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Effects of Gamma Radiation on Mature Pupae of the Cotton Bollworm, *Helicoverpa armigera* (HÜBNER) and Their F_1 Progeny

Prapon Pransopon[1] **Manon Sutantawong**[1] **Praparat Hormchan**[2]
and Arunee Wongpiyasatid[3]

ABSTRACT

Mature male pupae of cotton bollworm, *Helicoverpa armigera*, from laboratory culture were irradiated at 0, 50, 100, 150 and 200 Gy with dose rate of 33.6 Gy/min in ^{60}Co gamma irradiator. The results were found to have 99.17, 97.50, 98.75, 97.92 and 99.06% moth emergence, 1.56, 3.54, 2.91, 5.39 and 8.33% moth deformation, 13.35, 10.20, 9.45, 11.65 and 11.10 days longevity of P_1 moths, 27.04, 30.49, 33.12, 48.84 and 62.73% sterility of P_1 moths respectively.

Effects of radiation on F_1 progeny showed that survival of the immature stages of F_1 progeny significantly decreased with increasing doses irradiated to P_1 male and the sex ratio of the F_1 progeny was significantly skewed in favor of males. Longevity of F_1 male moths from male parents irradiated as mature pupae at 0, 50, 100, 150 and 200 Gy were 29.00, 26.13, 24.90, 26.35 and 22.55 days while those of F_1 female moths were 17.60, 18.00, 17.55, 17.15 and 17.19 days respectively. Fecundity of F_1 female moths was not significantly different but the sterility of F_1 progeny was significantly different compared with untreated moths. The sterility of F_1 male moths were 26.17, 52.77, 92.1, 96.84, 100.00% while those of F_1 female moths were 26.17, 52.75, 84.76, 98.91 and 100.00% respectively.

Key words : *Helicoverpa armigera*, gamma radiation

INTRODUCTION

The cotton bollworm, *Helicoverpa armigera*, is a well known and serious key pest of economically important crops. Insecticide resistance and the mounting concern over pesticide pollution have encouraged scientists to seek new methods of control for the cotton bollworm.

Knipling (1970) first demonstrated the potential advantage of the inherited sterility over the sterile insect technique (SIT) through the use of population models. North and Holt (1969) induced inherited sterility in the cabbage loopers, *Trichoplusia ni*, by irradiating males with 200 Gy of gamma radiation and mating them with normal females. They concluded the result to be the ideal candidate for the use of inherited sterility for population suppression. Carpenter *et al*.(1987) studied the effects of substerilizing doses of radiation and inherited sterility on the corn earworm

1 Biological Science Division, Office of Atomic Energy for Peace, Bangkok 10900, Thailand.
2 Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
3 Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand.

reproduction. Their findings supported earlier conclusion. Henneberry and Clayton(1988) reported that radiation exposure of old pink bollworm pupae with 0 to 150 of gamma radiation resulted high incidence of moth deformity. The sterility of F_1 moths was higher than P_1 moths, and F_1 sex ratio skewed in favor of males.

The objective was to study effects of gamma radiation on mature pupae of the cotton bollworm, *Helicoverpa armigera*, and their F_1 progeny in terms of morphology as well as physiology.

MATERIALS AND METHODS

The cotton bollworms used in this study were reared on artificial diets. The various biological parameters were recorded from laboratory rearing at 27±2°C, 70±10% relative humidity (RH) and 10:14 (light:dark) photoperiod.

Mature male pupae (9±1 days) from the laboratory culture were irradiated at 50,100,150 and 200 Gy with dose rate of 33.6 Gy/min in a ^{60}Co gamma irradiator (Gamma Beam 650). The similar group of pupae was held as a control. Treated and untreated pupae were held in the same conditions described above. Data on moth emergence, moth deformation and longevity were recorded.

Production of parents

The sterility of parent moths was recorded from the following crosses of each radiation dose:

a) UTF × UTM (control)
b) UTF × TM

Where UT, T, M and F stand for untreated, treated, male and female, respectively. Each treatment was replicated using oviposition cages with five pairs of moth per cage per replication.

Production of F_1 progeny

The moths used in this experiment were obtained from the parents (P_1) crosses of the respective radiation doses. The F_1 moths of each dose were crossed separately in the following combinations to record their sterility, fecundity and longevity:

a) UTF × UTM (control)
b) UTF × F_1M
c) F_1F × UTM

Where F_1F stands for females and F_1M stands for males obtained from P_1 irradiated as mature male pupae. The procedures adopted to record sterility, fecundity and longevity were similar to those for production of parents. The data were analysed by the analysis of variance (ANOVA) and the means compared by Duncan's new multiple range test at p = 0.05.

RESULTS

Radiation effects on mature male pupae.

Moth emergence

Moth emergences following irradiation of mature male pupae at 0, 50, 100, 150 and 200 Gy were 99.17, 97.50, 98.75, 97.92 and 99.06 % while moth deformation were 1.56, 3.54, 2.91, 5.39 and 8.33 %, respectively (Table 1). Moth emergence was found not to be significantly different with the radiation dose whereas moth deformation following irradiation of mature pupae varied significantly with the irradiation doses and positive correlation was also noticed to exist between moth deformation and radiation doses. The number of moth deformation were not significantly different when their pupae irradiated at 50,100 and 150 Gy while those were comparatively higher when the pupae irradiated at 200 Gy (Table 1).

Longevity

The longevity of P_1 moth from irradiated mature male pupae varied significantly with the irradiation doses. The longevity at 0, 50, 100, 150 and 200 Gy of P_1 moth were 13.35, 10.20, 9.45, 11.65 and 11.10 days respectively. The longevity of P_1 moths from irradiated pupae was less than those of untreated moths (control) at every dose. The longest longevity was found in P_1 moths from irradiated pupae at 150 Gy (Table 1).

Production of parents

When treated P_1 males (TM) were crossed with untreated virgin females (UTF), a Duncan's new multiple range test (DMRT) analysis revealed the significant difference between untreated and treated groups in the sterility. Females mating with males irradiated at 150 and 200 Gy laid eggs that showed a significantly lower hatching than the controls while the sterility of females mating with males irradiated at 50,100 Gy was not significantly different from the control. The sterility of unirradiated (control) moths and males irradiated at 50,100 ,150 and 200 Gy were 27.04, 30.49, 33.12, 48.84 and 62.73 %, respectively (Table 1). The sterility increased with increasing gamma radiation doses.

Production of F_1 progeny

The F_1 males crossed with untreated females and the F_1 females crossed with untreated males were studied. The incidence of sterility was found to increase significantly in all crosses with increasing radiation doses of 50, 100, 150 and 200 Gy. The sterility of F_1 males were 52.77, 92.01, 96.84 and 100 % while those of F_1 female were 52.75, 84.76, 98.91 and 100 % respectively. The sterility of untreated males crossed with untreated females (control) were 26.17 % (Table 2). Sterility of F_1 males were found to be more sterile than their parents

It was encountered that fecundity and longevity of F_1 female moths were not significantly different while longevity of F_1 males was highly variable. F_1 males from 50 Gy and 150 Gy irradiated parents were not significantly different whereas F_1 males from 100 Gy and 200 Gy irradiated parents were shorter-lived than the F_1 males from untreated parents (Table 2).

The F_1 males descended from P_1 males treated with doses of 150 and 200 Gy were caged with normal females. The incidence of sterility was significantly higher than that of the control but the survival of F_1 progeny from P_1 males treated with 150 Gy was higher than P_1 males treated with 200 Gy (Table 3).

DISCUSSION

The effects of radiation on mature male pupae of cotton bollworm, *Helicoverpa armigera* when old pupae were treated with dose ranging from 50 to 200 Gy found moth emergence for both irradiated and untreated pupae to be significantly different while pupal irradiation showed a higher incidence of moth deformation at dose of 200 Gy when compared with untreated insects. Moth deformation was positively correlated with radiation dose. The incidents were similarly reported on pink bollworms, *Pectinophora gosspiella*, (Saunders) by Henneberry and Clayton (1988). Longevity of P_1 moth decreased with increasing radiation doses. The results were also similar to those reported by Qureshi *et al*. (1991) on pink bollworm when old pupae were treated with dose ranging from 50 to 200 Gy but contrast to that of Henneberry and Clayton (1988). The difference remained unexplained, but might be related to the quality of insect. The results indicated that pupal irradiation may be a viable option if pupal harvesting techniques that are compatible with other mass rearing procedures could be developed.

The sterility from matings of treated males at doses of 50 to 200 Gy with untreated females was considerably higher than that from the reciprocal matings. The sterility slightly increased with increasing radiation doses. Similar results were also reported by Henneberry and Clayton (1988) , Qureshi *et al*. (1991) on pink bollworms, *Pectinophora gosspiella* , Sutrisno *et al*. (1991) on

Table 1 Effects of gamma radiation on moth emergence, moth deformation, longevity and sterility of cotton bollworm, *Helicoverpa armigera*, following irradiation of mature male pupae.

Dose (Gy)	Moth emergence (%)	Moth deformation (%)	Longevity (day)	Sterility (%)
0	99.17 a	1.56 a	13.35 c	27.04 a
50	97.50 a	3.54 ab	10.20 ab	30.49 a
100	98.75 a	2.91 ab	9.45 a	33.12 a
150	97.92 a	5.39 ab	11.65 bc	48.84 b
200	99.06 a	8.33 b	11.10 ab	62.73 c

Means in columns followed by the same letter are not significantly different at 5% level.

Table 2 Effects of gamma radiation on fecundity, longevity and sterility of the F_1 progeny from male parents of cotton bollworm, *Helicoverpa armigera*, irradiated as mature pupae.

Dose	Fecundity	Longevity (day)		Sterility (%)	
(Gy)	(eggs/female)	Male	Female	Male	Female
0	1,356 a	29.00 c	17.60 a	26.17 a	26.17 a
50	1,519 a	26.13 bc	18.00 a	52.77 b	52.75 b
100	1,347 a	24.90 ab	17.55 a	92.01 cd	84.76 c
150	1,292 a	26.35 bc	17.15 a	96.84 d	98.91 d
200	1,085 a	22.55 a	17.19 a	100.0 d	100.0 d

Means in columns followed by the same letter are not significantly different at 5% level.

Table 3 Larvae survival and male progeny of F_1 progeny of irradiated cotton bollworm, *Helicoverpa armigera*, from male parents irradiated as mature pupae.

Dose to P_1 male (Gy)	No. larvae implanted for rearing	Larvae surviving to adult (%)	Male progeny (%)
0	1,080	78.25 a	52.58 a
50	245	74.00 a	50.38 a
100	332	73.75 a	51.03 a
150	232	70.75 a	63.85 ab
200	378	51.50 b	77.22 b

Means in columns followed by the same letter are not significantly different at 5% level.

diamondback moth, *Plutella xylostella*. They suggested that the sensitivity differential between males and females might be an advantage if a single dose of radiation would partially sterilize males and completely sterilize females.The sterility probably occurred because of the lack of eupyrene sperm transferred by irradiated males during mating (Henneberry and Clayton 1981).

The effects of radiation and inherited sterility on the reproduction of cotton bollworm, *Helicoverpa armigera* were similar to those described for other species of Lepidoptera. The results of this study were concluded that lower doses of irradiation reduced survival of F_1 larval to adult stages. The number of survival larvae decreased as the dose applied to P_1 males increased. At all doses, the number of F_1 larvae surviving to emerge as adults was lower than the control. The sex ratio of the emerging F_1 adults was also skewed in favor of males, and significantly more males were obtained than in controls when the P_1 males were treated with dose of 200 Gy. The similar results were reported by LaChance *et al.* (1973) on pink bollworm. They reported that the surrival to adult stage of F_1 larvae at all doses were significantly lower than the control and the sex ratio of the emerging F_1 adults was also skewed in favor of males and significantly more males were obtained than the control when P_1 males were treated with dose of 50 Gy and above. Carpenter *et al.* (1987) similarly reported on fall armyworm when irradiated P_1 adults with dose of 100 Gy.

Knipling (1970) and LaChance *et al.* (1973) reported that the F_1 progeny were either fully or partially sterile depending on radiation doses received by the male parent. The F_1 progeny was more sterile than the treated P_1 male parent regardless of the dose to the male parent, and the F_1 males were usually more sterile than the F_1 females. The studies showed the similar characters of the F_1 progeny, both male and female. The sterility of F_1 progeny was significantly different from that of untreated insects. Furthermore, the average egg hatch of F_1 males treated with doses of 50 to 150 Gy was higher than that in F_1 females. Similar results were also reported by Omar and Mansor (1991) and Sutrisno *et al.* (1991) on diamondback moth; F_1 progeny were more sterile than the parents at all doses when male pupae were treated at 50 to 250 Gy.

Fecundity of F_1 females were not significantly different from that of untreated insects. The results was in contrast to the report of Qureshi *et al.* (1991) who reported that fecundity of F_1 females of pink bollworm obtained from male parent irradiated as mature pupae with doses of 50 to 150 Gy were reduced as compared with untreated insects. This difference probably occurred because F_1 female moths were not equal in number of the design.

Longevity of F_1 female was not significantly different while that of F_1 male was significantly different from untreated insects. F_1 males from 200 Gy irradiated parents lived significantly shorter than F_1 males from untreated parents. The results also agreed with those reported by Henneberry and Clayton (1988) , and Qureshi *et al.* (1991) on F_1 progeny of pink bollworms, *Pectinophora gosspiella.* All these changes on the reproduction of F_1 progeny must be related to altered genetic information inherited from the treated male parent.

The studies support results obtained with other Lepidopterous insects an irradiated sperm that dose not contain a dominant lethal mutation and permits production of a viable larva was definitely not free from genetic changes that debilitate the progeny inheriting an irradiated genome, i.e., reduced survival of larvae, the shift of sex ratio in favor of males in the F_1 generation, and the lower reproductive ability of the F_1 males. All these changes must related to the altered genetic information inherited from the treated male parent.

The results of efficiency of artificial diet and effects of gamma radiation on mating and reproduction of mature pupae and the inherited effects on mating and reproduction of their F_1 progeny were also studied under laboratory conditions but not yet reported. Therefore, before the final judgment is made, it is necessary to study the inherited effects on mating and reproduction of F_1 progeny in the field that the partially sterile cotton bollworm and their F_1 progeny can establish their populations.

CONCLUSION

The results of this study can be concluded as the followings:

1. Moth emergence was not significantly different but moth deformation was significantly high with a dose above 200 Gy.

2. Longevity of male moths from irradiated pupae was lower than the untreated moths (control) at all doses.

3. When parent males were treated with lower doses (50 to 200 Gy), F_1 progeny was either fully or partially sterile depending on the dose of irradiation received by the male parent. The sterility of F_1 progeny was higher than the treated male parent regardless of the dose to the male parent, and F_1 males were more sterile than F_1 females.

4. F_1 progeny produced by irradiated parent males, the sex ratio was skewed in favor of males and increased with doses.

5. The fecundity and longevity of F_1 female moths were not significantly different when compared with the untreated moths (control) but longevity of F_1 male moths was shorter than the untreated moths (control) at the dose of 200 Gy.

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