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Gamma Irradiation-Induced Parental and Inherited Sterility in Gram Pod Borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae)

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ABSTRACT

Phorates of *Helicoverpa armigera* reared on artificial diet were irradiated with sub-sterilizing dose of gamma radiation (100 Gy) and examined the emerged adults for inherited sterility. The impact of radiation on fecundity and fertility was ascertained in parental (P) and F_1 generations. 44% adult emergence in irradiated pupae was recorded as compared to 84% in normal pupae. Pupal period of irradiated pupae was found to be increased by two days in P generation. Significant reduction ($p \leq 0.01$) in fecundity was recorded in treated P crosses while, it was almost fell within the normal range in F_1 crosses when compared to controls. Fertility was significantly affected in all the crosses of P and F_1 generations. The deleterious effect was inherited in the F_1 generation and was expressed when F_1 progeny of the Nf × Tm cross were inbred.

Key words: Fecundity, Fertility, Gamma irradiation, *Helicoverpa armigera*, Inherited sterility

Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) is an economically important polyphagous pest in India. This pest is reported to attack a wide range of agricultural crops causing substantial losses every year (Sharma 2001). It causes 24 to 68% losses of cotton (Vadodaria *et al*. 1998) and 28 to 40% losses of pulses (Srivastava *et al*. 2005) at a national level. In order to avoid the insecticides hazards, there is a great need to develop a multifaceted approach for the control of this pest because it has developed resistance against a range of insecticides (Kranthi *et al*. 2001, Choudhary *et al*. 2004). The sterile insect technique has been a favoured alternative.

F_1 progeny resulting from sub-sterile parental (P) male moths are also sterile and are more competitive than P generation moths. Inherited sterility or F_1 sterility in the progeny of treated males has been shown to have potential in suppressing population of lepidopteran pests (Knipling 1970, LaChance 1985). Previous studies of sub-sterilizing gamma radiation does on the growth and reproductive behaviour of lepidopteran pests in the F_1 progeny of treated moths indicated the potential of managing lepidopteran pests by using inherited sterility (Guerra and Garcia 1976, Carpenter *et al*. 1987, Carpenter and Gross 1993, Seth and Sehgal 1993, Makee and Saour 1997, Seth and Sharma 2001). Current study is undertaken to evaluate the fecundity and fertility of *H. armigera* in response to sub-sterilising dose (100 Gy) when reared on artificial diet in the laboratory.

MATERIALS AND METHODS

A colony of *H. armigera* was initiated from late instar larvae collected from the cotton fields of Central Institute for Cotton Research, Nagpur and reared on the agar-based chickpea diet (Nagarkatti and Prakash 1974). The rearing conditions were kept at 70 ± 5% RH, 27 ± 1°C with a photoperiod of L: D 14:10. The source (CO60) used for gamma irradiation was made available from the Chemistry Department of Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur. 50 pupae of approximately 4-5 days old were kept in glass petridish for gamma ray irradiation. A dose of 100 Gy of gamma radiation delivering at the dose rate of 13.5 Gy/min. was applied. Number of emergence (mortality rate) was observed after emergence of adult moths. Reproductive parameters were assessed by pairing treated insects (irradiated P moths and F_1 moths derived from the treated P adults crossed with normal moths). Emerging males and females were paired with normal (N) males and females. N × N crosses served as controls. The progeny resulting from Nf × Nm and Nf × Tm crosses were used in the F_1 crosses and the mating scheme for all crosses performed is shown in (Table 1).

Each individual cross was placed inside the plastic jars (30 cm dia. × 30 cm high) to mate and egging. A cotton ball soaked in 30% honey solution was provided as a food source. The top of each jar was covered with rough cotton cloth that served as an ovipositional substrate. Moths were allowed to lay eggs for 7 days. Ovipositional cloths were changed daily and eggs were counted to assess female fecundity from the different crosses. Egg cloths were incubated for 3 days and the number of egg that hatched was counted. The data on fecundity and fertility were analyzed statistically by following the Analysis of Variance (ANOVA). Means were separated using Tukey's (HSD) multiple comparisons test ($p < 0.01$) (SPSS 1999).

Table 1 Mating crosses

Generation	Type of crosses (f × m)
P	N × N*
	N × T*
	T × N
	T × T
F_1	$NF_1 \times NF_1$
	$NF_1 \times TF_1$
	$TF_1 \times NF_1$
	$TF_1 \times TF_1$

*Progeny used for F_1 crosses

RESULTS AND DISCUSSION

In the present study whole body irradiation at pupal stage with gamma rays shows effects on the pupal period, fecundity and egg hatchability in *H. Armigera*. The percentage of adult emergence was decreased in gamma irradiated pupae as compared to emergence in normal pupae. Emergence was only 44% in gamma irradiated pupae for 100 Gy as compared to 84% emergence in normal pupae; pupal period was increased by 2 day as compared to normal pupal period. However, there was no change in sex ratio, mating behaviour and life span as that of controls (Table 2). Proverbs (1962), Proverbs and Newton (1962), in codling moth *Carpocapsa pomonella* and Szlendak *et al.* (1987) in *Acarus siro* reported that gamma irradiation has lethal effects on spermatogenesis but no effect on mating activity and life span.

Table 2 Effect of gamma irradiation on pupal period and emergence of *H. armigera*

Dose (Gy)	No. of pupae tested	Pupal period (days)	Emergence (%)	No. of Males (%)	No. of Females (%)
0	50	11	41 (82.00)	23 (56.00)	18 (43.00)
100	50	13	22 (44.00)	6 (54.54)	5 (45.45)

In the P generation, significant reduction ($p \leq 0.01$) in fecundity was recorded for T × N and T × T crosses while, it was not affected from N × T cross when compared with the control (N × N) cross. Fertility was significantly ($p \leq 0.01$) affected in all crosses of P generation. Fertility, when untreated females were mated to treated males was only 42.2% of the control (Table 3). Similar results are also reported by other workers in different insects. (Offori and Czock 1975, Glenn and Ducoff 1976, Sacchi *et al.* 1977, Carpenter *et al.* 1983, Lachance 1985, Sallam and Ibrahim 1993, Ismail 1994, Makee and Saour 1997).

In the F_1 generation, significantly ($p \leq 0.01$) reduced fecundity was recorded from the cross of TF_1 females mates with TF_1 males; however, no significant differences were recorded from the NF_1 females mated with TF_1 males, and TF_1 females mated with NF_1 males. Fecundity in F_1 crosses almost fell within the normal range. The inherited deleterious effects in the F_1 generation caused a significant reduction in egg hatch when the F_1 progeny of normal females and treated males were inbred. In particular, all the crosses exhibited significant ($p \leq 0.01$) reduction in fertility when compared with control ($NF_1 \times NF_1$) (Table 3). Similar findings were reported for *Heliothis zea* (LaChance 1985, Carpenter *et al.* 1987, Carpenter and Gross 1993), for *Helicoverpa virescens* (Guerra and Garcia 1976), for *Phthorimaea opercula* (Makee and Saour 1997) and for *Spodoptera litura* (Seth and Sharma 2001).

Table 3 Effect of 100Gy of gamma irradiation applied to pupae of *H. armigera* on fecundity and fertility of P and F_1 adults

Cross type (f × m)	No. of pairs	Eggs per female (mean ± SD)	Percent egg hatch (mean ± SD)
P Crosses			
N × N	10	689.6 ± 77.82a	80.4 ± 4.0a
N × T	05	603.7 ± 63.62a	42.2 ± 1.8b
T × N	05	103.8 ± 28.39b	16.0 ± 2.9c
T × T	05	108.1 ± 27.07b	0
F_1 Crosses			
$NF_1 \times NF_1$	10	688.7 ± 57.09a	81.5 ± 3.3a
$NF_1 \times TF_1$	05	652.5 ± 75.09a	48.8 ± 0.8b
$TF_1 \times NF_1$	05	715.4 ± 46.26a	42.3 ± 1.1b
$TF_1 \times TF_1$	05	411.8 ± 56.51d	5.2 ± 0.8e

Means (± SD) on same column, followed by the same letter are not significantly different at $p \leq 0.01$ (ANOVA followed by Tukey's HSD test), f= Female; m= Male; N= Untreated; T= Treated

The F_1 progeny from TF_1 parents has problems with moulting and resulted in an incidence of deformed larvae and pupae. However, individual that did survive has similar developmental period to the controls. Lachance (1985) described 3 types of sterility caused by gamma irradiation on the screw-worm fly, *Cochliomyia hominivorax*. These were aspermia, sperm immotility and dominant lethal genes carried in the sperm. Irradiation of the screw-worm caused permanent genetic damage to spermatogonial cells, spermatocytes, spermatids and spermatozoa (Shen and Berryman 1967). Proshold and Bartell (1970) suggested that the sterility of the male could arise from any one of three causes: (1) lack of mating, (2) lack of sperm transfer, and (3) reduced hatch of fertilized eggs. The data on fertility demonstrates that reduced hatch of egg could be the major cause of sterility. Similarly, Seth and Reynolds (1993) reported that the main cause of sterility in F_1 generation of *Manduca sexta* was the induction by radiation of lethal mutations that arrested the development in late embryonic life. Also, Marec *et al*. (1999) observed sterile eggs and inviable eggs (in which embryos died during different stages of embryogenesis) while studying the gamma radiation induced sterility combined with genetic sexing in *Ephestia kuehniella.*

In view of the overall reproductive performance of P and F_1 moths, our findings suggests the use of 100 Gy gamma radiation as an effective dose for the suppression of *H. armigera* populations by the release of partially sterile males.

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