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Susceptibility of the peach fruit fly, *Bactrocera zonata* (Saund.) (Diptera: Tephritidae), previously irradiated as pupae or as adults, to the insecticides widely used in the field for fruit fly control in Egypt.

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ABSTRACT

The proper doses of certain insecticides that concord with gamma rays were established to develop a coordinated release program against *Bactrocera zonata*. The relative susceptibility of the peach fruit fly adults greatly varied according to dosage of irradiation, insect stage, sex and the insecticide involved. Adults (especially females) pre-irradiated with 40 Gy, as pupae 2-days before eclosion , were more tolerant to malathion, than the respective 2-days -old pupae previously exposed to 90 Gy while became less tolerant to deltamethrin at the same treated stage with the same gamma ray dose. Also, direct application of malathion to 6-days old adults irradiated with 90 Gy made them more tolerant than the respective early adults (2-days old). Deltamethrin is more favorable in case of releasing adults emerging from early pupae pre-irradiated and treated as adults with this insecticide; where the tolerance ratio (TR) values were 1.8 and 1.5 for males and females, respectively.

Keywords: Susceptibility, insecticides, gamma ray, tolerance ratio, *Bactrocera zonata*

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INTRODUCION

The peach fruit fly, *Bactrocera zonata* (Saunders)(Diptera: Tephritidae), is a serious polyphagous pest that attacks over 50 cultivated and wild plants in many parts of the world [1,2,3]. This pest considered the main pest of guava and mango in India and Pakistan [4] and attacks other fruits such as peach, mango, guava, apricot, fig, and citrus [1,2]. *B. zonata* was recorded for the first time in Egypt in 1998 and established rapidly in most Egyptian provinces causes great losses in all fruit crops [5,6]. Annual losses due to the peach fruit fly are estimated at 190 million € in Egypt [7]. The effect of gamma radiation on the peach fruit fly was studied by many authors [5, 8- 12]**.** Also, there are several publications on the effect of different insecticides on the peach fruit fly [13-18]. On the other hand the tolerance of sterile released insects to sprayed insecticides in the area under control especially in the IPM programs has no attention on fruit fly control.

It has been confirmed that the insecticidal toxicity can be altered if the insects are exposed to radiation prior to insecticidal treatment [19-22] and there is a mutual effect of radiation and insecticides on the biology of the insect [8]. Various physical and chemical methods have been combined with ionizing radiation to enhance the effectiveness of each. Gamma radiation has also been used in conjunction with insecticides [23-25] to study the possible additive effects of treatments, their interaction and possible cost advantages by using various methods of insecticide application on the insect. The application of the sterile insect release technique is not economically feasible, nowadays, to control the peach fruit fly. In the meantime population suppression of the insect by chemical means may affect man and his environment. Combination of these methods in well-coordinated program, however, may provide successful, economic and safe pest control management.

The idea is to decrease the natural population of the target insect in the area by applying low concentration of the tested insecticide before releasing gamma sterilized insects in the area under control.

The present research aims to evaluating the susceptibility of peach fruit fly adults irradiated as pupae or as adults to the insecticides mostly used by the farmers in controlling the fruit flies in the field; also, to determine the tolerance of irradiated released flies to these insecticides and to make use of the results in controlling the peach fruit fly, *B. zonata*.

MATERIALS AND METHODS

Peach fruit fly, *Bactrocera zonata* was reared in the laboratory according to the method of [5] and maintained at temperature of 25±2 C° and 60-65% relative humidity. Pupae and adults were irradiated with the proper doses of gamma ray [11] by using a cobalt-60 source installed at Middle Eastern Regional Radioisotope Center for Arab Countries, Dokki, Egypt.

Insecticides used:

1- Malathion 90%: (0, 0-Dtmethyl 5-(1, 2 dicarbethoxy ethyl) phosphorodithioate)
2-Deltamethrin 95% (-Cyano-3-phenoxybenzy1-(2,2dibromoviny1) 2, 2 dimethyl cyclopropane carboxylate)

Experimental Work:

For determination of LD50 and LD90 of tested insecticides the peach fruit fly adults (two-and six- days old) were immobilized by using a piece of cotton pad moistened with ether for a minute. Series of concentrations of each insecticide in acetone were prepared. Individual adult males and females separately, were treated topically on the mesonotum with l µl of a given concentration, using Hamilton dispenser type PB 6500. Toxicity lines were drawn on Log-Probit paper [26] and LD50 and LD90 values of each insecticide were determine.

Response of adults previously irradiated as pupae or adults to the tested insecticides:

Peach fruit fly pupae (two-days old and two-day before adult emergence) and adults (two-and six-days old) were irradiated with the proper doses of gamma rays : 40Gy in the case of two days old pupae or

90Gy against pupae two-days before adult emergence and two-and six-days old adults. Adults of each sex, either emerging from irradiated pupae or irradiated as adults, were treated topically with LD50 and LD90 of each insecticide as mentioned before. In both experiments, three replicates, each of ten males and females, were used.

Statistical analysis

Mortality data were recorded 24 hours after treatment and results corrected [27]**.** The averages percentages of adult mortality were plotted against tested concentrations of each insecticide on a logarithmic probit paper. Toxicity lines were drawn and LD50 and LD90 were determined for each sex, separately. The data were subjected to statistical analysis [28]**.**

RESULTS AND DISCUSSION

Susceptibility of adults irradiated as pupae or as adults to malathion:

Results present in (Table 1) show that gamma irradiation applied to early pupal stage resulted in flies slightly high susceptible to malathion, as LD50 values were 0.008 µg/insect after irradiation of parental pupae as compared to 0.012 µg/insect for unirradiated control. The same trend of results was also noticed in the irradiated females. Thus, irradiating peach fruit fly adults at early pupal stage (2- days-old pupae) with 40Gy proved to be more susceptible to the insecticide malathion. These results indicate unpreferable release of sterile peach fruit fly irradiated as early pupae.

Table 1: Effect of irradiating the peach fruit fly pupae on the susceptibility of the emerged adults to malathion insecticide.

Treated stage	Type of treatment	Males				Females			
		LD50 (µg/fly)	TR	LD90 (µg/fly)	TR	LD50 (µg/fly)	TR	LD90 (µg/fly)	TR
Early pupae	Radiation + malathion	0.008	0.6	0.018	0.4	0.010	0.8	0.020	1.0
	Malathion	0.012	-	0.040	-	0.012	-	0.020	-
Late pupae	Radiation + malathion	0.010	0.8	0.020	0.5	0.040	3.3	0.080	4.0
	Malathion	0.012	-	0.040	-	0.012	-	0.020	-

- Irradiation dose of early pupae = 40 Gy
- Tolerance Ratio (TR)= LD 50 or LD 90 of irradiated stage / LD 50 or LD 90 of unirradiated stage
- Irradiation dose of late pupae = 90 Gy
- TR >1 the treated stage is more tolerant.
- TR <1 the treated stage is less tolerant.
- TR =1 No change in susceptibility to the insecticide.

On the other hand, females eclosed from irradiated late pupae exhibited high level of tolerance (more than 3.0 folds) than those eclosed from irradiated early pupae; where LD50 values were 0.040 and 0.010 µg/insect, respectively. Moreover, all tolerance ratios (TR) of adult males either irradiated as early or late pupae did not exceed the value of 1. This means that irradiated males became less tolerant to malathion than irradiated females.

Thus, peach fruit fly adults (especially females) pre-irradiated as pupae 2-days before eclosion with 90Gy were more tolerant to malathion and more preferable for releasing than adults pre- irradiated with 40Gy as 2-days old pupae. This result should be taken into consideration when using late pupal stage in the sterile male programs.

Gamma irradiation increased the susceptibility of *Spodoptera littoralis* adults previously irradiated as pupae to three insecticides methomyl, pyridaphenthion and fentrothion and irradiated females showed high increase in their susceptibility to insecticides than irradiated males [29].

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Table 2: Effect of irradiating the peach fruit fly adults on their susceptibility to malathion insecticide.

Treated stage	Type of treatment	Males				Females			
		LD50 (µg/fly)	TR	LD90 (µg/fly)	TR	LD50 (µg/fly)	TR	LD90 (µg/fly)	TR
2-days old adults	Malathion	0.012	-	0.040	-	0.012	-	0.020	0.0
	Radiation + malathion	0.006	0.5	0.020	0.5	0.012	1.0	0.020	1.0
6-days old adults	Malathion	0.010	-	0.020	-	0.008	-	0.020	-
	Radiation + malathion	0.016	1.6	0.060	3.00	0.040	5.0	0.16	8.0

- Irradiation dose = 90 Gy in each case.
- Tolerance Ratio (TR)= LD 50 or LD 90 of irradiated stage / LD 50 or LD 90 of unirradiated stage
- TR > 1the treated stage is more tolerant.
- TR < 1the treated stage is less tolerant.
- TR = 1 No change in susceptibility to the insecticide.

Table (2) shows that the irradiated 2-days old males exhibited relatively high sensitivity to malathion than unirradiated ones, where LD50 values were 0.006 and 0.012 µg/insect, respectively. Irradiated females also became more tolerant to malathion than irradiated males.

Pre irradiation of 6-days old adults with 90Gy induced various degrees of tolerance to malathion, irradiated males displayed more tolerance (1.6 times) than unirradiated ones; LD50 values were 0.016 and 0.010 µg/insect, respectively. The tolerance, however, was more pronounced (4.2 times) in the case of irradiated females as compared to unirradiated ones, where LD50 values were 0.040 and 0.008 µg/fly, respectively.

It seems that, irradiating both sexes of peach fruit fly using 90Gy increased their tolerance to the tested insecticides as compared to the control. These results are in agreement with aforementioned results concerning adults irradiated as pupae in which irradiated females were also more tolerant to malathion than irradiated males.

Thus, peach fruit fly adults (6-days old) irradiated with 90Gy were more tolerant to malathion than 2-days old adults and thus more preferred in control programs.

Susceptibility of adults previously irradiated as pupae or as adults to deltamethrin:

Table 3: Effect of irradiating the peach fruit fly pupae on susceptibility of the emerged adults to deltamethrin insecticide.

Treated stage	Type of treatment	Males				Females			
		LD50 (µg/fly)	TR	LD90 (µg/fly)	TR	LD50 (µg/fly)	TR	LD90 (µg/fly)	TR
Early pupae	Radiation + deltamethrin	0.020	1.4	0.140	3.5	0.020	1.2	0.082	2.1
	Deltamethrin	0.014	-	0.040	-	0.016	-	0.041	-
Late pupae	Radiation + deltamethrin	0.012	0.8	0.020	0.5	0.014	0.8	0.060	1.5
	Deltamethrin	0.014	-	0.040	-	0.016	-	0.040	-

- Irradiation dose of early pupae = 40 Gy
- Tolerance Ratio (TR)= LD 50 or LD 90 of irradiated stage / LD 50 or LD 90 of unirradiated stage
- Irradiation dose of late pupae = 90 Gy
- TR > 1the treated stage is more tolerant.
- TR < 1the treated stage is less tolerant.
- TR = 1 No change in susceptibility to the insecticide.

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Table (3) indicates the high tolerance of peach fruit fly males irradiated as 2-days old pupae, to deltamethrin, where the tolerance ratios were 1.4 and 3.5 at LD50 and LD90 levels, respectively, whereas they were 0.8 and 0.5 for males irradiated as pupae 2-days before emergence at the same level, respectively.

Similarly, females emerging from 2-days old pupae exhibited relatively high tolerance (TR= l.2 and 2.1 at LD50 and LD90, respectively) to deltamethrin as compared to females emerged from irradiated late pupae (2- days before emergence) which exhibited a slight degree of tolerance where TR= 0.8 and 1.5 at LD50 and LD90 levels, respectively.

Table 4: Effect of irradiating the peach fruit fly adults on their susceptibility to deltamethrin insecticide.

Treated stage	Type of treatment	Males				Females			
		LD50 (µg/fly)	TR	LD90 (µg/fly)	TR	LD50 (µg/fly)	TR	LD90 (µg/fly)	TR
2-days old adults	Deltamethrin	0.014	-	0.042	-	0.015	-	0.036	-
	Radiation + deltamethrin	0.008	0.5	0.023	0.5	0.012	0.8	0.024	0.6
6-days old adults	Deltamethrin	0.010	-	0.026	-	0.023	0	0.230	-
	Radiation + deltamethrin	0.006	0.6	0.021	0.8	0.011	0.4	0.043	0.1

- Irradiation dose = 90 Gy in each case.
- Tolerance Ratio (TR)= LD 50 or LD 90 of irradiated stage / LD 50 or LD 90 of unirradiated stage
- TR > 1 the treated stage is more tolerant.
- TR < 1 the treated stage is less tolerant.
- TR = 1 No change in susceptibility to the insecticide.

Table (4) shows the tolerance ratios of irradiated adults to deltamethrin. The data reveal that irradiated 2-and 6-days old adults exhibited high level of susceptibility to deltamethrin than unirradiated controls at the two tested levels.

In irradiated 2-days old adults, the degree of susceptibility of both males and females was nearly the same where tolerance ratio ranged from 0.5 to 0.8 at both LD50 and LD90, respectively. In irradiated 6-days old adults, tolerance ratios of irradiated males were 0.6 and 0.8 at LD50 and LD90 levels, respectively. The tolerance ratios reached to their lowest values in irradiated 6-days old females (TR = 0.4 and 0.1 at LD50 and LD90 levels, respectively). .

According to the previous results, deltamethrin is more promising in the peach fruit fly management programs when releasing sterile adults from irradiated early pupae, whereas releasing sterile adults irradiated directly or as late pupae has no value in this respect.

The susceptibility of irradiated insect to different insecticides was investigated on larvae and moths of codling moth *Laspeyresia pomonella* [30] and on the cotton leaf worm *Spodoptera littoralis* [31]. Combination studies carried on *Lucilia cuprina* suggested that the alternation in response may be due to an internal stimulus due to radiation which cannot be solely attributed to the loss of detoxification mechanism [19]. Similar to the present results insecticidal toxicity can be altered if insects are exposed to radiation prior to insecticidal treatment. The combined effect of gamma radiation and azadirachtin on the growth and development of *Spodoptera litura* was studied and it is concluded that azadirachtin feeding synergistically enhanced the adverse effect on growth and reproduction that reflects the combination of irradiation and azadirachtin treatment might be compatible for insect pest suppression and it could be increase the efficiency of F-1 sterility technique [24]. Alteration in the susceptibility of the tobacco caterpillar to thiocarb due to gamma radiation was recorded [25]. When newly molted sixth instar larvae were bioassayed with thiocarb LD50 of the insecticide was 6.76µg/g in the combined treatment as compared with 28.67 µg/g in the chemical treatment indicating that the toxicity of the insecticide was increased 4.24 times by the radiation treatment [25]. The effect of sub-lethal dose (0.08 KGy) of gamma radiation on susceptible adult of *Callosobruchus*

maculatus to fenvalerate and cypermethrin in laboratory was investigated [32]. LC50 values, 2 days after radiation, to fenvalerate and cypermethrin was recorded as 1.630 and 0.235 µg/cm2 respectively for non-irradiated adult and 0.811 and 0.242 µg/cm2 respectively for irradiated adults [32]. Increased susceptibility to malathion, methylbromide and duradin was also reported in irradiated *T. confusum*, and the dissimilarity of larval response to some insecticides may be due to the enzyme alterations, either quantitative or qualitative and are the key to these irradiation effects on toxicity of insecticides to insects [21].

Alteration in the responding of irradiated insect to insecticides may be due to the probable action of the radiation that alter somatic tissues to the extent of either (a) decreasing or increasing the efficiency of the cells which can detoxify pesticides or (b) modify the permeability, transportation or retention mechanism for the agent [33].

CONCLUSION

It could be concluded that peach fruit fly adults (especially females) pre-irradiated as pupae 2-days before eclosion with 90Gy were more tolerant to malathion and more preferable for releasing than adults pre-irradiated with 40Gy as 2-days old pupae. This result should be taken into consideration when using late pupal stage in the sterile male programs. While deltamethrin is more promising in the peach fruit fly management programs when releasing sterile adults from irradiated early pupae.

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