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Cayenne oil, *Capsicum annuum* L. with Gamma-Ray for Enhancing *Bacillus thuringiensis* (Kurs.) Efficacy to *Pectinophora gossypiella* (Saund.) Control

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ABSTRACT

Cayenne oil (*Capsicum annuum* L.) was exposed to gamma doses of 45, 90 & 180 Gy for bioassay, biological and life table assays of *Pectinophora gossypiella* (Saund.) treated as newly hatched larvae. Also, cayenne oil singly or exposed to gamma doses was combined with *B. thuringiensis* for efficacy enhancing purposes against the newly hatched larvae and 1-day old egg of *P. gossypiella.*

GC-MS analysis observed three major components percent that was increased with increasing gamma doses exposed (Cayenne oil+ 180 Gy, cayenne oil + 90 Gy, cayenne oil + 45 Gy and cayenne oil singly). The compounds were 9-octadecenoic acid (z)-, methyl ester; 9,12 octadecadienoyl chloride, (z, z) and Hexadecanoic acid methyl ester.

Cayenne oil + 180 Gy was the best treatment effect on the major tested assays; bioassay, biological and life table of *P. gossypiella* treated as newly hatched larvae. Also, the same compound can enhance *B. thuringiensis* efficacy against the newly hatched larvae and egg mortality percent.

INTRODUCTION

The pink bollworm, *Pectinophora gossypiella* (Saunders) [Lepidoptera: Gelechiidae] is considered a flower-boll pest that causes deleterious harm to cotton (El Hamaky *et al.*, 1990). *P. gossypiella* larvae damage the squares, flower buds, flowers and bolls of cotton, okra, hibiscus, …exc.) for that decreases the crop quality and quantity of lint, seed and oil (Khan *et al.*, 2007).

Cayenne oil (*Capsicum annuum* L.) is a medicinally and economically important species, profusely used as culinary spice and condiment all over the world, which is used as a food preservative and as an essential component in traditional medicines. The traditional uses include analgesic, antipyretic, anti-inflammatory, antioxidant, anticonvulsant, antibacterial, anti-tumor and hepatoprotective activities, antihypertensive, antiplatelet, anti-asthmatics, anti-diarrheal, antispasmodic, antidepressants, immunomodulatory, anticonvulsant, anti-thyroids, antifungal, hepato-protective, insecticidal and larvicidal activities. Also, it can be used to help in the pain relief, rheumatism, chills, flu, colds, exhaustion, muscular aches, physical and emotional coldness, fevers, as a 6-nerve tonic and increase the circulation. Furthermore, it increases the flow of saliva, stimulates appetite,

encourages peristalsis, tones the colon muscles and is a general digestive tonic (Pruthi, 1993).

Use of plant compounds (essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids) having anti-insect effects and their importance as an alternative to the chemical compound's usage in insect control, namely repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemo-sterilant, and attractants. Botanical insecticides affect only target insects and save beneficial natural enemies, residue-free food and a safe environment. Therefore, recommend by using botanical insecticides as an integrated pest management program can greatly minimal of synthetic insecticides usage (Hikal *et al.*, 2017).

Among botanical extracts used as insecticides, essential oils are promising alternatives to chemical insecticides. Also, attractive the pollinators and beneficial insects. Plants producing essential oils are called aromatic plants and are distributed worldwide. Essential oils can control Coleoptera which was the most studied insect order (85.41%) followed by Lepidoptera (11.49%), whereas few studies targeted new emerging pests (e.g., *Psocoptera*) (Campolo *et al.*, 2018). Also, Salah El-Din, *et al.* (2020) illustrated that jojoba oil proved flax oil as the most effective compound against the newly hatched larvae of *P. gossypiella* and *E. insulana*. Also, tested oils proved a higher increase of larval and pupal durations than untreated, reductions in the number of deposited eggs/female and hatched eggs, which was developed after treating the larvae with the tested oils compared with the control.

Authors used gamma radiation for oil properties enhancement as Shala (2019) showed gamma radiation (0, 5, 10, 15, 20, 25, 30 kR) is an important agent used to improve the productivity and quality of many plants and essential oil components. Also, germination percentage, vegetative growth, photosynthetic pigments, oil yield, oil components and total phenolic content of *Ocimum basilicum* L. Addition, Balakrishnan, *et al.* (2022) observed that a low irradiation dose is sufficient for dried chili to reduce microbial load to an acceptable level and eliminate pathogens even though a dose of 10 kGy is required for complete sterilization. However, gamma radiation is an approved radiation source for dried chili in most countries and has been proved to be effective for dried chilli preservation.

The work aims to assess the bioassay, biological and life table assays of *P. gossypiella* treated as newly hatched larvae with cayenne oil (*Capsicum annuum* L.) exposed to gamma doses (45, 90 & 180 Gy). In addition, enhance the biocide, *Bacillus thuringiensis* (Kurs.) efficacy by combination with cayenne oil exposed to gamma-ray doses to increase the toxicity of *B. thuringiensis* for *P. gossypiella* newly hatched larvae and egg stages.

MATERIALS AND METHODS

Pest:

A laboratory strain of the pink bollworm, *Pectinophora gossypiella* (Saund.) was reared at the Bollworms department, Plant protection research Institute, A.R.C on a semi-artificial diet as described by Rashad and Ammar (1985). Rearing conditions were adjusted at 27±1^{o}C and 65-75 RH.

Compounds:

a- Cayenne oil, *Capsicum annuum* L. were obtained from the El-Captain company. It was exposed to gamma-ray doses of 45, 90 & 180 Gy with Indian Canada cell (Ce w000A) at dose rate of 1.081 KGy/h. Irradiation work was done at National Center for radiation research and Technology, Nasr City, Cairo, Egypt.

b. Protecto i a commercial formulation of *Bacillus thuringiensis* (Kurs.). It is a product of special unit for producing bio-insecticides, Plant Protection Research Institute, A.R.C.,

Egypt, with 32000 international toxicity units (spores and protein crystals) per mg. The active ingredient is 6.4% W.P and the application rate is 300 gm/feddan.

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis:

The GC-MS analysis work for cayenne oil analysis was done at the Faculty of Agriculture, Alexandria university according to the method by AbdEl-Kareem, *et al*. (2016). The chemical composition of samples was performed using GC-TSQ mass spectrometer (Thermo Scientific, Austin, TX, USA) with a direct capillary column TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness). The column oven temperature was initially held at 60°C and then increased by 6°C /min to 250°C withhold 1 min then increased to 300 with 30 C/min. The injector temperature was kept at 270°C. Helium was used as a carrier gas at a constant flow rate of 1 ml/min. The solvent delay was 4 min and diluted samples of 1 µl were injected automatically using Autosampler AS3000 coupled with GC in the split mode. EI mass spectra were collected at 70 eV ionization voltages over the range of m/z 50–650 in full scan mode. The ion source and transfer line were set at 200 °C and 280 °C respectively. The components were identified by comparison of their mass spectra with those of WILEY 09 and NIST14 mass spectral database. The components identified from cayenne oil treatments are tabulated in Tables (1-4) as follows:

Table 1. The components were identified from the cayenne oil by using GC-MS.

No.	Compounds	RT (min.)	Area (%)	Molecular weight (KDa)
1	2H-inden-2-one, octahydro-3A-phenyl-oxime, trans-	4.06	2.08	229
2	Dichloromethyl ethyl sulfone	5.39	0.98	176
3	1,3,5-triazine-2,4-diamine, 6-chloro-N-ethyl-	8.64	0.71	173
4	Dithiocarbamate, S-methyl-, N-(2-methyl-3-oxobutyl)	10.44	1.16	191
5	3-oxo-20-Methyl-11-a-Hydroxyconanine-1,4-diene	12.61	0.50	341
6	Phenol,2,4-Bis (1,1-dimethylethyl)-	13.46	1.02	206
7	Tert-Hexadecamethiol	16.62	0.43	258
8	1,2,4-Trioxolane-2-octanoic acid, 5-octyl-, methyl ester	17.13	0.61	344
9	Cyclopropanedodecanoic acid, 2-octyl-, methyl ester	18.20	0.62	366
10	Isochiapin B	18.29	0.66	346
11	2,6-nonadienoic acid, 7-ethyl-9-(3-ethyl-3-methyloxiranyl)-3-methyl-, methylester, [2R- [2a (2E, 6E), 3a]]-	18.96	0.34	294
12	Hexadecanoic acid, methyl ester	20.51	28.48	270
13	2,2- Dideutero octadecanal	21.50	0.49	270
14	9,12- octadecadienoic acid (z,z)-, methyl ester	23.12	15.41	308
15	9- octadecenoic acid (z)-, methyl ester	23.21	27.92	296
16	9,12- octadecadienoyl chloride, (z,z)-	23.32	11.86	298
17	14- pentadecynoic acid methyl ester	23.63	1.37	252
18	1-Heptatriacotanol	24.63	0.59	536
19	Cholestan-3-ol, 2-methylene-, (3a, 5a)-	25.33	1.87	400
20	2- Acetyl-3-(2- cinnamido) Ethyl-7- Methoxy indole	25.60	1.53	362
21	15,17,19,21- Hexatriacontatetrayne	26.97	0.51	490
22	2- Acetyl-3-(2-cinnamido) ethyl-7-Methoxy indole	29.36	0.48	362
23	Ethyl iso-allocholate	34.34	0.38	436

Table 2. The components identified from the cayenne oil + 45 Gy by using GC-MS.

No.	Compounds	RT (min.)	Area (%)	Molecular weight (KDa)
1	Dichloro methyl ethyl sulfone	4.07	0.44	176
2	Phenol, 2,4-Bis (1,1- dimethyl ethyl)-	13.48	0.77	206
3	Hexadecanoic acid, methyl ester	20.52	23.16	270
4	9,12- octadecadienoic acid (z,z)-, methyl ester	23.14	17.43	294
5	9- octadecenoic acid (z)-, methyl ester	23.23	37.16	296
6	9,12-octadecadienoyl chloride, (z,z)-	23.33	15.16	298
7	Cyclopentanetridecanoic acid, methyl ester	23.64	2.23	296
8	Cholestan-3-ol, 2- methylene-, (3a, 5a)-	25.34	1.71	400
9	E-8-methyl-9- tetradecenol acetate	25.62	1.42	268
10	N-Butyl ricinoleate	26.97	0.53	354

Table 3. The components identified from the cayenne oil + 90 Gy by using GC-MS.

No.	Compounds	RT (min.)	Area (%)	Molecular weight (KDa)
1	2H- Inden-2-one octahydro- 3A- phenyl-, oxim, trans-	4.09	2.32	229
2	Trichloromethane	4.52	0.27	118
3	N, N-Dimethyl -2H- pyran- 2- 1 Minimum chloride	4.59	0.43	159
4	Acetic acid, trichloro-	4.68	0.30	162
5	Methane, oxybis [dichloro]-	4.74	0.79	182
6	TCA; [trichloroacetic acid]; (Erbitox T95), (occigram) (cycocel) (Radapon), (Basfapon)	4.87	0.24	162
7	Dichloromethyl ethyl sulfone	5.54	2.8	176
8	Hexanoic acid, z- methyl-3-oxo-, Ethyl ester	5.73	1.90	172
9	Methane, trichloro	5.86	0.22	118
10	10- Heptadecen- 8- ynoic acid, methyl ester, (E0-	11.03	0.81	278
11	3-oxo-20-methyl-11-a- Hydroxyconanine – 1,4- Diene	11.12	0.37	341
12	2,6 – octadienal, 2,6- dimethyl-8- (tetrahydro- 2H- 2- pyranyloxy	11.90	1.25	341
13	Disulfide, di-tert-dodecyl	12.60	3.26	402
14	1,1,3,3- Tetramethyl- 1,3- Disila indan	13.49	1.86	206
15	1- tetradecanol	14.61	0.38	214
16	1,3,5- triazine-2,4-Diamine, 6- chloro- N- ethyl-	14.72	0.96	173
17	2,2,3,3,4,4- Hexadeutero octadecanal	14.85	0.45	274
18	1- Chlorooctadecane	16.62	0.67	288
19	Pentadecanoic acid	17.39	1.52	242
20	9- octadecenoic acid (z)-	18.21	0.78	282
21	2,2- Dideutero octadecanal	18.29	1.43	270
22	4,25- Secoobs curinervan 21- Dexoy-16- methoxy-22- methyl-, (22a)-	18.98	0.52	368
23	Dotriacontane	20.25	0.75	450
24	Hexadecanoic acid, methyl ester	20.52	18.23	270
25	Pentadecanoic acid 14-methyl-, methyl ester	20.95	0.27	270
26	Oxiraneundecanoic acid, 3- pentyl-, methyl ester, cis-	21.50	1.14	312
27	9- octadecenoic acid (z)-, methyl ester+ 9,12-octadeadienoyl chloride, (z,z)-	23.24	49.78	296
28	13,16-octadecadiynoic acid, methyl ester	23.66	1.32	290
29	Oleic acid	24.52	0.72	282
30	Cholestan-3-ol, 2- methylene-, (3a, 5a)	25.43	0.44	400
31	9- octadecenoic acid (z)-	25.66	1.32	282
32	[1, 1- Biphenyl]-2,3-diol, 3,4,5,6- tetrakis (1,1-dimethyl ethyl)-	26.97	1.31	410
33	Isochiapin B	29.39	0.69	346
34	Ethyl iso-Allocholate	34.35	0.47	436

Table 4. The components identified from the cayenne oil + 180 Gy by using GC-MS.

No.	Compounds	RT (min.)	Area (%)	Molecular weight (KDa)
1	Dichloromethyl ethyl sulfone	4.08	1.12	176
2	Hexanoic acid, 2-methyl -3-oxo-, ethyl ester	8.20	0.55	172
3	2-Oxo-20-methyl-11-a-Hydroxyconanine- 1,4-diene	8.94	0.46	182
4	1,3,5- triazine- 2,4- diamine, 6- chloro -N- ethyl-	12.24	0.52	368
5	1- Chloro octadecane	12.59	0.46	288
6	Phenol, 2,5-BIS (1,1- Dimethyl ethyl)-	13.49	1.72	206
7	1-tetra decanol	14.59	0.39	214
8	1- Hexadecanol, 2- methyl-	14.70	0.79	256
9	2- (Tetradecyl-180-oxy)- 1,2- propanediol	16.62	0.43	288
10	Octadecanoic acid methyl ester	17.18	1.73	298
11	Cyclopentanetridecanoic acid, methyl ester	17.39	0.38	296
12	2-Methyl-z-4- tetradecene	18.20	0.66	210
13	Tert- Hexadecanethiol	18.29	0.71	258
14	2,2,3,3,4,4 Hexadeutero octadecanal	20.25	0.46	274
15	Hexadecenoic acid methyl ester	20.51	31.89	270
16	9- Hexadecenoic acid	21.50	0.84	254
17	9- octadecenoic acid (z)-, methyl ester + 9,12- octadeadienoyl chloride, (z,z)-	23.21	51.41	296
18	14- pentadecynoic acid, methyl ester	23.65	1.53	252
19	Cis- vaccenic acid	24.52	0.44	282
20	Oleic acid	25.37	0.84	282
21	Oxiraneoctanoic acid 3- octyl-, methyl ester, trans	25.64	1.29	312
22	Cholest-22-ene-21-ol, 3,5-dehydro-6-methoxy-, pivalate	26.97	0.88	498
23	Phen-1,4-diol, 2,3- dimethyl-5- trifluoromethyl-	29.39	0.51	206

Bioassay.

Cayenne Oil Experiments:

Twenty-five larvae of the pink bollworm, *Pectinophora gossypiella* (Saund.) newly hatched larvae with 2 gm semi-artificial in Petri-dishes were prepared. Four replicates for each concentration were done. The cayenne oil concentrations were 10-90% with ethanol solvent used for dilution and untreated ethanol. The alive larvae transfer after 6h. to an untreated diet. The alive larvae were counted at 1-5 days passed.

The LC_{25}, LC_{50}, LC_{90} and slope values were calculated according to probit analysis (Finney 1971) and corrected with Abbot's formula (1925) using Ldp line software (Bakr, 2000).

Protecto Experiments:

Twenty-five larvae of *P. gossypiella* newly hatched placed in 2 gm of semi-artificial diet mixed with 1 ml of each protecto conc. (40, 20, 10, 5 & 2.5 gm/L). The larvae were left at 6 h. and transferred to an untreated diet. The results register at 72 h. after treatments. The untreated one (diet with water) was done.

The LC_{25} was calculated according to probit analysis (Finney 1971) and corrected with Abbot's formula (1925) using Ldp line software (Bakr, 2000).

Mixing of protecto + cayenne oil alone or exposing to gamma-ray was LC_{25} from protecto**:** LC_{25} of each cayenne oil were done to determine the protecto toxicity enhancement against *P. gossypiella* newly hatched larvae and 1- day old egg by the same concentrations.

Biological Assay:

The LC_{50} of the pink bollworm, *P. gossypiella* treatments with cayenne oil exposed to gamma-ray were done to determine some biological assays as follows:

Larval and Pupal Stages: Duration (days), weight (g) and % mortality.

Moth Stage: Pre-oviposition (days), oviposition (days), post-oviposition times (days), ♂ and ♀ adult longevity (days), sex ratio (female/total), no.of egg/female, %hatchability, %fecundity and % sterility (observed and corrected).

Fecundity Percentage: It was calculated according to Crystal and Lachance (1963):

$$\% \text{ Fecundity} = \frac{\text{No. eggs/ treated female}}{\text{No. eggs/ untreated female}} \times 100$$

Sterility Observed and Corrected Percentages. Calculated according to Zidan and Abdel-Megeed (1987) as follows:

$$\% \text{ Sterility observed} = 100 - \% \text{ Egg hatchability}$$

$$\% \text{ Corrected sterility} = \frac{\% \text{ Sterility observed - Check}}{100 - \text{Check}} \times 100$$

Life Table Assays: Analyzed with life 48 basic computer programs of Abou-Setta, *et al.* (1986). The program has output data: Egg-laying rate (M), number of females alive at age x (L), mean female age at each interval mid-point (X), female progeny per female produced during the day (Mx) and rate of survival (Lx). In addition, generation time (T), net reproductive rate (Ro), intrinsic rate of natural increase (r_m), finite rate of increase (e^{rm}) and many times that the population multiplies in a unit time (doubling time, T).

Statistical Analysis:

The biological and life table assays data were analyzed using costat statistical program software (1990) and Duncan's multiple range test (Duncan, 1955) at a 5% probability level to compare the differences among time means.

RESULTS

Bioassay Experiments:

The pink bollworm, *Pectinophora gossypiella* (Saund.) newly hatched larvae treated with cayenne oil alone or exposed to gamma-ray doses (45, 90 & 180 Gy). The LC_{25}, LC_{50}, LC_{90} & slope values were determined in Table (5) from 1- day passed up to 5- days after treatments.

Table (5) described that cayenne oil + 180 Gy was the best cayenne oil treatment to have a lethal effect on *P. gossypiella* newly hatched larvae from 1-day passed to 3-day passed from treatment. Also, more toxicity appeared 4&5 to days passed from treatments (Table, 5). In addition, the same table described that cayenne oil exposed to gamma-ray has a toxicity effect more than cayenne oil when used alone.

Table (6) illustrated the bioassay of *P. gossypiella* newly hatched larvae with LC_{25} of *B. thuringiensis* + LC_{25} of cayenne oil treatments combinations with a ratio of 1:1 when the newly hatched larvae were treated with a note that *B. thuringiensis* LC_{25} against *P. gossypiella* newly hatched larvae was 0.15 gm/L at 3- day passed from treatment.

The newly hatched larval mortality in *B. thuringiensis* + cayenne oil treatments had enhanced efficacy on *P. gossypiella* newly hatched larvae than uses of each compound alone compared with untreated *P. gossypiella* in each with water or ethanol. Treatment of *B. thuringiensis* +cayenne oil + 180 Gy had the best %mortality of *P. gossypiella* newly hatched larvae compared with other treatments used. *P. gossypiella* 1-day old egg treatments had the same trend mentioned in *P. gossypiella* newly hatched %mortality (Table, 6).

Table 5. Bioassay of cayenne oil exposed to gamma ray doses on *P. gossypiella* newly hatched larvae

Compounds	LC_{25} (%) ± Confidence limit	LC_{50} (%) ± Confidence limit	LC_{90} (%) ± Confidence limit	Slope ± SE
1- day passed				
Cayenne oil	45 42±48	90 85±98	150 120±165	0.365± 0.145
Cayenne oil+ 45 Gy	40 28±49	80 72±87	100 89±105	0.306± 0.149
Cayenne oil+ 90 Gy	35 30±40	70 61±79	90 83±99	0.324± 0.134
Cayenne oil+ 180 Gy	25 18±31	50 44±58	80 70±90	0.352± 0.123
2- Day passed				
Cayenne oil	40 30±54	80 73±89	100 95±110	0.324± 0.134
Cayenne oil+ 45 Gy	35 30±40	70 61±79	95 88±102	0.274± 0.110
Cayenne oil+ 90 Gy	30 23±37	60 50±70	90 80±100	0.257± 0.100
Cayenne oil+ 180 Gy	20 15±28	40 30±54	65 60±75	0.160± 0.094
3- Day passed				
Cayenne oil	35 30±40	70 61±79	90 80±100	0.352± 0.123
Cayenne oil+ 45 Gy	30 23±37	60 50±70	80 70±90	0.196± 0.105
Cayenne oil+ 90 Gy	25 20±30	50 44±58	75 65±85	0.143± 0.095
Cayenne oil+ 180 Gy	15 10±20	28 23±33	55 50±60	0.383± 0.097
4- day passed				
Cayenne oil	33 30±36	65 58±72	85 75±91	0.274± 0.110
Cayenne oil+ 45 Gy	28 23±33	55 50±62	75 63±82	0.144± 0.102
Cayenne oil+ 90 Gy	20 15±25	40 30±50	65 58±72	0.140± 0.094
Cayenne oil+ 180 Gy	11 9±14	20 15±25	40 30±50	0.178± 0.102
5- Day passed				
Cayenne oil	30 23±38	60 54±67	80 71±93	0.167± 0.101
Cayenne oil+ 45 Gy	25 20±30	50 43±58	70 64±80	0.176± 0.100
Cayenne oil+ 90 Gy	18 14±23	35 30±44	60 54±67	0.160± 0.094
Cayenne oil+ 180 Gy	8 6±11	15 10±20	35 30±44	0.246± 0.106

Table 6. Mortality percentages of *P. gossypiella* newly hatched larvae and 1- day old egg treated with *B. thuringiensis* + cayenne oil exposed to gamma-ray

Compounds	Corrected Newly hatched mortality %	Corrected Egg mortality %
B. thuringiensis	25 [d]	7.5 [cd]
Cayenne oil	25 [d]	3 [d]
B. thuringiensis+ Cayenne oil	28 [d]	11.5 [c]
B. thuringiensis+ cayenne oil +45 Gy	45 [c]	26.7 [b]
B. thuringiensis + cayenne oil +90 Gy	55 [b]	42.4 [a]
B. thuringiensis+ cayenne oil+ 180 Gy	70 [a]	48.2 [a]
Untreated water	3 [e]	3 [d]
Untreated ethanol	3 [e]	3 [d]
L.S.D$_{0.05}$	6.3891	6.5339

B. thuringiensis LC_{25} = 0.15 gm/L

Values of *P. gossypiella* newly hatched larvae treated with LC_{25} (*B. thuringiensis*) + LC_{25} (cayenne oil treatments) at 3- days after treatments

Biological Assays:

Table (7) obtained the *P. gossypiella* newly hatched larvae with LC_{50} of cayenne oil treatments at 3-days passed from treatments. The biological assay had many deleterious effects in all the stages assessed; larval, pupal & adult stages. Treatment of *P. gossypiella* newly hatched larvae with cayenne oil + 180 Gy was the most treatment that caused the major injurious on the tested insect compared with other treatments and untreated.

The treatment aforementioned increased the larval duration by about 3- days compared with untreated (water-ethanol) and other treatments used; decrease the larval weight by about 0.04 gm and the larval mortality % reached 56.2%. Also, in the pupal stage, the same treatment (cayenne oil + 180 Gy) decreased the pupal duration by about 1-2 days with a weight decrease of about 0.03 gm and had the least pupation % (43.8%) compared with other treatments and untreated. The same trend appeared in the adult stage. The least adult emergency was 30.7%, the pre-oviposition was as well as oviposition time (4 days), the post-oviposition time (3 days), ♂&♀ adult longevity had only 9&12 days, the sex ratio reaches 40.4%. Moreover, no. egg/female had depressed (87.2 egg/female) and its hatchability was 65% with hatchability control of 32.3% that lead to 34.9% fecundity and 32.3% corrected sterility with the same treatment of cayenne oil + 180 Gy compared with other treatments and untreated (water-ethanol) as illustrated in Table (7).

Table 7. Biological assays of *P. gossypiella* treated as newly hatched larvae with LC_{50}'s of cayenne oil exposed to gamma-ray doses

Biological assays	Compounds						L.S.D $_{0.05}$
	Cayenne oil	Cayenne oil+ 45 Gy	Cayenne oil+ 90 Gy	Cayenne oil+ 180 Gy	Untreated water	Untreated ethanol	
Larval duration (day)	17.4^{a}	17.7^{a}	18.5^{a}	19.1^{a}	16.2^{a}	16.5^{a}	3.4065
Larval weight (g)	0.0521^{b}	0.05^{b}	0.048^{b}	0.042^{b}	0.081^{a}	0.079^{a}	0.0162
Larval mortality (%)	35.2^{c}	37.3^{c}	42.2^{b}	56.2^{a}	7.4^{d}	8.5^{d}	4.2967
Pupal duration (day)	11.22^{ab}	11.8^{ab}	12.1^{ab}	12.9^{a}	11.1^{ab}	10.0^{b}	2.4088
Pupal weight (g)	0.045^{b}	0.041^{b}	0.038^{b}	0.031^{b}	0.069^{a}	0.067^{a}	0.01454
Pupation (%)	64.8^{b}	62.7^{b}	57.8^{c}	43.8^{d}	92.6^{a}	91.5^{a}	4.2349
Adult emergency (%)	51.8^{b}	49.1^{b}	42.2^{c}	30.7^{d}	87^{a}	88^{a}	2.9051
Pre-oviposition time (day)	1^{c}	2^{bc}	3^{ab}	4^{a}	2^{bc}	2^{bc}	1.2579
Oviposition time (day)	7^{b}	7^{b}	5^{b}	4^{b}	14^{a}	15^{a}	3.248
Post-oviposition time (day)	2^{b}	2^{b}	3^{ab}	3^{ab}	4^{a}	4^{a}	1.6239
♂ adult longevity (day)	9.5^{b}	10^{b}	10^{b}	9^{b}	17^{a}	18^{a}	2.40877
♀ adult longevity (day)	10^{b}	11^{b}	11^{b}	11^{b}	20^{a}	21^{a}	3.91109
Sex ratio	50.2^{ab}	48.8^{ab}	45.5^{bc}	40.4^{c}	52.2^{a}	52.9^{a}	5.5786
No. egg/female	115.5^{b}	112.2^{b}	98.9^{b}	87.2^{b}	248^{a}	250^{a}	29.2138
Egg hatchability (%)	85^{b}	80^{b}	70^{c}	65^{c}	98^{a}	96^{a}	7.4065
Control of hatchability (%)	11.5^{d}	16.7^{c}	27.1^{b}	32.3^{a}	-^{e}	-2.08^{e}	2.6186
Fecundity (%)	46.2^{b}	44.9^{b}	39.6^{c}	34.9^{d}	99.2^{a}	100^{a}	4.65040
Sterility observed (%)	15^{b}	20^{b}	30^{a}	35^{a}	2^{c}	4^{c}	7.2627
Sterility corrected (%)	11.5^{d}	16.7^{c}	27.1^{b}	32.3^{a}	-2.08^{e}	0.0^{e}	2.29667
Life cycle (day)	23.4^{b}	24^{ab}	23.9^{ab}	25^{ab}	29.3^{ab}	29.5^{a}	5.45107
Life span (days)	33.4^{b}	35^{b}	34.9^{b}	36^{b}	49.3^{b}	50.5^{a}	5.53111

Life Table Assays:

The newly hatched larvae of *P. gossypiella* were treated with LC_{50}'s with cayenne oil alone or exposed to gamma-ray doses (45, 90 & 180 Gy) to assay prediction assessments of *P. gossypiella* using the life table program.

Table (8) reverse the *P. gossypiella* treated as newly hatched larvae affected with cayenne oil treatments, especially in cayenne oil + 180 Gy by prediction assays deleterious as generation time (T) that had decreased about 5-8 days compared with untreated. Net reproductive rate (Ro) that assess no. of female daughter/ female parent in one generation had drastically depressed to 20.06 female daughter/ female parent at the mentioned treatment (cayenne oil + 180 Gy) compared with untreated that was 114 nearly female daughter/ female as well as happened in intrinsic rate of increase (r_m) (the ability to inherit increase) that was 0.0641 times/ female/ day and finite rate of increase (e^{rm}) or the daily population per female that was 1.066 times/day.

The same treatment of cayenne oil + 180 Gy with *P. gossypiella* treated as newly hatched larvae effect on population doubling time (DT) or population become twice to spend

10.814 days to become doubling population, that value was the higher about 3-days comparing with untreated values.

Table 8. Life table assays of *P. gossypiella* treated with LC_{50}'s of cayenne oil exposed to gamma-ray doses

Life table assays	Compounds						
	Cayenne oil	Cayenne oil+ 45 Gy	Cayenne oil+ 90 Gy	Cayenne oil+ 180 Gy	Untreated water	Untreated ethanol	L.S.D $_{0.05}$
Generation time (T)	43.6 ^{b}	46.3 ^{b}	46.03 ^{b}	46.82 ^{b}	51.075 ^{a}	51.138 ^{a}	3.4065
Net reproductive rate (Ro)	44.63^{b}	33.48 ^{c}	26.18 ^{cd}	20.06 ^{d}	114.89 ^{a}	114.06 ^{a}	8.3758
Intrinsic rate of increase (r_m)	0.0871 ^{ab}	0.0758 ^{abc}	0.0709 ^{bc}	0.0641 ^{c}	0.09289 ^{a}	0.09263 ^{a}	0.01786
Finite rate of increase (e^{rm})	1.091 ^{ab}	1.0788 ^{abc}	1.0735 ^{bc}	1.066 ^{c}	1.097 ^{a}	1.097 ^{a}	0.01785
Duplicate time (DT)	7.958 ^{a}	9.144 ^{a}	9.776 ^{a}	10.814 ^{a}	7.462 ^{a}	7.483 ^{a}	3.1657

Figure (1) described the female daughter progeny/female (Mx) and its survival rate (Lx). Mx of untreated water and ethanol ranged between 0.78- 26.1 and 0.53-23.81 female daughter progeny/ female with survival rates (Lx) that were 0.39-0.98 and 0.58-0.96.

Cayenne oil + 180 Gy had Mx from 2.83-17.78, and its survival rate had a highly decreased 0.39-0.52, followed by cayenne oil + 90 Gy, cayenne oil + 45 Gy and cayenne oil only as shown in Figure (1).

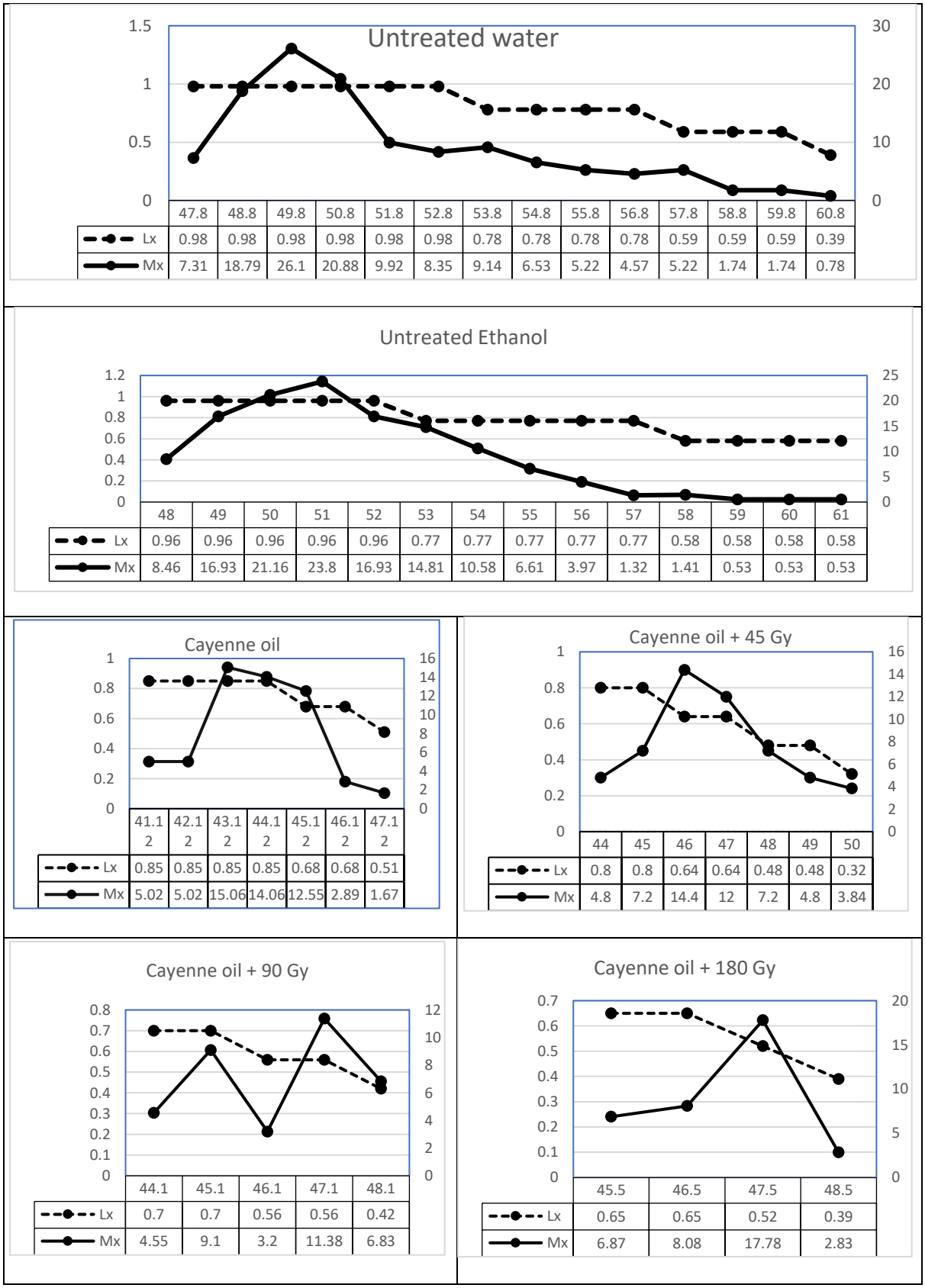

Fig 1. Female daughter progeny/female (Mx) and survival rate (Lx) of *P. gossypiella* treated as newly hatched larvae with LC_{50}'s of cayenne oil exposed to gamma-ray doses.

DISCUSSION

The bioassay, biological and life table assays of *P. gossypiella* treated as newly hatched larvae were considered as an inverse effect of cayenne oil chemical structure that was modified by exposing to gamma-ray doses of 45, 90 & 180 Gy that caused the modification and rearrangement for a chemical component of the oil structure to become new modified cayenne oil compound. Liberty, *et al.* (2013) stated that gamma rays are labelled 'ionizing' because the energy generated by them is able to disintegrate molecular bonds and alter the original placement of electrons from atoms and molecules. As a consequence, two electrically charged particles (ions) are created. Similarly, Muhammad, *et al.* (2009) demonstrated the changes in phenolics compound and stable proximate content in dried red chillies after radiation at 2, 4, and 6 kGy. In addition, Woodside (2015) showed that irradiation treatment minimally affects the quality parameters in dried chilli such as total carotenoids, volatile compounds, vitamins, ascorbic acids, and phenolic compounds provided an appropriate radiation dose is applied. Moreover, Iqbal, *et al.* (2016) reported that radiation doses up to 6 kGy did not affect the initial level of ascorbic acid and total phenolics even though a slight drop in carotenoids was observed.

In the current study, Cayenne oil + 180 Gy was the most affecting compound on *P. gossypiella* treated as newly hatched larvae because its major component percent contains 9-octadecenoic acid (z)-, methyl ester and 9,12- octadecadienoyl chloride, (z,z)- at 51.41% for both compounds, followed by Hexadecanoic acid methyl ester at 31.89%. The components aforementioned of cayenne oil + 180 Gy increased the deleterious affecting on the most bioassay, biological and life table assays of the pest. The mentioned three components were found in cayenne oil + 90 Gy and cayenne oil + 45 Gy treatment in a percent less than cayenne oil + 180 Gy. On the other hand, cayenne oil treatment alone has the same component but in the least percent compared with the same compounds exposed to gamma doses.

In addition, cayenne oil with gamma doses contributed to enhancing *B. thuringiensis* efficacy to become more lethal on *P. gossypiella* newly hatched larvae and 1-day old egg in case of combinations with cayenne oil exposed to gamma doses than in *B. thuringiensis* or cayenne oil treatment when used each of them alone.

Many authors used essential oils for controlling many pests as El-Mesallamy, *et al.* (2015) analyzed the Egyptian *Capsicum annuum* oil (Pepper oil) and found thirty-three components; the five majors were identified as Eicosan (12.11%), Nonacosane (10.94%), Nonadecane (5.75%), capsaicin (5.37%) and octadecane, 14- dibutyl (4.60%). The pepper oil has a toxic effect against *Tetranychus urticae*, 1st instar larvae of the cotton leafworm and the least effect recorded against the newly hatched larvae of spiny bollworm. The treated newly hatched larvae of spiny bollworm using pepper oil at 60 and 70% concentrations had significant prolonged larval duration; shortened pre-oviposition and oviposition periods. Also, it decreased larval and pupal weights, pupation and hatchability percentages. Also, Al-Khazraji and Majeed (2017) conducted a study for knowing the effect of black oil extract (*Piper nigrum* L.) on some aspects of cotton leafworm *S. littoralis*. The highest percent of egg hatching was 36.7% when exposed to the egg at 24-hour with a 5% concentration. The larvae 2nd phase was more sensitive to the oil extract and the highest %mortality was 32.6% compared with 6th stage larvae, which were less affected. The effect of exposure to aromatic extracts was reduced in adult productivity. The number of eggs was 720.3, 885 and 917 eggs/female that were treated as 2nd & 6th stages; the percentage of egg hatch in each treatment was affected. When adults were exposed to the smells of the oil extract directly, they caused a 100% Mortality rate after 24 hours of exposure to 5% conc.; while the adult mortality rate in the comparison treatment was 0%. Moreover, Amer, *et al.* (2020) tested

nine compounds related to bio-agent groups, one of them (orange oil) was exposed to gamma radiation doses of 160, 320 & 640 Gy for potentiating purposes with *B. thuringiensis* mixture. The treatments were *B. thuringiensis,* orange oil, *B. thuringiensis* + orange oil, *B. thuringiensis* + orange oil 160 Gy, *B. thuringiensis* + orange oil 320 Gy, *B. thuringiensis* + orange oil 640 Gy, azadirachtin, azadirachtin + orange oil and emamectin benzoate. *B. thuringiensis* + orange oil 640 Gy was considered the best treatment and caused a reduction percentage in population and infestations of three pests; *P. gossypiella, E. insulana* and *O. hyalinipennis*, but lower than emamectin benzoate efficacy. In addition, the compounds used, especially *B. thuringiensis* + orange oil 640 Gy enhanced the most cotton crop parameters.

CONCLUSION

Cayenne oil exposed to gamma-ray doses at 45, 90 & 180 Gy modified its chemical components percent that inverse on the bioassay, biological and life table assays of *P. gossypiella* treated as newly hatched larvae compared with the same oil (cayenne oil) alone without exposing to gamma doses.

Also, cayenne oil with gamma doses contributes to the enhancement of the efficacy of *B. thuringiensis* when combined with them against the newly hatched larvae and 1-day old egg of *P. gossypiella* mortality.

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ARABIC SUMMARY

زيت الشطة مع آشعة جاما لتحسين الكفائة الإبادية لبكتيريا الباسيلس ثورينجينسيز لمكافحة دودة اللوز القرنفلية

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تم تعريض زيت الشطة لجرعات أشعة جاما (45- 90- 180 جراى) لتقييم قياسات السمية – البيولوجية وجداول الحياة لدودة اللوز القرنفلية. كما تم اضافة زيت الشطة منفردا او معرضا لجرعات اشعة جاما الى بكتيريا الباسيلس ثورينجينسيز بغرض تحسين فعلها الابادى ليرقات الفقس الحديث وبيض عمر يوم لدودة اللوز القرنفلية.
أظهر تحليل الغاز الكرماتوجرافى (GC-MS) 3 مكونات بنسب اعلى فى زيت الشطة عن باقى المكونات والتى تزيد نسبتها بزيادة جرعة جاما المستخدمة. والمركبات هى (9,12 ;9-octadecenoic acid (z)-, methyl ester octadecadienoyl chloride, (z, z) and Hexadecanoic acid methyl ester).
وعلى ذلك تعتبر معاملة زيت الشطة + 180 جراى أفضل معاملة أعطت تأثيرا على معظم قياسات السمية والبيولوجية وجداول الحياة لدودة اللوز القرنفلية المعاملة فى طور الفقس الحديث. كما استطاع نفس المركب من تحسين الفعل الإبادى لبكتيريا الباسيلس ثورينجينسيز فى زيادة النسبة المئوية لموت يرقات الفقس الحديث والبيض لدودة اللوز القرنفلية.