.58	57	36.67± 0.58	51	43.33± 2.08	42	53.33± 2.31	36	60.00± 0.58	
Orange oil	2	90	51	43.33± 2.08	39	56.67± 0.58	27	70.00± 0.00	18	80.00± 1.00	0	100.00 ±0.00	49.33^{b}
	1	90	60	33.3±0 .58	54	40.00± 1.00	36	60.00± 1.00	24	73.33± 0.58	6	93.33± 1.15	
	0.5	90	66	26.67± 0.58	60	33.3±0 .58	51	43.33± 0.58	45	50.00± 1.73	33	63.33± 0.58	
	0.25	90	90	0.00±0 .00	81	10.00± 1.00	63	30.00± 1.00	57	36.67± 0.58	51	43.33± 0.58	
Peppermint oil	2	90	76	13.33± 0.58	39	56.67± 1.53	33	63.33± 1.15	24	73.33± 0.58	15	83.33± 2.08	38.83^{c}
	1	90	84	6.67±0 .58	54	40.00± 1.00	42	53.33± 2.31	36	60.00± 1.00	27	70.00± 2.65	
	0.5	90	87	3.33±0 .58	69	23.33± 0.58	57	36.67± 0.58	48	46.67± 0.58	42	53.33± 0.58	
	0.25	90	90	0.00±0 .00	78	13.33± 0.58	75	16.67± 0.58	66	26.67± 0.58	57	36.67± 1.53	
Linseed oil	2	90	90	0.00±0 .00	51	43.33± 0.58	39	56.67± 1.53	30	66.67± 1.53	21	76.67± 0.58	32.0^{d}
	1	90	90	0.00±0 .00	57	36.67± 0.58	48	46.67± 0.58	39	56.67± 0.58	33	63.33± 0.58	
	0.5	90	90	0.00±0 .00	75	16.67± 1.53	69	23.33± 0.58	60	33.3±0 .58	51	43.33± 0.58	
	0.25	90	90	0.00±0 .00	81	10.00± 1.00	75	16.67± 1.53	72	20.00± 1.0/0	63	30.00± 1.00	
Mean of red. %at inspection time				17.91^{e}		37.50^{d}		48.33^{c}		57.71^{b}		68.33^{a}	
Control		90	90		90		90		90		90		

L.S.D for treatments =5.748 L.S.D for inspection time = 6.838 red.= reduction

2.3. Lethal Concentrations Of The Tested Essential Oils Against 2nd Instar Larvae of *S. frugiperda*:

LC_{50} values are recorded in Table (5) with corresponding slopes and toxicity indexes for each plant oil tested against 2nd larval instar of *S. frugiperda*. LC_{50} values of Lemongrass oil recorded 0.19ml /100ml, which showed the most effectiveness among the tested oils.

Also, the Lemongrass oil had the first arrangement recording the most effective during the treatment by LC_{90} and LC_{95}.

The efficiency of tested oils can be arranged descending according to the length of LC_{50}, LC_{90} and LC_{95} as follows Lemongrass oil > Orange oil > Peppermint oil and Linseed oil to 2nd instar larvae of *S. frugiperda* 10 days post treatments.

Table 5. Lethal concentrations of many essential oils against 2nd instar larvae of *S. frugiperda* 10 days post-treatment:

Essential oils	LC_{50}	LC_{90}	LC_{95}	Slope ± SD	*Toxicity index- LC50	R
Lemongrass oil	0.19 (0.11-0.34)	0.58 (0.33-1.04)	0.80 (0.45-1.43)	2.08±0.48	100	0.98
Orange oil	0.38 (0.22-0.66)	2.01 (1.17-3.48)	3.23 (1.87-5.57)	1.78±0.55	50	0.91
Peppermint oil	0.48 (0.30-0.79)	2.21 (1.35-3.61)	3.40 (2.08-5.55)	1.94±0.50	39.58	0.87
Linseed oil	1.09 (0.71-1.66)	3.87 (2.52-5.92)	5.54 (3.62-8.49)	2.32±0.42	17.43	0.92

*Toxicity index = $LC_{50}$of standard X 100/ LC_{50} of a test sample.

2.1.5. Lethal Concentrations of the Tested Essential Oils Against 4th Instar Larvae of *S. frugiperda*:

LC_{50} values are shown in Table (6) with corresponding slopes and toxicity indexes for each plant oil tested against the 4th larval instar of *S. frugiperda*. According to LC_{50} values, Lemongrass oil was the most effective among the tested. LC_{50} values recorded 0.28 ml/100mL

Toxicity parameters are the toxicity index developed by Sun (1950). As for the toxicity index, it is obtained by comparing the toxicity or efficiency of a fixed level (LC_{50} or LC_{90}) to their most effective oils.

The efficiency of tested oils can be arranged descending according to the length of LC_{50}, LC_{90} and LC_{95} as follows Lemongrass oil > Orange oil > Peppermint oil and Linseed oil to 2nd instar larvae of *S. frugiperda* after 10 days post treatments.

Since Lemongrass oil was the most toxic oil among the tested ones, it was used as a standard in calculating the toxicity index, which can be determined by the following equation:

Sun's toxicity index = LC_{50} or LC_{90} of the standard material/ LC_{50} or LC_{90} of a test sample X100.

Table 6. Lethal concentrations of many essential oils against 4th instar larvae of *S. frugiperda* 10 days post-treatment:

Essential oils	LC_{50}	LC_{90}	LC_{95}	Slope ± SD	*Toxicity index- LC50	R
Lemongrass oil	0.28 (0.14-0.55)	1.19 (0.60-2.37)	1.81 (0.91-3.59)	1.47±0.68	100	0.95
Orange oil	0.44 (0.23-0.88)	3.76 (1.90-7.41)	6.88 (3.49-13.58)	1.39±0.72	63.63	0.97
Peppermint oil	0.66 (0.33-1.31)	5.83 (2.94-11.58)	10.83 (5.45-21.50)	1.35±0.74	42.42	0.99
Linseed oil	0.92 (0.49-1.75)	6.90 (3.64-13.09)	12.22 (6.44-23.16)	1.47±0.68	30.43	0.98

*Toxicity index = $LC_{50}$of standard X 100/ LC_{50} of a test sample.

Essential oils can exert significant effects on insect reproduction, survival and behavior, and are therefore considered to be ideal green insecticides (Pavela and Benelli 2016; Cetin *et al.*, 2007; Masetti 2016). Over the past 50 years, some plants have been screened as potential sources of insecticides, however, the assumed low environmental and mammalian toxicity of most plant-derived products has not yet been fully investigated (Trumble 2002; Kim *et al.,* 2003). There is a significant relationship between the chemical structure of essential oils and their biological action against insects, i.e., the higher lipophilicity, the stronger the ability of the essential oil to penetrate insects (El-Wakeil 2013). Therefore, in this study, we determined the effects of essential oils from Lemongrass oil, Orange oil, Peppermint oil and Linseed oil on the 2nd and 4th instar larvae of *S. frugiperda*. Bioassay results showed that the four selected essential oils had significant bioactivity against *S. frugiperda* larvae, indicating that essential oils can be developed as new insecticides for the biological control of *S. frugiperda*. Previous studies have reported that rosemary essential oil had excellent insecticidal activity against *S. frugiperda* larvae (Dos Santos *et al.,* 2016; Sousa *et al.,* 2021).

Declarations:

Ethical Approval: Not applicable

Competing interests: The authors declare that they have no duality of interest associated with this manuscript.

Authors Contributions: Contribution is equal between authors.

Funding: No specific funding was received for this work

Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

Acknowledgements: Not applicable.

REFERENCES

Abbott W. W. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology,* 18:265- 267.

Awmack C. S. and Leather S. R. (2002). Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology,* 47:817–844.

Baudron F., Zaman-Allah M. A., Chaipa I., Chari N. and Chinwada P. (2019). Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* JE Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. *Crop Protection,* 120:141-150.

Barros E., Torres J. B., Ruberson J. R. and Oliveira M.D. (2010). Development of *Spodoptera frugiperda* on different hosts and damage to reproductive structures in cotton. *Entomologia Experimentalis et Applicata,* 137: 237-245.

CABI (2017). New report reveals cost of Fall Armyworm to farmers in Africa, provides recommendations for control. Retrived from: https://www.cabi.org/news-article/ new-report-reveals- cost-of-fall-armyworm- tofarmers- in-africa-provides-recommendations-for-control/

CABI (2018). Crop Protection Compendium. Retrived from: https://www.cabi.org/cpc/

Cetin H, Erler F, Yanikoglu A (2007) A comparative evaluation of Origanum onites essential oil and its four major components as larvicides against the pine processionary moth, *Thaumetopoea wilkinsoni* Tams. *Pest Management Science,* 63: 830–833. https://doi.org/10.1002/ps.1401

Dos Santos A. C. V., Fernandes C. C., Lopes and Sousa A. H. D. (2016). Insecticidal oils from Amazon plants in control of fall armyworm. *Revista Caatinga,* 29:642-647. https://doi.org/10.1590/1983-21252016v29n314rc.

Duncan D. B. (1955). Multiple range and multiple F test. Biometrics. 1955; 11:1–42.

Ebadollahi A. (2011). Iranian plant essential oils as sources of natural insecticide agents, *International Journal of Biological Chemistry,* 5:266-290. http://doi.org/10.3923/ ijbc.2011.266.290.

El-Wakeil N. E. (2013). Botanical pesticides and their mode of action. *Gesunde Pflanzen,* 65:125-149.

FAO (2017). FAO Advisory Note on Fall Armyworm (FAW) in Africa. Food and agriculture Organization of the United Nations, 7.

FAO (2019). Regional Workshop for Asia Sustainable Management of Fall Armyworm. Retrived from: http://www.fao.org/3/ca7615en/ca7615en.

Finney D. J. (1971) "Probit Analysis". Cambridge University Press, Cambridge, London, pp 333.

Gamil W. E. (2020). Fall Armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) Biological Aspects as A New Alien Invasive Pest in Egypt. *Egyptian Academic Journal of Biological Sciences. A, Entomology,* 13:189-196.

Guo J., Zhang M., Gao Z., Wang D., He K. and Wang Z. (2021). Comparison of larval performance and oviposition preference of *Spodoptera frugiperda* among three host plants: Potential risks to potato and tobacco crops. *Institute of Zoology, Chinese Academy of Sciences*, 28, 602–610. DOI 10.1111/1744-7917.12830.

Kansiime M. K., Mugambi I., Rwomushana I., Nunda W., Lamontagne-Godwin J., Rware H. and Day R. (2019). Farmer perception of fall armyworm (*Spodoptera frugiderda* JE Smith) and farm-level management practices in Zambia. *Pest management science*, 75:2840-2850.

Kim E. H., Kim H. K., Choi D. H. and Ahn Y. J. (2003). A caricidal activity of clove bud oil compounds against *Tyrophagus putrescentiae* (Acari: Acaridae). *Applied Entomology and Zoology*, 38:261-266. https://doi.org/10.1303/aez.2003.261.

Krinski D., Massaroli A. and Machado M. (2014). Potencial inseticida de plantas da família annonaceae. *Revista Brasileira de Fruticultura*, 36:225-242. http://dx.doi. org/10. 1590/ S0100-29452014000500027.

Masetti A. (2016). The potential use of essential oils against mosquito larvae: A short review. *Bulletin of insectology*, 69:307-310.

McCormick A. C., Arrigo L., Eggenberger H., Mescher M. C. and De Moraes C. M. (2019). Divergent behavioral responses of gypsy moth (*Lymantria dispar*) caterpillars from three different subspecies to potential host trees. *Scientific Reports*, 9:8953.

Noack S. and Reichmuth C. H. (1978). Einrechnerisches verfahren zur bestimmung von beliebigen dosis- werten eniens wirkstoffes aus empirisch dosis- wirkungsdaten Mitt. *Boil Bundesanstalt fur Land Forst Wirtsch, Berlin Dahlem, Haft* 185: 1- 49.

Pavela R. and Benelli G. (2016). Essential oils as ecofriendly biopesticides? Challenges and bonstraints. *Trends in Plant Science,* 21:1000-1007. https://doi.org/10.1016/j. tplants.2016.10.005.

Reddy J. (2019). Fall Armyworm control methods and symptoms. Agrifarming. Retrived from https://www.agrifarming.in/fall-armyworm-control-methods-and-symptoms.

Silva D. M., Bueno A. F., Andrade K., Stecca C. S., Neves P. M. O. J. and Oliveira M. C. N. (2017). Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. *Journal of Agricultural Sciences,* 74:18-31.

Sisay B., Simiyu J., Malusi P., Likhayo P., Mendesil E., Elibariki, N. and Tefera T. (2018). First report of the fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae), natural enemies from Africa. *Journal of Applied Entomology,* 142(8), 800-804.

Sisay B., Tefera T., Wakgari M., Ayalew G. and Mendesil, E. (2019). The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in maize. *Insects*, 10: 45.

Sousa R. M. O. F., Cunha A. C. and Fernandes-Ferreira M. (2021). The potential of Apiaceae species as sources of singular phytochemicals and plant-based pesticides. *Phytochemistry*, 187:112714. https://doi.org/10.1016/j.phytochem. 2021.112714

Sun Y. P. (1950). Toxicity index – an improved method of comparing the relative toxicity of insecticides. *Journal of Economic Entomology*, 43-45.

Tefera T., Goftishu M., Ba M. and Muniappan, R. M. (2019). A Guide to Biological Control of Fall Armyworm in Africa Using Egg Parasitoids.book1-109.

Todd E. l., Poole R. W. (1980). Keys and illustrations for armyworm moths of the noctuid genus *Spodoptera Guenee* from the Western hemisphere. *Annals of the Entomological Society of America*, 73, 722-738.

Trumble J. T. (2002). Caveat emptor: safety considerations for natural products used in arthropod control. *Entomological Society of America*, 48:7-13.

Viegas Júnior C. (2003): Terpenos com atividades inseticidas: uma alternativa para o controle químico de insetos. *Química Nova*, 26:390-400. http://dx.doi.org/10.1590/ S0100-40422003000300017.

ARABIC SUMMARY

بعض الجوانب البيولوجية ومحاولة لمكافحة حشرة دودة الحشد الخريفية باستخدام بعض الزيوت العطرية المختارة تحت الظروف المعمليه

مها صبرى الغنام[1]- بانسيه عبد السلام عزام[1]- سارة عيد الديب[2]

[1] معهد بحوث وقاية النبات- مركز البحوث الزراعية- الجيزة- مصر

[2] قسم وقاية النبات- كلية الزراعة- جامعة بنها- مصر

دودة الحشد الخريفية *Spodoptera frugiperda* هي واحدة من الآفات الحشرية المدمرة. وهي آفة متعددة العوائل تسبب أضراراً اقتصادية لمحاصيل الحبوب المهمة مثل الذرة والأرز والذرة الرفيعة والقطن ومحاصيل الخضروات المختلفة. تم تسجيل أول ظهور في مصر في عام 2019. هدفت هذه الدراسة إلى دراسة بعض الجوانب البيولوجية من خلال تقييم بعض النباتات مثل الذرة والذرة الرفيعة والخروع والطماطم كمصدر غذاء لليرقات. بشكل عام سجلت للحشرة التى تغذت يرقاتها على نبات الذرة أقصر مراحل لكلا من الطور اليرقى من العمر الأول إلى السادس، مرحلة ما قبل العذراء، مرحلة العذراء، طول عمر الحشرة الكاملة (♀ & ♂)، متوسط الخصوبة (عدد البيض ونسبة الفقس). كما شملت الدراسة تقييم كفاءة بعض الزيوت العطرية ضد العمر اليرقي الثاني والرابع للحشرة تحت الظروف المعملية. كما أشارت النتائج بوضوح إلى أن الزيوت العطرية المختبرة (زيت حشيشة الليمون، زيت البرتقال، زيت النعناع وزيت بذر الكتان) تباينت بشكل كبير في كفاءتها لمكافحة اليرقات المختبرة (العمرالثاني والرابع) وأن التركيز العالي أدى إلى إنخفاض أعلى في أعمار اليرقات التي تم اختبارها. بشكل عام، أوضحت النتائج أن كفاءة الزيوت العطرية المختبرة ضد العمر الرابع للحشرة كانت بنفس اتجاه العمر الثاني مع قيم متغيرة. يمكن ترتيب كفاءة الزيت المختبر لمكافحة حشرة دودة الحشد الخريفية تنازلياً حسب قيم LC_{50} و LC_{90} و LC_{95} على النحو التالي: زيت حشيشة الليمون > زيت البرتقال > زيت النعناع > زيت بذر الكتان بعد 10 أيام من المعاملة.