Gamma Irradiation Effects on Reproductive Potential and Egg-Viability of the Housefly Musca domestica

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ABSTRACT

Gamma radiation effects on the development of the houseflies, M. domestica were investigated in the present study. As the doses of gamma radiation increased, a progressive increase in sterility percentage and a reduction in eggs-viability occurred. The highest sterility and non-hatched eggs percentages occurred when the pupae were irradiated with high doses such as 10 and 12 Gy. Mating of the resulting irradiated males and females or irradiated males with non-irradiated females caused the highest sterility and non-hatched eggs percentages. Males were more radiosensitive than their female counterparts.

Keywords: Gamma Radiation, Reproductive Potential, Musca domestica

1. INTRODUCTION

The houseflies, Musca domestica L. (Diptera: Muscidae), being a human commensally pest throughout the world, is of much concern to public health (1). Among vertebrates, mammals are generally more radiosensitive than birds, amphibians and reptiles. Most invertebrates have been shown to be more resistant than vertebrates (2). The degree of radio sensitivity varies greatly within a single species (individual radio sensitivity), while for a definite individual, it depends on the age and sex. Insects show a very high degree of radio resistance. The molecular rationale for this radio resistance is believed to involve a very efficient DNA repair process (3) which allows them to maintain their genetic integrity. Moreover, the radio resistance varies among insect orders, where Lepidoptera are more radio resistance than other insect orders like Hemiptera, Diptera and Homoptera (4).

The effects of gamma radiation on reproductive potential of some dipteran species were reported by many workers. Khan and Islam (5) found that the proportion of non-hatched eggs of M. domestica increased as the dose of gamma radiation increased. Gamma radiation induced sterility in irradiated insect species and the sterility percentage increased as the dose increased as found in M. autumnalis (6), in M. domestica (7,5) and in Culex pipiens (8). The present study was undertaken to investigate the effect of gamma radiation at various doses on reproductive potential and egg-viability of the housefly, M. domestica.

2. MATERIALS AND METHODS

2.1. Laboratory Maintenance of Musca domestica

A culture of the housefly M. domestica was maintained for several generations at the laboratory of insects, Zoology Department, Faculty of Science, Al-Azhar University (Cairo), under controlled conditions of 27±2 °C and 70-75% RH and 12-12 light - dark. The emerged flies were fed on dry diet (milk powder) and sucrose solution (cotton pads soaked in 10 % sucrose solution). Eggs were collected from paper strips or from cotton pads of feeding, where they were deposited by the females.

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Larvae were reared on an artificial diet (wheat bran, milk, powder yeast; 200:100:5 gm) per 200 ml distilled water according to the method described by Busvine (9).

2.2. Irradiation Process

The irradiation process was performed using the gamma cell-40 (cesium-137 irradiation unit), at the National Center for Radiation Research and Technology (NCRRT), the Atomic Energy Authority, Cairo. The dose rate was 2.3 Gy/min.

2.3. Biological Activity

2.3.1. The Susceptibility of Musca domestica Resulting from Irradiated Pupae with Gamma Radiation

Three days old pupae were irradiated with 6 doses of 2, 4, 6, 8, 10 and 12 Gy, fecundity (No. of eggs laid), fertility (No. of eggs hatched) were detected in the resulted females. Response percentages of non-hatching eggs were corrected using Abbotts’ Formula (10). The LD_{50} were calculated according to the method of Finney (11). Three crossing combination was set up for each dose as follows: 4 replicates were used for each combination (each one has 10 males and 10 females). One crossing combination from non-irradiated insects was used as control.

2.3.2. Reproductive Potential of Irradiated Musca domestica

Adults that succeeded to emerge from the irradiated pupae with each dose were collected and transferred with normal insects obtained from the colony to the wooden cages (30×30×30 cm) and fed with dry diet (milk powder) and sucrose solution (cotton pads soaked in 10 % sucrose solution) for four days, the adult lay egg on an artificial diet rafts. The number of egg/raft was counted using binocular and then the mean values were calculated.

a. Egg – Hatchability Percentage

The egg-hatchability was calculated using the following equation: Egg-hatchability % = A / B × 100

Where:

A = Total No. of hatched eggs. 
B = Total No. of eggs laid.

b. Sterility Index (S.I.)

The Sterility percentage was estimated according to the formula of Toppozada et al., (12):

Sterility percentage = 100 – [a×b /A×B] 100

Where:

a = Number of eggs laid / female in treatment. 
b = Percentage of hatched eggs in treatment 
A = Number of eggs laid / female in control. 
B = Percentage of hatched eggs in control

2.4. Statistical Analysis

All data obtained for (biological studies) were statistically analyzed and the variance ratios were calculated by the method of one way ANOVA using (SPSS/PC) computer program calculated at 5% level.

3. RESULTS

3.1. Efficacy of Gamma Radiation against Musca domestica L.

3.1.1. Effects of Gamma Radiation on Reproductive Potential and Embryonic Lethality of Treated Females (TF) and Untreated Males (UTM)

The effects of gamma radiation on fecundity of M. domestica females resulting from 3-days old pupae irradiated with 0 (control), 2, 4, 6, 8, 10 and 12 Gy and crossed with untreated males (UTM) are presented in Table (1). As shown from the results, the fecundity was significantly decreased as the gamma-radiation dose increased, where the number of eggs laid by treated female (TF) decreased from 59.1±2.0 eggs/female at 0 Gy (control) to 6.0±1.0 eggs/female at 12 Gy (Table 1).
The hatchability % was significantly decreased as the dose of gamma radiation increased; it decreased from 99.3 % at 0 Gy to 38.3 % at 12 Gy (Table1). This means that embryonic development lethality is gamma-radiation dose dependent i.e. it increases as the dose increases.

The sterility % of females significantly increased as the dose of gamma radiation increased, where it increased from 0.0 % at 0 Gy to 99.6% at 12 Gy (Table1).

Table (1): Reproductive potential of *Musca domestica* of irradiated females crossed with normal males

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>No. of eggs laid</th>
<th>No. of hatched eggs</th>
<th>No. of non–hatched eggs</th>
<th>Sterility Index (S. I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean±SD</td>
<td>mean±SD</td>
<td>%</td>
<td>mean±SD</td>
</tr>
<tr>
<td>Control</td>
<td>59.1±2.0</td>
<td>58.7±2.4</td>
<td>99.3</td>
<td>0.4±0.1</td>
</tr>
<tr>
<td>2</td>
<td>16.8±0.7^d</td>
<td>15.1±0.7^d</td>
<td>89.9</td>
<td>1.7±0.1^c</td>
</tr>
<tr>
<td>4</td>
<td>14.8±0.7^d</td>
<td>11.3±0.3^d</td>
<td>76.4</td>
<td>3.5±0.5^d</td>
</tr>
<tr>
<td>6</td>
<td>12.3±0.3^d</td>
<td>8.0±0.4^d</td>
<td>65</td>
<td>4.3±0.1^d</td>
</tr>
<tr>
<td>8</td>
<td>10.5±0.5^d</td>
<td>5.7±0.5^d</td>
<td>54.3</td>
<td>4.7±0.3^d</td>
</tr>
<tr>
<td>10</td>
<td>8.1±0.3^d</td>
<td>4.7±0.3^d</td>
<td>58</td>
<td>4.0±0.2^d</td>
</tr>
<tr>
<td>12</td>
<td>6.0±1.0^d</td>
<td>2.3±0.4^d</td>
<td>38.3</td>
<td>3.7±0.6^d</td>
</tr>
</tbody>
</table>

| No. of females tested= 15 | No. of males tested= 15 |

3.2. Effect of Gamma Radiation on Reproductive Potential and Embryonic Lethality of Untreated Females (UTF) and Treated Males (TM)

The effect of gamma irradiation on the fecundity of *Musca domestica* when males resulting from 3-days old pupae were crossed with untreated females (UTF) is given in Table (2). The number of eggs/female was decreased from 59.1±2.0 at 0 Gy to 37.0±1.0 at 12 Gy.

The egg-hatchability % decreased from 99.3% at 0 Gy to 7.3 % at 12Gy. This means that the hatchability% or embryonic lethality is dose dependent i.e. the egg-hatchability % decreased and embryonic lethality % increased to 92.7 % as the gamma-radiation dose increased as shown in (Table2).

The sterility % of normal untreated females (UTF) crossed with treated males (TM) which resulted from irradiated pupae was dose dependent as they increased when the gamma irradiation dose increased i.e. it increased from 0% at 0 Gy to 97.1% at 12 Gy (Table 2).
Table (2): Reproductive potential of Musca domestica of normal females crossed with irradiated males

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>No. of eggs laid mean±SD</th>
<th>No. of hatched eggs mean±SD</th>
<th>No. of non–hatched eggs %</th>
<th>Sterility Index (S. I.) %</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>59.1±2.0</td>
<td>58.7±2.4</td>
<td>99.3</td>
<td>0.4±0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>58.0±2.0</td>
<td>39.0±1.0</td>
<td>67.2</td>
<td>19.0±1.7</td>
<td>32.8</td>
</tr>
<tr>
<td>4</td>
<td>54.5±1.3</td>
<td>21.1±1.0</td>
<td>38.7</td>
<td>33.5±2.1</td>
<td>61.3</td>
</tr>
<tr>
<td>6</td>
<td>50.2±0.7</td>
<td>15.0±1.0</td>
<td>29.9</td>
<td>35.2±0.7</td>
<td>70.1</td>
</tr>
<tr>
<td>8</td>
<td>44.4±1.0</td>
<td>10.7±0.8</td>
<td>24.1</td>
<td>33.6±0.5</td>
<td>75.9</td>
</tr>
<tr>
<td>10</td>
<td>41.5±1.4</td>
<td>4.1±0.5</td>
<td>9.9</td>
<td>37.4±1.2</td>
<td>90.1</td>
</tr>
<tr>
<td>12</td>
<td>37.0±1.0</td>
<td>2.7±0.3</td>
<td>7.3</td>
<td>34.3±0.7</td>
<td>92.7</td>
</tr>
</tbody>
</table>

No. of females tested= 15  No. of males tested= 15

3.3. Effect of Gamma Radiation on Reproductive Potential and Embryonic Lethality of Treated Females (TF) and Treated Males (TM)

The effects of gamma radiation on the fecundity of M. domestica females resulting from 3-days old pupae irradiated with 0, 2, 4, 6, 8, 10 and 12 Gy (TF) and crossed with males irradiated with the same gamma-radiation doses (TM) are given in Table (3) the number of eggs/female decreased from 59.1±2.0 at 0 Gy to 2.2±0.2 at 12 Gy.

The percentage of egg-hatchability was decreased from 99.3% at 0 Gy to 0% at 12 Gy. On the other hand, lethality % of egg increased from 0.7 % at 0 Gy to 100 % at 12 Gy as shown in Table (3).

The sterility % of irradiated females crossed with irradiated males also was dose dependent, where it increased as the dose of gamma radiation increased; it increased from 0 % at 0 Gy to reach 100 % at 12 Gy.

Table (3): Reproductive potential of Musca domestica of irradiated males and females

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>No. of eggs laid mean±SD</th>
<th>No. of hatched eggs mean±SD</th>
<th>No. of non–hatched eggs %</th>
<th>Sterility Index (S. I.) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>59.1±2.0</td>
<td>58.7±2.4</td>
<td>99.3</td>
<td>0.4±0.1</td>
</tr>
<tr>
<td>2</td>
<td>37.9±1.0</td>
<td>23.5±0.5</td>
<td>62</td>
<td>14.3±0.8</td>
</tr>
<tr>
<td>4</td>
<td>24.6±3.5</td>
<td>12.5±2.1</td>
<td>50.8</td>
<td>12.1±3.2</td>
</tr>
<tr>
<td>6</td>
<td>23.6±1.5</td>
<td>6.4±0.9</td>
<td>27.1</td>
<td>17.2±0.7</td>
</tr>
<tr>
<td>8</td>
<td>19.4±1.5</td>
<td>1.7±0.2</td>
<td>8.8</td>
<td>17.7±1.3</td>
</tr>
<tr>
<td>10</td>
<td>3.0±0.3</td>
<td>0.13±0.12</td>
<td>4.3</td>
<td>2.9±0.3</td>
</tr>
<tr>
<td>12</td>
<td>2.2±0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>2.2±0.2</td>
</tr>
</tbody>
</table>

No. of females tested= 15  No. of males tested= 15
Table (4): LD_{50} of gamma radiation affecting the egg-hatchability of *Musca domestica* L

<table>
<thead>
<tr>
<th>Treatments</th>
<th>(LD_{50}) values in (Gy)</th>
<th>(LD_{50}) values in (Gy).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiated♀ × normal♂</td>
<td>9.728 (8.4094-11.8741)</td>
<td>1.8984 ± 0.1957</td>
</tr>
<tr>
<td>Irradiated♂ × normal♀</td>
<td>3.2129 (2.3825-3.8438)</td>
<td>2.1642 ± 0.0902</td>
</tr>
<tr>
<td>Irradiated♀ × Irradiated♂</td>
<td>3.0393 (2.3—3.6)</td>
<td>2.367 ± 0.14</td>
</tr>
</tbody>
</table>

From the aforementioned results, it is obvious that embryonic lethality, egg-hatchability and sterility percentage in all treatments were dose dependent, where the egg-hatchability % was decreased as the gamma radiation doses of irradiated pupae increased, meanwhile the sterility % of females was increased as the doses of irradiated pupae increased. Also, it is obvious that the embryonic lethality (non-hatching eggs) values based on the calculated LD_{50} of gamma radiation indicated that the highest sterility and non-hatched eggs percentage occurred when irradiated females crossed with irradiated males resulted from the irradiated pupae. In addition, the results indicated that males were more radiosensitive than females as shown from LD_{50} values in table(4), where the LD_{50} for lethality of eggs laid by normal females mated with irradiated males was 3.213 Gy compared to 9.728 Gy for egg-lethality laid by irradiated females mated with normal males. However, the LD_{50} value was 3.039 Gy when both male and female were irradiated.

4. DISCUSSION

The present study revealed that the number of eggs laid by females resulted from pupae irradiated with different doses of gamma radiation decreased as the dose increased. The highest reduction in number of eggs was occurred at the highest doses (10, 12 Gy) and when the irradiated females were crossed with irradiated males. These results are in contrast with those of Khan and Islam (5), where they observed that gamma radiation (0–10 Gy) significantly increased oviposition in *Musca domestica*. Also, Mansour (7), demonstrated that irradiation of pupae of the face fly, *Musca autumnalis* using gamma radiation did not affect female fecundity. Moreover, Nahar et al., (13) observed that irradiation of guava fruit fly, *Bactrocera correcta* pupae before emergence with 30 Gy and mating non-irradiated females with the resulting irradiated males did not affect the production of eggs.

The present study aimed to evaluate the effects of gamma radiation on the productive potential and embryonic development of *M. domestica*. Most invertebrates have been shown to be more radiosensitive than vertebrates (2). The degree of radiosensitivity varies greatly within a single species (individual radiosensitivity) while for a definite individual, it depends on the age and sex (14).

The sterility index of *M. domestica* females resulting from irradiated pupae was increased as the dosage of gamma radiation increased. Compared to the sterility percentage in controls (0.0%) gamma radiation resulted in a progressive increase in the sterility % of all different treatments. The highest sterility % occurred when irradiated females were crossed with irradiated males or when non-irradiated females were crossed with irradiated males. The complete sterility (100%) occurred at 12 Gy when irradiated females crossed with irradiated males. These results are consistent with those obtained by *Musca autumnalis*, where Mansour (6) found that sterility in gamma radiation-treated males and females increased as radiation dosage increased. Puanmanee and Wongpiyasatid (15) also
reported an increase in sterility of *Bactrocera correcta* when treated males were crossed with untreated females and the sterility % was increased as the gamma dosage increased.

The results of the present study revealed that *M. domestica* males were more radiosensitive than females, where a high sterility % of 97.1 occurred when males resulting from pupae irradiated with 12 Gy were crossed with normal untreated females, compared to 0.0% in controls. These results are comparable with those obtained by Khan and Islam (5), where they reported that *M. domestica* could be manipulated affectively by the irradiation of newly emerged adults from 5 to 10 Gy and concluded that males of houseflies are more radiosensitive than their female counterparts. The current study indicated that sterility of *Lucilia cuprina* was increased with increasing dose to reach 100 % at 30 Gy, and males were affected by semi-sterility at 25 Gy (7). Similar results were reported by Karunamoorthy and Lalitha (16) in *L. cuprina*.

Compared to the lethality of eggs (non-hatched eggs) in controls (0.7%), gamma radiation resulted in a progressive increase in egg lethality giving an estimated LD$_{50}$ values of 3.039, 9.728 and 3.213 Gy in eggs laid by irradiated females crossed with irradiated males, in eggs laid by irradiated females crossed with normal males, and in eggs laid by normal females crossed with irradiated males; respectively. Also, the percentage of non-hatched eggs increased from 0.7 in controls to 61.7, 92.7 and 100 for eggs laid by irradiated females crossed with normal males, irradiated males crossed with normal females and irradiated females crossed with irradiated males at the dose of 12 Gy; respectively. These results indicate that male houseflies are more radiosensitive than their female counterparts. A similar conclusion was reported by Khan and Islam (5) when they irradiated the adult houseflies, *M. domestica* with gamma radiations (0-10 Gy). Attempts to induce sterility or egg lethality in the dipterans by employing various doses of gamma radiation yielded varying results, mainly because of varying dose rate applied to eggs, immature stages, pupae or adults (17, 18). For example sterilization dose for females and males of *Anopheles quadrimaculatus* was 130 Gy (19). Newly-eclosed female adults of *M. domestica* were completely sterilized at 30 Gy (17). However, the present study has shown that complete sterility in the houseflies when both irradiated males and females were mated at the dose of 12 Gy. Pranson and Sutantawond (20) reported the dose of gamma radiation for sterilization of *B. correcta* to be 60 Gy, which gave a high percentage of sterility in males, but caused no egg laying in females. Nahar et al. (13) irradiated *B. cucurbitae* pupae before emergence with 30 Gy and observed that the mating of non-irradiated females with irradiated males did not affect the production of eggs, but egg viability was reduced to 0.93 %.

**4- CONCLUSION**

Gamma radiation effects on the development of the houseflies, *M. domestica*. The highest sterility and non-hatched eggs percentages occurred when the pupae were irradiated with high doses such as 10 and 12 Gy. Males were more radiosensitive than their female counterparts. Consequently, these radiation doses are consistent with those used in the already established SIT programmes against *M. domestica*.

**REFERENCES**


