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Interaction of gamma radiation and deltamethrin on resistant and susceptible strain of *Trogoderma granarium*

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ABSTRACT

A study was conducted during 2006 on the interaction of gamma radiation and deltamethrin against susceptible and resistant strain of *Trogoderma granarium* (Everts). Two doses of radiation, i e 0.02 and 0.06 KGy were applied on susceptible as well as deltamethin-resistant strain of *T. granarium*. After radiation, insects were bioassayed with deltamethrin. The LC_{50} of deltamethrin for susceptible strain was 0.0249 % which was decreased to 0.0069 % when insects were irradiated at 0.02 KGy. As the treatment dose increased to 0.06 KGy the LC_{50} was further decreased to 0.0039% with susceptible strain. Similar to the susceptible strain the susceptibility of deltamethrin resistant strain was also increased to 2-fold against deltamethrin after radiation.

Key words: Deltamethrin, Radiation, Resistant, Susceptible, *Trogoderma granariun*

Post harvest losses by insect damage, microbial deterioration and other factors are estimated to be of 10.25% world wide (Mathews 1993), whereas annual losses of stored grains by insects are up to 9% of the world's grain production (GIFAP 1989).

Resistance in stored product insect has become an increasingly serious problem owing to increase in the number of resistant species against the most commonly used grain protectant, ie synthetic pyrethroids and rapid spread of these resistant strains of insect from one country to other through trade. Thus pesticide resistance is a widespread phenomenon in stored product insect, prominent among them being *Trogoderma granarium, Callosobruchus maculatus, Rhyzopertha dominica* and *Tribolium castaneum* to various insecticides and fumigants (Bhatia 1986, Srivastava *et al.* 2000, Kumar 2010). Introduction of synthetic pyrethroids, like deltamethrin, bifenthrin and cyfluthrin emerged as alternatives to organophosphates for better and longer residual toxicity along with helpful in combating resistance (Reddy *et al*. 2004). But again resistance to deltamethrin is being reported in field as well as in laboratory studies (Padhee *et al.* 2002, Lorini and Galley 1999).

Ionising radiations, though expensive initially is a possible alternative to chemical insecticides for control of such insects in stored grains as insecticide resistance is unrelated to radiation sensitivity. Presently, however, radiation sensitivity of only a few insecticide resistant strain of insect has been reported. If the insecticide resistance strain of insect is equally or more susceptible to radiation as their susceptible counterparts, then disinfestations of grains or other stored commodities by irradiation would be more economical where insect populations resistant to insecticides exist. 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 (Mehta *et al.* 2006, Sharma and Seth 2004 and Ramesh *et al*. 2002) to study the possible additive effects of treatments, their interaction and possible cost advantages by using various methods of insecticide application on the insect. Combination of deltamethrin and gamma radiation may be helpful in combating resistant strain wherever gamma radiation is available as a control method. The success of these combined treatments will depend upon the susceptibility of the pest population to radiation and post-radiation treatment and possible interaction of the treatment on the pest species.

MATERIALS AND METHODS

Two strains of *Trogoderma granarium*, one susceptible and the other laboratory selected resistant to deltamethrin were used. The susceptible strain was taken from laboratory culture which had not been exposed to insecticides earlier.

Based on a part of Ph D thesis of the first author submitted to IARI, New Delhi during 2006

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The deltamethrin-resistant strain (×3.656) was developed in the laboratory after 6 generations of selection (Kumar *et al*. 2010). The culture of Khapra beetle *Trogoderma granarium* (Everts) was mass multiplied on preconditioned (14% moisture content) on susceptible 'HD 2329' wheat, which was sterilized in an oven at 60°C for 2 hr prior to preconditioning to eliminate any possible presence of stored product insect eggs or their developmental stages. The culture of *T. granarium* throughout the study period was maintained at a constant temperature of 35 ± 1°C and 70 ± 5% relative humidity.

Larvae of susceptible and deltamethrin resistant strains were irradiated at various doses in a well type ^{60}cobalt gamma source (Gamma chamber, 5000, BRIT, BARC, Trombay) at a discharge rate of 2.8805 Gy/sec. at Nuclear Research Laboratory, IARI, New Delhi. Healthy active fourth instar larvae in batches of 60 were irradiated to 6 different doses, ie 0.02, 0.04, 0.06, 0.08, 0.10 and 0.12 KGy of gamma radiation. After irradiation 10 larvae from each treatment were transferred to plasic vials (7 cm × 5 cm) containing 50 sound healthy grains of 'HD 2329' in 3 replications. The control was also kept likewise without being treated with gamma radiation. Treated larvae were kept in culture room at 35 ± 1°C and 70 ± 5% relative humidity and the mortality of larvae and pupae was observed after every 3 days up to one month. The data were subjected to probit analysis to calculate LD_{50}.

Film residue method was adopted for bioassay test and 6 to 7 concentrations of deltamethrin emulsifiable concentrate was prepared in distilled water. Insecticidal films of different concentrations of various insecticides were prepared on the lower inner surface of petridishes (9 cm) by spraying 1.0 ml solution through Potter's tower at pressure 5lb/sq inches.The insecticide film on the Petri-dish was air dried. Ten healthy, freshly sieved fourth instar larvae (15– 20 days old) of *T. granarium* were released in each Petri-dish. The treated petridishes with insects were kept at a temperature of 35 ± 1°C and 70 ± 5% R.H. Control was kept with distilled water. After 24 hr of exposure period mortality was recorded. Moribund insects were considered as dead. The insects, which could move away by probing with camel's hair brush, were taken as alive.

The sensitivity of deltamethrin resistant and susceptible strains to gamma radiation was tested by comparing the LD_{50} values determined by procedure described above. The interaction of gamma radiation and deltamethrin treatment in the susceptible and resistant strain was studied.

The interaction effect of gamma radiation and deltamethrin against susceptible and deltamethrin resistant strain was studied using the insecticidal bioassay method described earlier. Active fourth instar larvae of both susceptible and deltamethrin resistant strains were exposed to gamma radiation dose of 0.02 and 0.06 KGy and then treated with 6 to 7 different concentrations of deltamethrin after one day of irradiation. These two doses of gamma radiation were chosen based on gamma radiation bioassay studies. The lower dose of 0.02 KGy was chosen because it is a sub-lethal dose, but this was not effective against *T. granarium* in terms of arresting further progeny development. So the higher dose of gamma radiation 0.06 KGy, which was close to LD_{50} was also chosen for deltamethrin interaction studies. Observations on mortality were recorded after 24 hr of exposure to insecticides.

Each treatment was replicated thrice with 10 larvae/ replication and irradiated larvae without deltamethrin exposure were kept as control. The effect of gamma radiation to deltamethrin susceptibility of both susceptible and deltamethrin resistant strain was expressed in terms of LC_{50} in comparison with deltamethrin alone in both the strains bioassayed earlier.

RESULTS AND DISCUSSION

The LC_{50} values of deltamethrin against susceptible and deltamethrin-resistant strain of *T.granarium* were 0.025 and 0.091 % respectively showing ×3.656 resistance developed through selection pressure in 6 generations. Susceptible and deltamethrin-resistant strain of *T. granarium* were irradiated with 6 different doses of gamma radiation and results showed (Table 1) that LD_{50} value for susceptible strain was 0.070 KGy and for deltamethrin resistant strain it was 0.079 KGy. Similarly, at LD99 level, value was 0.330 KGy and 0.429 KGy with susceptible and resistant strain, respectively. Thus, selection with deltamethrin does not involve any change in susceptibility to gamma radiation with respective to treatment dose.

Perusal of literature showed that there is no report on the

Table 1 Susceptibility of fourth instar larvae of *T. granarium* (susceptible and deltamethrin-resistant strain) to gamma radiation

Strain	Heterogeneity		Regression equation	LD_{50} fiducial limits (KGy)	R/r	LD_{99} fiducial limits (KGy)	R/r
	df	χ^2					
Susceptible	4	6.01	4.104+3.699×	0.077 (0.068–0.091)	1.00	0.331 0.229–0.648	1.00
Resistant	4	8.47	3.489+3.166×	0.079 0.034–0.936	1.03	0.429 0.171–3.452	1.29

R/r- Resistance ratio

effect of gamma radiation against deltamethrin resistant strain of *T. granarium*. However, there are some reports on the susceptibility of contact and fumigant resistant storage insects to gamma radiation. Misra (1995) also found that fenvalerate resistant strain of *T. castaneum* did not show any change in susceptibility to gamma radiation.

To study the gamma radiation interaction with deltamethrin, two doses of radiation, ie 0.02 and 0.06 KGy were applied on susceptible as well as deltamethin resistant strain of *T. granarium*. After the treatment with radiation, the survived insects were allowed to live for 24 hr and then bioassayed with deltamethrin, and LC_{50} was calculated. These lethal doses of both susceptible and resistant strain of *T. granarium* after radiation were compared with lethal doses of unirradiated strains. Results showed (Table 2), that lethal doses of deltamethrin was decreased at both LC_{50} and LC_{99} levels as the radiation was given in the susceptible strain. The LC_{50} of deltamethrin for susceptible strain was 0.0249% which was decreased to 0.0069% when insects were irradiated at 0.02 KGy. As the treatment dose increased to 0.06 KGy the LC_{50} was further decreased to 0.0039% with susceptible strain. The pattern of increase in deltamethrin susceptibility against irradiated insect was also evident at LC_{99} level. Thus, the results showed that irradiation provides good protection and the susceptibility for deltamethrin was further increased

Similar to the susceptible strain the susceptibility of deltamethrin resistant strain was also increased to × 2 against deltamethrin when the radiation was given at 0.02 KGy. But the increase in susceptibility was not so sharp at LC_{99} level with resistant strain. At both the doses of radiation treatment, the LC_{50} for deltamethrin was more or less similar, ie 0.045 and 0.041 %. There are no reports on the effect of gamma radiation on the susceptibility of deltamethrin to larvae of *T. granarium*. Earlier Cogburn and Speirs (1972) conducted laboratory test on the toxicity of topically applied malathion and its residue to the adult of *T. castaneum* some of which have been earlier exposed to gamma radiation. They observed that radiation at 0.1 KGy following topical application of malathion was more lethal to malathion than either treatment alone.

In the present study, when larvae of deltamethrin resistant strain were irradiated with 0.02 KGy, LC_{50} and LC_{99} value of deltamethrin were 0.045% and 0.0127% whereas the value for non-irradiated insect was 0.091% and 0.144% respectively. Further, when radiation dose was increased to 0.06 KGy, although LC_{50} value was lower in comparison to non-irradiated larvae, it was more or less similar to the LC_{50} value of 0.02 KGy irradiation. With the susceptible strain, when the radiation dose was increased and larvae were bioassayed with deltamethrin, the lethal dose was decreased as compared to the larvae treated with lower doses of radiation, but with the resistant strain variation in the doses of radiation did not show effect on lethal dose of deltamethrin although it was lower than non-irradiated larvae.

Similar to the present results Sharma and Seth (2005) reported that insecticidal toxicity can be altered if insects are exposed to radiation prior to insecticidal treatment. They studied the combined effect of gamma radiation and azadirachtin on the growth and development of *Spodoptera litura* and 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. Increased susceptibility was also reported by Ramesh *et al*. (2002) who studied that interaction of substerilizing gamma radiation and thiodocarb treatment for the management of the tobacco caterpillar *S. litura*. They reported that when newly molted sixth instar larvae were

Table 2 Gamma radiation interaction with deltamethrin against susceptible and deltamethrin-resistant strains of *T. granarium*

Strain	Heterogeneity		Regression equation	LD_{50} fiducial limits (KGy)	R/r	LD_{99} fiducial limits (KGy)	R/r
	df	χ^2					
Susceptible	6	2.310	6.933+4.321x	0.025 (0.012–0.028)		0.086 (0.067–0.133)	
Susceptible+ 0.02 K Gy	5	0.553	5.842+2.704x	0.007 (0.005–0.009)	3.61	0.050 (0.035–0.092)	1.71
Susceptible+ 0.06 K Gy	5	2.579	7.191+2.991x	0.004 (0.002–0.005)	6.38	0.024 (0.017–0.048)	3.64
Resistant	7	2.023	12.014+11.583x	0.091 (0.087–0.094)		0.145 (0.132–0.168)	
Resistant + 0.02 K Gy	6	1.936	6.914+5.136x	0.045 (0.038–0.050)	2.02	0.128 (0.103–0.198)	1.13
Resistant+ 0.06 K Gy	6	3.511	6.341+4.551x	0.040 (0.031–0.046)	2.25	0.131 (0.102–0.230)	1.10

S/r -, Susceptibility ratio

bioassayed with thiodicarb LD_{50} 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. El-Sayed *et al.* (1988) also investigated the effect of sub-lethal dose (0.08 KGy) of gamma radiation on susceptible adult of *Callosobruchus maculatus* to fenvalerate and cypermethrin in laboratory. LC_{50} values, 2 days after radiation, to fenvalerate and cypermethrin was recorded as 1.630 and 0.235 µg/cm^2 respectively for non-irradiated adult and 0.8110 and 0.242 µg/cm^2 respectively for irradiated adults. Increased susceptibility was also reported by Abdel-Salem *et al.* (1992) in irradiated *T. confusum* with malathion, methylbromide and duradin treatments, respectively who speculated that 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.

The results of interaction of gamma radiation and deltamethrin treatment in the present investigation revealed that mortality due to insecticide was increased after radiation treatment and it was different in both susceptible and resistant strains of *T. granarium.* Response due to the increase of radiation doses were also diffusing in two strains which 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.

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