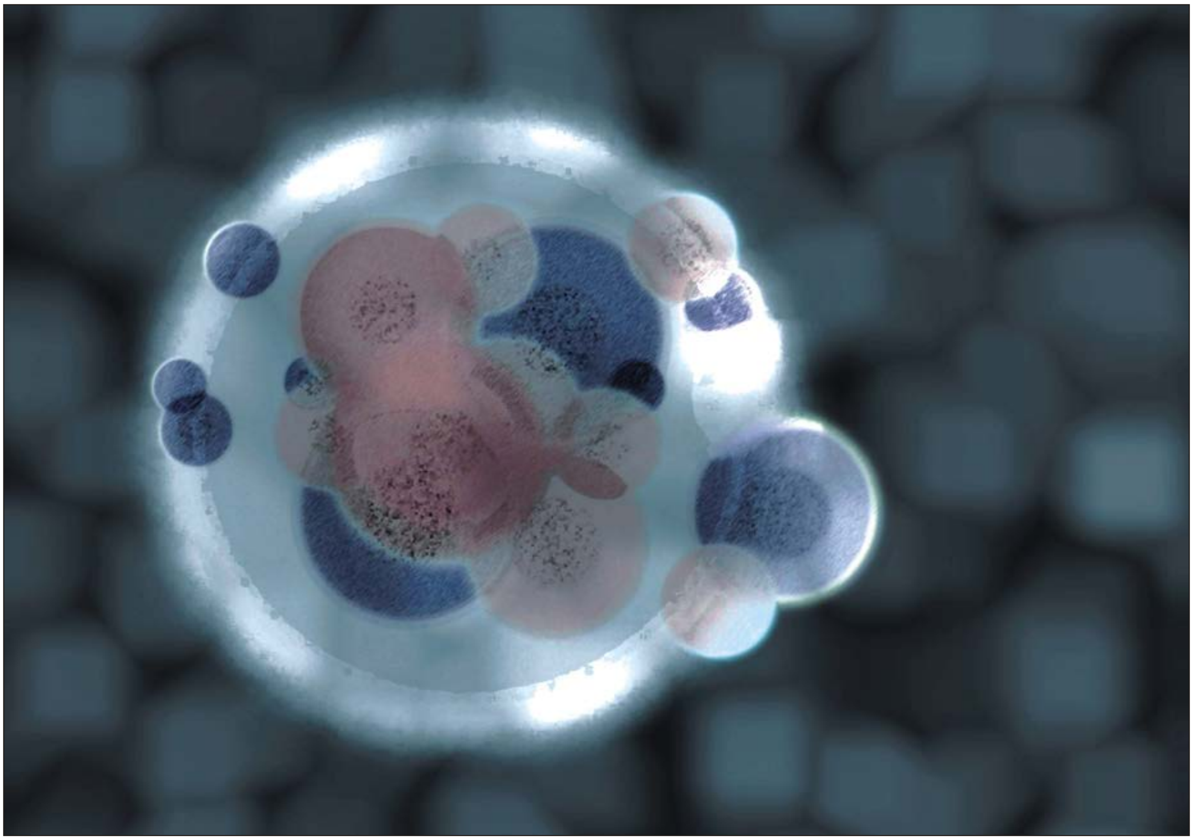

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Effect of Insecticide on the Irradiated Tropical Warehouse Moth, *Cadra cautella* (Walker) (Lepidoptera:Phycitidae)

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Abstract: The effects of the synthetic pyrethroid, Fenom® on the gamma-irradiated Tropical Warehouse Moth, *Cadra cautella* (Walker) (Lepidoptera:Phycitidae) larvae have been studied. Both the insecticide and gamma irradiation either singly or in combination, significantly increased larval mortality and developmental periods. The pupation and adult eclosion, reproductive potential and longevity of the adults from treated larvae were significantly decreased.

Key words: *Cadra cautella*, pyrethroid, gamma irradiation, mortality, pupation, adult eclosion, development, reproductive potential, longevity

INTRODUCTION

Integrated pest management has received much recent attention. Irradiation becomes an established technique for controlling stored grain insects because of incomplete protection obtained with insecticides[1,2] and retention of the quality and nutritive value of the products would be additional benefits of radiation technology[3]. The effects of a combination of gamma radiation with insecticides on pest species have been reported by Cogburn and Gillenwater[4], Cogburn and Speirs[5], Moffit and White[6], Moustafa and Abdel-Salam[7]. The Tropical Warehouse Moth, *Cadra cautella* (Walker) (Lepidoptera:Phycitidae) is a major pest of several storage commodities throughout the tropical and subtropical parts of the world. Pyrethroids have quick knock-down effects, longer persistence and a greater safety to mammals, parasites and predators[8-10]. Moreover, the chances of environmental pollution is very low and they are very much effective at lower dosages.

The present investigation reports the effects of the pyrethroid, Fenom® and gamma irradiation, when applied singly or jointly, on some biological parameters of *C. cautella*.

MATERIALS AND METHODS

C. cautella larvae from laboratory cultures, maintained at the Insect Research Laboratory, Institute of Biological Sciences, University of Rajshahi, were exposed to gamma-radiation with a dose rate of 1 kr min^{-1}. The source of radiation was 50000 Curie Co^{60} irradiator installed at the Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh. Irradiated larvae were then subjected to synthetic pyrethroid, Fenom®-treated groundnut kernels up to pupation. Fenom® has been formulated and supplied by CIBA-GEIGY (Agrochemical Division) (Now NOVARTIS), Bangladesh Ltd. It has a low mammalian toxicity and is both a contact and a stomach poison. The chemical component of Fenom® is (R,S)-α-cyano-3-phenoxybenzil (R, S)-cis,"trans"3-(2, 2-dichlorovenyl) 2, 2-dimethyl cyclopropane-carboxylate.

The experiment was set up into two groups: the first group comprised variable radiation doses with a single constant insecticide dose and the second group was with variable insecticide doses with a single constant radiation dose. Three replications were made for each treatment with 30 larvae each. A similar batch of non-irradiated controls was identically raised on untreated groundnut kernels for each set of experiments. Larval mortality was assessed at 24-72 h postexposure and up to pupation, which was corrected by Abbott's[11] formula.

The classification of synergism and antagonism was made according to Benz[12]. The expected values for mortalities from various treatments were calculated following the formula of independent synergism where two components act independently and do not interfere with each other as Geervliet *et al.*[13]:

$$M_E = M_I + M_R (1 - M_I/100)$$

where, M_E= expected mortality percentage, M_I = mortality caused by insecticide and M_R= mortality caused by radiation.

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Results from χ^2 tests were compared with the tabulated χ^2 values (df=1, p=0.05). If the calculated χ^2 value was less than the tabular value, mortalities for the radiation-insecticide combinations were within the range expected, called additive effect. When the calculated χ^2 values exceeded the tabular values, mortalities in combined treatments were significantly different from the expected mortality and a synergistic or antagonistic effect was suspected[14].

Larvae were checked regularly approximately at 12 h intervals for pupation while noting the larval period. After pupation the insects were sexed and kept in separate beakers for adult eclosion. The number of adults that emerged from various treatments was recorded for computing the pupal period. The pupal and adult recoveries (%) were also noted and analyzed by computing standardized normal deviate values (d) for determining the differences in parameters having binomial distribution. Data on the developmental periods were analyzed following Duncan's Multiple Range Test[15]. All the experiments were conducted in an incubator at 29±1°C.

Freshly emerged moths of the opposite sexes were allowed to mate and the females were observed for oviposition. The number of eggs laid was counted for each pair. The Percentage Reproduction Control (PRC) was calculated using the formula of Rizvi *et al.*[16] as:

$$PRC = (V_1 - V_2)/V_1 \times 100,$$

where, V_1= eggs laid by untreated females and V_2= eggs laid by treated females. Eggs were kept in Petridishes for observing their viability. The relative index (RI) for egg-viability was calculated using the formula:

$$RI = (\bar{X}_1 - \bar{X}_2)/\bar{X}_1 \times 100,$$

where, $\bar{X}_1$ = mean viability of eggs from untreated females and $\bar{X}_2$ = mean viability of eggs from treated females. The longevity of mated moths was carefully observed twice a day at 12 h intervals and the data were analyzed following Duncan's Multiple Range Test[15]. The experiments were conducted at a mean room temperature of 25±1°C and a mean room humidity of 82±4%. The photoperiod was maintained at 12 h a day using a 40W tube light during the rearing period.

RESULTS AND DISCUSSION

Effect on larval mortality: The results on the combined effect of gamma radiation and Fenom® on the larval mortality of *C. cautella* are shown in Table 1. The χ^2-test showed that only the highest doses of radiation and insecticide produced synergistic effects when applied with lower doses of either insecticide or radiation. It was found that both gamma rays and Fenom®-treatment in combinations were more effective than the separate treatments when exposure was done up to pupation.

Moustafa and Abdel-Salam[7] reported that the integration of gamma rays with chlorpyrifos, cyanophos, deltamethrin and cyfluthrin increased the susceptibility of *Spodoptera littoralis* (Boisd.) F_1 larvae to all the tested insecticides. Similarly, Rush and Ware[17] recorded an increased susceptibility to azinphosmethyl in the pink bollworm, *Pectiniphora gossypiella* (Saunders) adults that emerged from gamma irradiated pupae. Abdel-Salam *et al.*[18] irradiated the red flour beetle, *Tribolium castaneum* (Herbst) pupae with gamma rays before 1-day and 2-days of eclosion and noted that irradiation significantly decreased the tolerance of adults to duradin. Moffitt and White[6], on the other hand, observed no effect on the susceptibility to insecticides after irradiation. They observed that the codling moth, *Laspeyresia pomonella* (L.) were equally susceptible to azinphosmethyl, carbaryl and DDT, whether irradiated or not. It has been reported that gamma irradiated *T. castaneum* adults showed an increased tolerance to lindane, DDT and malathion[19].

The present results on the mortality showed that all combinations of gamma rays and Fenom® were more effective for the control of *C. cautella* than the application of either radiation or insecticide alone. Discussing the combined effects, Georghiou[20] pointed out that radiation may alter the somatic tissues to the extent of either (a) decreasing or increasing the efficiency of cells which can detoxify pesticides or (b) modify the permeability, transportation or retention mechanism for the agent. But Erdman[21] mentioned that the exact cause(s) of death from irradiation remains unknown because the nuclear and cytoplasmic effects are difficult to differentiate. According to O'Brien[22], pyrethroids may also affect sodium and potassium permeability of insects cells and nitrogen metabolism. However, pyrethroids affect the peripheral and central nervous systems causing rapid paralysis and eventually death.

Effect on the formation and duration of various developmental stages: It has been noted that all the doses of gamma rays, Fenom® and gamma rays-Fenom® combinations appreciably reduced pupation and adult eclosion in the insect as compared to the untreated controls (Table 2). This reduction increased as the doses were increased. In both the group of experiments the

Table 1: Potency of various combinations of γ-radiation and Fenom® against *C. cautella* larvae

Treatment schedule	Duration of exposure	Fenom® doses (ppm)	γ-ray (kr)	Fenom® mortality (%) (M_I)	γ-ray mortality (%)(M_R)	Expected mortality (%)(M_E)	Combined mortality (%) (O_C)	χ^2-value	Effect
		10	0.5	9.09	6.82	15.29	17.05	0.20	Additive
	24 h[a]	10	1.0	10.23	9.09	18.39	21.59	0.56	Additive
		10	1.5	11.36	12.50	22.44	26.14	0.61	Additive
		10	2.0	10.23	13.64	22.47	31.82	3.89	Synergistic
A.		10	0.5	17.64	10.59	26.36	31.77	1.11	Additive
	72 h[b]	10	1.0	17.64	14.11	29.26	37.64	2.40	Additive
		10	1.5	18.82	19.99	35.05	45.88	3.35	Additive
		10	2.0	17.64	25.88	38.95	51.76	4.21	Synergistic
	Up to	10	0.5	27.16	25.63	48.74	58.02	1.77	Additive
	Pupation[c]	10	1.0	27.16	35.80	53.24	65.43	2.79	Additive
		10	1.5	25.92	44.44	58.84	74.08	3.95	Synergistic
		10	2.0	27.16	55.56	67.63	82.71	3.36	Additive
		10	1.0	10.23	7.96	17.38	20.45	0.54	Additive
	24 h[a]	20	1.0	15.91	7.96	22.60	27.28	0.97	Additive
		40	1.0	20.45	9.09	27.68	31.82	0.62	Additive
		80	1.0	26.14	9.09	32.85	38.64	1.02	Additive
B.		10	1.0	18.82	14.11	30.27	36.47	1.27	Additive
	72 h[b]	20	1.0	30.58	14.11	40.38	50.58	2.58	Additive
		40	1.0	38.82	15.29	48.17	57.65	1.87	Additive
		80	1.0	48.23	14.11	55.53	71.76	4.74	Synergistic
	Up to	10	1.0	28.40	33.33	52.26	70.37	6.28	Synergistic
	Pupation[c]	20	1.0	38.27	34.57	59.61	77.08	5.12	Synergistic
		40	1.0	45.68	34.57	64.46	88.89	9.26	Synergistic
		80	1.0	58.02	34.57	72.53	93.82	6.25	Synergistic

A = Insecticide dose constant, B = Radiation dose constant; [a-c] Control mortalities 2.22, 5.56 and 10.00%, respectively

Table 2: Effect of γ-radiation-Fenom® treatments on the formation of pupae and adults in *C. cautella*

Treatment schedule	Fenom® doses (ppm)	γ doses (kr)	No. of insect used	Pupal recovery (%)				Adult recovery (%)			
				Fenom® recovery	γ recovery	Combined recovery	*d-value	Fenom® recovery	γ recovery	Combined recovery	*d-value
	10	0.5	90	65.56	63.33	37.78	8.70	63.33	60.00	33.33	8.37
A.	10	1.0	90	65.56	57.78	31.11	10.10	61.11	54.44	27.78	9.63
	10	1.5	90	66.67	50.00	23.33	12.17	61.11	44.44	21.11	11.23
	10	2.0	90	65.56	40.00	15.56	14.89	62.22	35.56	13.33	13.89
	O (Control)		90		90.00				85.56		
	10	1	90	64.44	60.00	26.67	11.19	60.00	55.56	23.33	10.67
B.	20	1	90	55.56	58.89	20.00	13.23	50.00	53.33	16.67	12.78
	40	1	90	48.89	58.89	10.00	17.90	43.33	53.33	7.78	16.58
	80	1	90	37.78	58.89	5.56	21.11	32.22	54.44	—	—
	O (Control)		90		90.00				85.56		

A = Insecticide dose constant, B = Radiation dose constant; *d = Standardized normal deviate

lowest number of progeny was obtained by radiation-insecticide combinations than by the application of either of the agents. It was also recorded that the effect was more pronounced when the insecticide doses were varied. It has been noted that no adults emerged from the highest dose combination, i.e. 80 ppm Fenom®+1.0 kr gamma rays. Some of the adults that emerged from treated larvae, had deformed wings and legs and were unable to mate. Similar reduction in adult emergence has been reported in the Indian meal moth, *Plodia interpunctella* Hübner due to gamma irradiation[23]. Kumar *et al.*[24], Hasan and Khan[25] also recorded a significant reduction in adult emergence from gamma-irradiated pupae of the Uzi fly, *Exorista sorbillans* Weidmann.

All the treatments excepting 10 and 20 ppm Fenom® significantly lengthened the larval and pupal durations ($p<0.01$) in comparison to untreated controls (Table 3). It was also observed that developmental periods were lengthened as the doses were increased. Significantly increased developmental periods were recorded when 1st, 3rd and final instar larvae of the rice moth, *Sitotroga cerealella* (Oliver) were subjected to gamma radiation at 10, 12 and 14 kr[26]. Similarly, Prasad and Sethi[27] observed significantly delayed development in the fruitfly, *Dacus dorsalis* Hendel when 3rd instar maggots and late pupae were irradiated with gamma rays.

Effect on reproductive potential: It was recorded that treatments significantly reduced the number of eggs laid by the females emerging from treated larvae ($F = 6.54$ and $F = 39.46$, $p<0.001$, respectively for constant insecticide and radiation doses) (Table 4). The egg-viability was also reduced significantly due to irradiation and insecticide treatments ($F = 5.65$, $p<0.001$ for constant insecticide dose

Table 3: Effect of γ-radiation-Fenom® treatments on the developmental periods of *C. cautella* (days)

Treatment schedule	Doses	Larval period Mean±SD	Pupal period Mean±SD
	O (Control)	27.65±4.48a (81)	8.21±2.04a (77)
	γ-ray (kr) 0.5	29.61±4.94bc (57)	9.17±2.70bc (54)
	Fenom®(ppm) 10	28.63±4.98ab (59)	8.63±2.25ab (57)
	γ-ray+Fenom® 0.5+10	30.09±5.23b-d (34)	9.73±2.26cd (30)
A.	1.0	30.48±5.27b-d (52)	10.10±2.15de (49)
	10	28.78±4.40ab (59)	8.64±2.23ab (55)
	1.0+10	31.14±5.28c-e (28)	10.36±2.02de (25)
	1.5	31.73±4.16d-e (45)	10.60±2.25e (40)
	10	28.93±4.28ab (60)	8.80±2.94ab (55)
	1.5+10	32.57±6.11e-g (21)	10.74±2.73e (19)
	2.0	33.14±5.01fg (36)	11.75±2.78f (32)
	10	28.52±4.80ab (59)	8.77±2.25ab (56)
	2.0+10	33.79±5.66g (14)	12.08±2.84f (12)
	O (Control)	27.28±4.50a (81)	8.26±1.92a (77)
	Fenom®(ppm) 10	28.76±4.74ab (58)	8.69±2.25a (54)
	γ-ray (kr) 1.0	30.57±5.29b-d (54)	10.06±2.27c (50)
	Fenom® +γ-ray 10+1.0	31.71±5.87c-e (24)	10.38±1.96cd (21)
B.	20	30.26±5.09a-c (50)	9.22±2.49b (45)
	1.0	30.60±5.90b-d (53)	9.98±2.37c (48)
	20+1.0	32.72±5.10c-e (18)	10.73±2.12de (15)
	40	32.45±4.78c-e (44)	10.15±1.87c (39)
	1.0	30.75±6.04b-d (53)	10.04±2.30c (48)
	40+1.0	33.22±4.71de (9)	11.00±2.24c (7)
	80	34.06±4.90e (34)	10.48±1.99cd (29)
	1.0	30.58±5.27b-d (53)	9.94±1.88c (49)
	80+1.0	34.33±4.73e (5)	—

A = Insecticide dose constant, B = Radiation dose constant; Means followed by the same letter(s) within each parameter of each treatment schedule are not significantly different at p<0.01 (DMRT); Figures in parentheses indicate number of observation

Table 4: Effect of γ-radiation-Fenom® treatments on the fecundity and egg-viability in *C. cautella* females resulting from treated larvae

Treatment schedule	Doses	Fecundity Mean±SD	Fecundity PRC	Egg-viability (%) Mean±SD	Egg-viability (%) RI
	O (Control)	221.27±43.12 (15)	—	97.01±1.79	—
	γ-ray (kr) 0.5	173.27±27.48 (15)	21.69	87.79±6.67	9.50
	Fenom® (ppm) 10	182.53±24.36 (15	17.51	91.98±3.56	5.19
	γ-ray+Fenom® 0.5+10	166.64±32.44 (11)	24.69	83.65±4.66	13.77
	1.0	155.60±29.02 (15)	29.68	80.95±7.66	16.55
A.	10	180.27±21.17 (15)	18.53	92.13±4.05	5.03
	1.0+10	142.33±38.99 (9)	35.68	77.71±6.08	19.89
	1.5	133.07±37.01 (15)	39.86	71.70±7.14	26.09
	10	183.47±22.90 (15)	17.08	91.97±3.88	5.20
	1.5+10	125.17±37.11 (6)	43.43	69.62±3.69	28.23
	2.0	122.80±31.90 (15)	44.50	64.33±5.87	33.69
	10	182.80±23.98 (15)	17.39	91.63±4.55	5.55
	2.0+10	118.00±33.29 (3)	46.67	62.90±4.65	35.16
	O (Control)	218.53±34.85 (15)	—	96.94±2.03	—
	Fenom® (ppm) 10	184.40±15.99 (15)	15.62	92.69±3.57	4.38
	γ-ray (kr) 1.0	151.93±34.47 (15)	30.76	80.97±6.68	16.47
	Fenom®+γ-ray 10+1.0	143.25±34.17 (8)	34.45	78.26±5.74	19.27
	20	174.80±25.82 (15)	20.01	87.70±4.42	9.53
B.	1	156.00±27.80 (14)	28.61	81.03±5.98	16.41
	20+1.0	140.40±36.37 (5)	35.75	71.44±7.04	26.30
	40	158.70±20.21 (14)	27.38	81.62±5.13	15.82
	1	152.47±34.50 (15)	30.23	80.79±6.43	16.66
	40+1.0	—	—	—	—
	80	148.30±34.63 (10)	32.14	76.21±5.33	21.38
	1	154.86±28.48 (14)	29.14	81.13±6.59	16.31
	80+1.0	—	—	—	—

A = Insecticide dose constant; B = Radiation dose constant, PRC = Percent Reproduction Control; RI = Relative Index, Figures in parentheses indicate number of ovipositing females

and F= 175.96, p<0.001 for constant irradiation dose) (Table 4). It was noted that oviposition was highly reduced at radiation-insecticide combinations and at increasing doses of the control agents. A similar trend was also found in case of egg-viability. No progeny was produced at 40 ppm+1.0 kr and 80 ppm+1.0 kr.

Table 5: Effect of γ-radiations-Fenom® treatment on the longevity (days) of *C. cautella* adults emerging from treated larvae (N=15)

Doses	Mean±SD	Doses	Mean±SD
O (Control)	9.20±3.21a	O (Control)	9.27±3.73a
γ-ray (kr) 0.5	9.13±2.82a	Fenom® (ppm) 10	8.73±2.49bc
Fenom® (ppm) 10	8.73±2.12b	γ-ray (kr) 1.0	8.80±2.40b
γ-ray+Fenom®0.5+10	8.80±3.00b	Fenom®γ-ray 10+1.0	8.53±2.29d
1.0	8.73±2.28b	20	8.67±3.37c
10	8.73±2.94b	1.0	8.73±3.26bc
1.0+10	8.60±3.16c	20+1.0	8.33±1.99e
1.5	8.53±2.64c	40	8.27±2.12e
10	8.80±2.86b	1.0	8.87±2.10b
1.5+10	8.20±1.90d	40+1.0	8.13±2.03f
2.0	8.20±2.81d	80	7.80±2.51g
10	8.87±2.10b	1.0	8.80±2.51b
2.0+10	*8.00±2.00e	80+1.0	-

Means followed by the same latter within each column are not significantly different at p<0.01 (DMRT); *Mean longevity of 10 adults

The present results are similar with those reported by Brower and Tilton[28]. They stated that the egg production was greatly reduced or eliminated by 10 kr gamma ray treatment in the beetles, *T. castaneum* and *Oryzaephilus surinamensis* (L.) and they observed no offspring production at the higher dose. Hasan *et al.*[29] also recorded a significant decline in the fecundity and fertility of *E. sorbillans* females from UV-irradiated pupae. Similar reduction in fecundity has also been reported in irradiated *E. sorbillans*[24]. Egg production was significantly reduced in *Chrysoperla carnea* (Stephens) females when the adults were exposed to permethrin or fenvalerate and the effect was increased with increasing concentrations[30]. North[31] claimed that in moth, the percentage of egg-hatch decrease in fertilized eggs that apparently results from a dose-dependent induction of dominant lethal mutations in the mature spermatozoa or oocytes. The present investigation indicates that all irradiation-insecticide combinations had detrimental effects on the reproductive potential of *C. cautella* which seems to be very much promising in reducing the population of insect pests in stored commodities.

Effect on adult longevity: All the treatments of gamma rays and Fenom® (either singly or in combination) except 0.5 kr gamma rays, significantly shortened the longevity of *C. cautella* adults in comparison to controls ($p<0.01$) (Table 5). The greatest reduction in longevity of moths was observed at radiation-insecticide combinations. The present results showed that combinations of low doses of gamma rays and Fenom® were very much effective in reducing the adult longevity of *C. cautella*.

Reimann and Flint[32] stated that in certain adult insects the midgut epithelium is renewed periodically, but since radiation and some chemosterilants inhibit mitosis the degenerated cells can not be replaced. This lead to an early death in the adult. The genetic make up of the irradiated insects appears to influence their life-span. In irradiated *Drosophila*, it was attributed to the induction of inoperable chromosomal breaks[33]. A theory of radiation-induced shortening of the lifespan based on the loss of cellular function has been suggested by Gartner[34].

A perusal of the results obtained in the present investigation clearly demonstrates that irradiation-insecticide doses produced significantly higher effects on the pest than the single application of the agents. This is expected to lower the use of chemical pesticides. Gamma ray-pyrethroid combinations are expected to be utilized in pest management programmes, including *C. cautella*. However, future experiments with the effects of several irradiation-insecticide combinations on the pests need to be elucidated.

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