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EFFICACY OF GAMMA RADIATION AGAINST HOUSEFLY (*MUSCA DOMESTICA* L.) REPRODUCTION AND SURVIVAL II. ADULT TREATMENT

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Abstract

Gamma radiation-induced changes in the reproductive parameters have been investigated using 0-10 Gy doses on adult houseflies *Musca domestica* L. Inheritance of the parameters was recorded in the parents and subsequent progenies up to F_3 generations. Compared to the untreated controls, irradiations significantly increased oviposition, sterility and immature mortality, and diminished adult and female eclosion in the treated lines. Sterility reached 100% above 8 Gy levels and males were readily radiosterilized than the females. Dose mortality (LD_{50}) and sterility (SD_{50}) responses of the test insects were determined to be 10.04 Gy and 6.23 Gy, respectively. Results are promising in connection with a sterile insect technique (SIT) for this pest species.

Key words: *Musca domestica,* gamma radiation, adult treatment, oviposition, sterility, mortality, eclosion

Introduction

Gamma radiation has long been employed to control a number of dipteran insects such as sheep blowfly (Donnelly 1960, Whitten and Tailor 1970, Karunamoorthy and Lalitha 1987, Huda and Khan 2000), fruit fly (Hooper 1975), screwworm fly (Crystal 1979, Spradberry *et al*. 1983) and uzi fly (Jahan *et al*. 1998). *Musca domestica* L. (Diptera: Muscidae), being a human commensal pest throughout the world, is of much concern to public health (Service 1980). Although previous workers have studied the possible use of radiation of houseflies to effect population suppression (Magaudda *et al.* 1969, McDonald 1970, McDonald and Overland 1972, Flint and McDonald 1972, Wagoner *et al.* 1974, Islam and Khan 2006), more information and knowledge is needed to implement any practical irradiation control strategy of this pest species.

The concept of sterilizing insects by irradiation and releasing such males for suppressing a pest species gained much attention after the successful eradication of the screwworm fly *Cochliomyia hominivorax* (Knipling 1960). Since female insects are of equal or less tolerance to radiosterility than males, considerable research has been done on doses required to sterilize male insects for sterile insect technique (SIT). It is almost assured that the dose required to sterilize the adult male insect will also sterilize the female (Hallman 2000). Recently Islam and Khan (2006) have shown an effective means of suppressing housefly population by treating pupae with gamma radiations. Reported here are the results of the investigations on the radiation-induced changes in the such as oviposition, sterility, larval and pupal mortalities, adult and female numbers, and female ratio of *M. domestica* treated as adults, which were conducted to evaluate two possible usages of gamma radiations: direct radiation effects on parental reproduction and on subsequent progeny parameters, and radio-sensitivity to the adult flies.

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Materials and Methods

Maintenance of the houseflies

Colonies of *M. domestica* were established in 45 cm × 28 cm × 33 cm rearing cages each containing *ca*. 200 unsexed adults on milk-yeast-water culture medium. Adult flies and their progenies were maintained from parental through F_3 generations.

Radiation treatments

Newly emerged adults (1-2 day-old) were collected from the stock culture. Both sexes were irradiated with gamma radiation at different doses, *viz*. 0 (control), 1, 2, 4, 5, 6, 8 and 10 Gy. Irradiation was carried out with a gamma beam 650 loaded with ^{60}Co with a rate of 18 Kr/hr established at the Institute of Food and Radiation Biology (IFRB), Atomic Energy Commission, Savar, Dhaka. For each dose, 20 adults of both sexes were irradiated and 5 replicates were made for each treatment. The irradiated adults were kept for mating in 500 ml beakers covered by muslin-mesh tops. After 24 hours of pairing, females were provided with oviposition medium for egg laying.

Mating types

In addition to untreated controls (U×U), crosses between irradiated parents (I×I), irradiated females and untreated males (I×U) and untreated females and irradiated males (U×I) were performed to evaluate radiation effects on both sexes by recording reproductive parameters from parental through F_3 generations.

Radiation effects on reproductive parameters

Twenty-four-hour egg laying by the newly-eclosed females constituted the oviposition whereas sterility was estimated from the number of non-hatched eggs. Immature mortalities were counted from the number of dead larvae and pupae in all treatment lines. Numbers of adult females and males emerged from all lines gave the adult survival data. Female ratio was calculated from the number of females divided by the total number of adults.

Dose-mortality and dose-sterility responses

Radiation dose needed to kill 50% adults (i *e* LD_{50}) gave the dose-mortality response, while dose required to sterilize 50% adults that emerged from the treated adults (i *e* SD_{50}) was estimated from the non-hatched egg data at all dose levels mentioned above.

Statistical analyses

Using SPSS (version 11.0), square-root transformed data were subjected to analysis of variation (ANOVA) followed by the least significant difference (LSD) tests for multiple comparisons. Effects of radiation doses, generations and mating types were analyzed for the reproductive parameters under study.

Results and Discussion

Because 100% sterility was induced at 10 Gy, and reciprocal crosses could not be continued due to fewer number of females that eclose from 6 Gy and 8 Gy treatment lines, detailed analyses were performed on data from 0 to 5 Gy levels. Sterility values of 46.5±4.2% and 74.5±5.4% were recorded in I×I crosses at 6 and 8 Gy, respectively.

Oviposition

Number of eggs laid by the experimental flies demonstrates that radiation doses increased egg laying significantly ($F_{4,\ 95}$ = 6.99; P<0.0001). Progenies from F_1 to F_3 generations laid greater number of eggs compared to those of the P generation (Fig. 1). Mating types also affected oviposition significantly (P<0.0001; Table 1).

Sterility

As expected, the number of non-hatched eggs increased significantly ($F_{4, 95}$ = 327.47; P<0.0001), indicating a dose-dependent radiation effect on sterility in this species (Fig. 1). Inheritance of sterility from parental through F_3 generations was not found to be significant (Table 1). However, a pronounced effect of mating types on sterility is observed ($F_{3, 236}$ = 28.94; P<0.0001). Analysis on the pooled data showed that compared to U×U, I×U and U×I crosses, I×I induced the highest sterility of eggs. That all radiation doses induced sterility significantly in the experimental flies was shown by the LSD values (P<0.001). Sterility differences between P and F_3, F_1 and $F_{3,}$ and F_2 and F_3 generations were statistically significant by LSD estimates (P<0.01). I×I matings resulted in increased sterility compared to both U×U and I×U crosses, clearly suggesting that male houseflies are more radiosensitive than female ones.

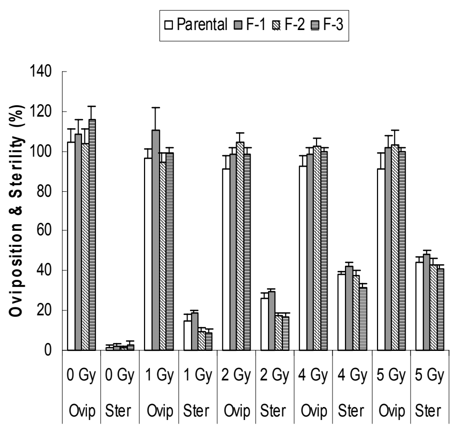

Fig. 1. Effects of radiation doses on the inheritance of oviposition (Ovip) and sterility (Ster) in *M. domestica.* Bars indicate mean±SD; F-1, F-2 and F-3 are designated for F_1, F_2 and F_3 generations, respectively.

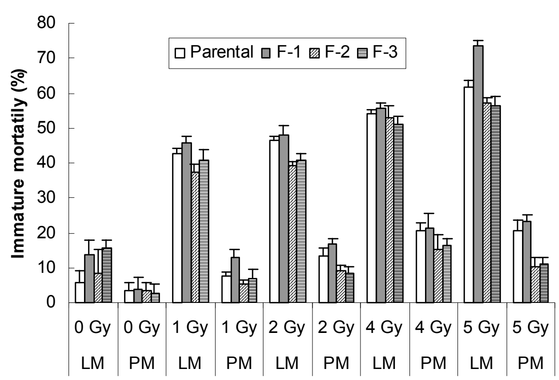

Fig. 2. Effects of radiation doses on the inheritance of immature mortalities in *M. domestica.* Bars indicate mean±SD; F-1, F-2 and F-3 are designated for F_1, F_2 and F_3 generations, respectively while LM and PM represent larval mortality and pupal mortality, respectively.

Immature mortalities

Number of dead larvae and pupae increased progressively following radiation treatments in *M. domestica* (Fig. 2). Further analyses demonstrate that immature mortalities reached their peaks in F_1 generation, and I×I mating produced the highest mortality effect among the progenies. Although larval mortality was not affected between generations, both larval and pupal mortalities were significantly increased by the radiation doses and mating types (Table 1).

Adult numbers

The number of adults emerged (Fig. 3) was adversely affected by the radiation treatments ($F_{4, 95}$ = 540.75; P<0.0001) and mating types ($F_{3, 236}$ = 126.95; P<0.0001). However, no appreciable effect of generations on this parameter was noticed (Table 1). I×I parents produced significantly fewer number of adults in comparison with I×U, U×I and U×U parents, suggesting that the mating types had a highly significant effect on adult eclosion in *M. domestica*. In addition, adult numbers in all three mating types differed significantly from that of U×U, while I×I induced significantly smaller number of adult eclosion than I×U, further indicating a male radiosensitivity of this species. Adult numbers varied significantly by LSD estimates among all dose levels, and between P-F_3, F_1-F_3 and F_2-F_3 generations.

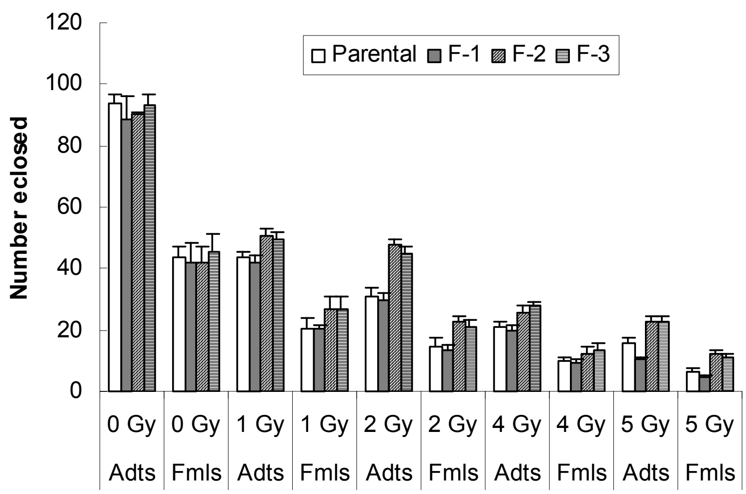

Fig. 3. Effects of radiation doses on the inheritance of the number of adults (adts) and females (Fmls) in *M. domestica.* Bars indicate mean±SD; F-1, F-2 and F-3 are designated for F_1, F_2 and F_3 generations, respectively.

Female numbers

Significantly less number of females (Fig. 3) was produced by the radiation doses ($F_{4, 95}$ = 225.72; P<0.0001) and mating types ($F_{3, 236}$=97.86; P<0.0001), but this effect was not apparent between generations. As expected, I×I resulted in the lowest number of females compared to the remaining mating types. Despite the progressive decrease in the female numbers, the overall female ratio in the experimental lines was not affected by the radiation doses, generations or mating types (Table 1).

Dose-mortality and dose-sterility responses

Compared to the mortality in controls (1.67%), gamma irradiations resulted in a progressive increase in the adult mortality, giving an estimated LD_{50} value of 10.04 Gy. Likewise, proportion of non-hatched eggs increased from 2.73% in the control to 74.47% at 8 Gy, giving an SD_{50} value of 6.23 Gy.

Here we demonstrate that inheritance of such reproductive parameters as oviposition, sterility, immature mortality, and adult and female numbers in *M. domestica* could be manipulated effectively by irradiating newly emerged adults from 5 to 10 Gy. Data also indicate that male houseflies are more radiosensitive than their female counterparts. Attempts to induce sterility in the dipterans by employing various doses of gamma radiations yielded varying results, mainly because of varying dose rate applied to eggs, immature stages, pupae or adults (Smittle 1967, Pal and Whitten 1974). Sterilization dose for females and males of *Anopheles quadrimaculatus* was 130 Gy (Davis *et al.* 1959). Gamma radiation treatments of 4-1200 Gy reduced the number of immature stages that pupated and the number of adults that emerged from puparia, and $LD_{99..99}$ = 1486 Gy were needed to stop pupariation and 88 Gy to stop flies emerging from puparia (Sharp 1999). Newly-eclosed female adults of *M. domestica* were completely sterilized at 30 Gy (Smittle 1967) whereas 62 Gy were required to sterilize female pharate adult screwworm, *C. hominivorax* (Baumhover 1963). In fruit flies 60-250 Gy were required to prevent adult emergence from third-instar. Female insects are sterilized with equal or lower doses than males. Several groups of pests such as fruit flies, white flies, weevils and scarab beetles may be controlled with doses <100 Gy; while some lepidopteran pests and most mites require about 300 Gy. Stored product moths may require as much as 1000 Gy to sterilize, and nematodes need >4000 Gy (Hallman 2000).

The present results on gamma radiation-induced alterations in reproductive parameters in *M. domestica* differ from those of other dipteran species reported earlier. *Lucilia serieata* pupae emerged normally at 120 Gy (Donnelly 1960), and no pupal mortality either in blowfly (Whitten and Tailor 1970) or in screwworm fly *Chrysomyia bezziana* (Spradberry *et al.* 1983) was noticed. Previous workers did not observe any appreciable effect of gamma radiations on adult survival in fruit fly *Dacus cucumis* (Hooper 1975), *C. bezziana* (Spradberry *et al.* 1983), or *L. cuprina* (Huda and Khan 2000). On the other hand, Huda and Khan (2000) demonstrated that sterility *L. cuprina* was increased with increasing dose to reach approximately 100% at 30 Gy, and males were affected by semi-sterility at 25 Gy. Similar results were reported by Donnelly (1960) in *L. serieata*, Crystal (1979) in *Coclio hominivorax* and Karunamoorthy and Lalitha (1987) in *L. cuprina*. Jahan *et al.* (1998) irradiated pupae of *Exorista bombycis* from 2.5 to 40 Gy where adult longevity, fecundity, oviposition period and fertility significantly reduced, sterility was induced at >20 Gy and complete infecundity was recorded at 40 Gy. The aforesaid differences reflect variation in radiation responses by various dipteran pest species. The present results clearly demonstrate that <10 Gy would be sufficient to control *M. domestica* reproduction and survival. In the study described here, radiation doses required to prevent adult eclosion and to induce sterility in *M. domestica*. It also provided data on such important reproductive parameters as oviposition, sterility, immature mortality and female ratio following adult treatment in parental generation and monitoring progeny parameters up to F_3 generation. These results would therefore assist designing an effective SIT for *M. domestica*.

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