# Effect of Irradiation on Growth and Development of Pulse Beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae)

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## Abstract

Laboratory experiment was carried out to estimate the effects of gamma radiation from Cobalt-60 source on different developmental stages (egg, larvae, pupae and adult) of *Callosobruchus maculatus* (F.) at 27 ± $3^0$C and 48 ± 5 % relative humidity (RH). Five different doses (0, 20, 40, 60 and 80 Gray) were used against different immature stages of *C. maculatus*. Eggs (Two and four days old), larvae (eight and twelve days old), pupae (fifteen and eighteen days old) along with mung bean seeds were irradiated at a dose of 0, 20, 40, 60 and 80Gy respectively. Data was recorded daily for about a month after irradiation. There were 5 treatments and each treatment was repeated thrice. Complete randomized design (CRD) was used for the said experiments. A dose of 20Gy caused complete mortality in two days old eggs whereas 100 percent mortality of four days old eggs of *C. maculatus* was experienced at 40Gy. Similarly, a dose of 80Gy caused 100 percent mortality in eight days old larvae and 92.50 mean percent mortality in twelve days old larvae. The data further showed that a dose of 80Gy caused 95.34 per cent mortality in fifteen days old pupae and 88.50 percent in eighteen days old pupae. Freshly emerged mated pairs of *C. maculatus* were also irradiated at a dose of 0, 200, 400, 600 and 800Gy respectively. Low dose of 200 Gy caused 18% mortality while the rest were deformed and unable to mate and lay eggs. A 100 percent mortality of the adults were observed at 800Gy. It is evident from the study that gamma irradiation is effective in controlling the main insect pest of pulses and can be used as a safe method to control store grain pests.

Keywords: Pulse beetle, Gamma Irradiation, Pulse, Dose response, Mortality

## Introduction

Legumes are one of the important food sources of amino acids, essential oils with high digestion ratio, less flatulence effect and are used for therapeutic purposes (Fery *et al.*, 2002). Due to antidotal activity they have also been used as medical or cosmetic material since ancient time (Sharma and Mishra, 2009). Among pulses, Mung bean (*Vigna radiata* L.; Fabaceae) is an important pulse crop which humans consumed as seed and animals consumed as hay worldwide (Mogotsi, 2006). Mung bean occupy important place as animal food, having high nutritional value due to crude lipids, amino acids, ash and crude protein (Ullah *et al*., 2014).

Mung bean plant is rich in protein, have high fiber content and essential oil acid, minerals such as vitamins, phosphorus and calcium. Moreover, this plant has higher energy value than other legumes (Wiryawan *et al.*, 1995). The bean plant has high adaptation ability against drought conditions and grow well on soil characterized by lack of essential nutrients (Beebe *et al.*, 2013).

Legumes grains are more prone to insect pests damages due to poor storage facilities especially in rural areas and more than 50 percent of the grain losses occurred due to different insect pests during storages (Bhatia and Sethi, 1976). The most important insects which infect pulses during storage belongs to the order Coleoptera and family Bruchidae. Pulse beetles attack extensive variety of pulses and the point of infestation depends on their inclination to different legumes (Shivanna, 2006). These bruchids not only consumed the grains but also destroy the quality of grains and making these grains unfit for human consumptions and also unfit for sowing. Pest-ridden seeds if sown, result in poor germination and anomalous seedlings (Raemaekers, 2001).

Different bruchids attack variety of legumes, among them the most important is pulse beetle, *Callosobruchus maculatus* and is mostly found infesting mung bean (*Vigna radiate*), Cowpea (*V. unguiculate*) and Chickpea (*Cicer arietinum*). The beetle infestation occurred both in field and during storage (Ahmad *et al*., 2003; Moravvej and Abbar, 2008). The Pulse beetle, *C. maculatus* lays eggs in stored grain products and gives us undesirable losses (Pascual-Villalobos and Ballesta-Acosta, 2003). When the eggs of bruchids hatches the larva of bruchids bores inside the grain and continuous to feed to reach to pupae. After completing pupal stage, the adult emerges from grain. Once the grains are infested, they rapidly multiply, resulting high damage losses to grains (Gill and Pajni, 1989). Yield losses up to 90% have been reported in cowpea seeds and make marketing value of mung bean unprofitable and unattractive (Diop and Marchioni, 1997).

To control this pest, the growers mostly opt for use of synthetic insecticides like fumigants (Methyl bromide or phosphine) for the disinfestation of mung bean on commercial basis (Mbata *et al*., 2004). However, during storage the use of chemical for controlling store grain insect pests leave toxic residue in grain which resulting health hazards, pollute the ecosystem and pest develops resistance against chemicals. By direct mixing of chemical for controlling insect pest during storage of grains are tenacious and the grains along with chemical (toxic dust) may prove dangerous for human health at a time of handling. A number of store grain pests have developed resistance against different group of chemicals like fumigants, organophosphates and pyrethroid (Reddy and Reddy, 1998). The usage of pesticides and its associated influence on the environment has needed consideration of alternate source of pest control methods (Phillips *et al*., 2000)

In recent years, gamma radiation has been used as an alternate of chemicals to control pest population in stored products. Unlike chemical control or fumigation methods, irradiation is highly perceptive, does not leave any residues which are toxic to health and the insect pests do not developed resistance. To prevent the storage losses, irradiation is highly effective in controlling all developmental stages (egg, larvae, pupa and adult) of store grain insect pests (Ignatowicz, 2004). Irradiation has been recommended as a potential quarantine treatment to control various insect pests including codling moth, seed weevils, fruit fly and various store product insect pests etc. (Hallman, 2001). Control of stored grain insect pests with gamma irradiations are gaining popularity among the consumers due to no residual effect in grains. With this method, the food products remain safe for longer time during storage (Hasan and Khan, 1998). The Joint Expert Committee of WHO, FAO and IAEA stated that the store product treated with a dose up to 1000Gy are healthful to stored grain pests and have no presence of any residue which are hazard to health (Anonymous, 1981).

Several researchers have used radiation technique in their experiment and successfully controlled pest populations. A dose of 100Gy is sufficient to make the *C. maculatus* adults sterile (Shashi *et al*., 2008). Similarly, Fawki *et al*. (2018) recorded a 100% mortality of cowpea beetle *C. maculatus* when adults were irradiated with Cobalt 60 gamma radiations at a dose of 70Gy. This technique offers a residue free method of controlling pests of stored products (Ignatowicz, 2004). Therefore, the present research was carried out to study the effect of gamma radiations on growth and development of pulse beetle, *C. maculatus* under lab conditions.

## MATERIALS AND METHODS

The study regarding the effect of gamma radiation on the different developmental stages of pulse beetle (*Callosobruchus maculatus*) was carried out at Nuclear Institute for Food and Agriculture (NIFA) Peshawar.

### Colonization of collected pulse beetle

The insect culture already present in the laboratory was mass cultured on mung bean seeds in a glass jar at 27 ± $3^0$C and 48 ± 5 % relative humidity (RH). The glass jar was covered with a piece of muslin cloth. When sufficient numbers of adults were obtained, various experiments were initiated.

### Effect of gamma irradiation on eggs

In this experiment, newly emerged adults of pulse beetle (*C. maculatus*) were collected from the reared colony and were released in a jar carrying fresh mung bean grains for oviposition. After 24 hours, the adults were removed. Grains carrying eggs were transferred to three different jars, each with 50 eggs per jar served as three replicates of the experiment. After two days, these jars carrying the eggs were exposed to gamma radiation from a Cobalt 60 source at a dose rate of 0, 20, 40, 60 and 80Gy. Post irradiated sample were kept at room temperature of 27±$3^0$C and 48±5% relative humidity (RH). Same procedure was also applied to 4 days old eggs. After radiation, the grains were checked daily for one month. Data on the eggs hatched was recorded daily.

**Effect of gamma irradiation on larvae**

Ten pairs of newly emerged adults of pulse beetle were released in glass jar containing mung bean seeds for oviposition. After sufficient egg laying, the adults were removed from the grains and eggs were checked daily for emergence of larvae and infestation of mung bean seeds. After 8 days of larval feeding (8 days age), 150 infested grains (50 grains per replicate) carrying larvae were collected in a jar and exposed to gamma radiation from Cobalt 60 source at doses of 0, 20, 40, 60 and 80Gy. The following day of the treatment, the grains were dissected and the larvae thus removed were released in Petri dishes (1 cm tall and 9 cm diameter) carrying fresh grains. The Petri dishes were then kept at 27±3$^0$C and 48±5% relative humidity (RH). Same procedure was also repeated with 14 days old larvae of pulse beetle. The data on larval mortality and impact on other developmental stages was recorded daily for one month.

**Effect of gamma irradiation on pupa**

For this experiment, ten pairs of newly emerged adults of pulse beetle were released in glass jar containing mung bean seeds. The adults were allowed for egg laying. After sufficient number of eggs laying, the adults were removed and eggs were observed for hatching and then larval development. After 15 days of larval emergence, 150 grains (50 grains per replicate) carrying pupae were collected in jars and exposed to gamma radiation from Cobalt 60 source at doses of 0, 20, 40, 60 and 80Gy. On the following day of the treatment, the grains were dissected and the pupae thus removed were released in Petri dishes (1 cm tall and 9 cm diameter) carrying fresh grains. The Petri dishes was then kept at 27±3$^0$C and 48±5% relative humidity (RH). Same procedure was also repeated with 18 days old larvae of pulse beetle. The data on pupal mortality and impact on their development to adult stages was recorded daily for one month.

### Effect of irradiation on adults

Newly emerged adults of pulse beetle *C. maculatus* were collected from infested mung bean jar carrying reared colony. These adults were then sexed and released in three different jars at the rate of 50 adults (25 male and 25 female) per jar as a replicate. These jars carrying adults of pulse beetles were exposed to gamma radiation from Cobalt 60 at a dose of 0, 200, 400, 600, 800Gy. After treatments, these adults were released in petri dishes (1 cm tall and 9 cm diameter) carrying mung bean seeds. The petri dishes were then kept at 27±3$^0$C and 48±5% relative humidity (RH). The data on the number of eggs laid and adult mortality was recorded daily for one month.

### Statistical analysis

The data obtained was analyzed using Statistix 8.1 computer software. Means were compared using LSD test at 5 % level of significance ($P < 0.05$).

## RESULTS

### Effect of irradiation on 2 days old egg of *Callosobruchus maculatus*

The data (Table -1) showed the effect of various doses of gamma radiations on 2 days old eggs of *C. maculatus* and other subsequent stages. Data showed that the various doses of the gamma radiations significantly affected percent egg hatching as compared to the control i.e. significantly maximum eggs hatching was recorded at 0Gy (97.33%), Similarly, percent larvae and pupae formation and percent adult emergence after eggs irradiation of *C. maculatus* were significantly high from eggs treated at 0Gy by recording 94.000% larvae formation, 91.33% pupae and 88.00% adult emergence. Eggs treated with higher doses i.e. 20, 40, 60 and 80Gy showed no signs of hatching.

**Table 1.** Effect of various doses of gamma irradiation on 2 days old eggs and other subsequent stages of *Callosobruchus maculatus*

| Treatments (Gy) | Eggs hatching (%) | Larvae formed (%) | Pupa formation (%) | Adult emergence (%) |
|---|---|---|---|---|
| **0** | 97.33±0.66a | 94.00±1.154a | 91.33±0.66a | 88.00±1.15a |
| **20** | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b |
| **40** | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b |
| **60** | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b |
| **80** | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b | 0.00±0.00b |

Means in column followed by the same letters are not significantly different, the values are means of three replicates ± standard error, egg hatching, larvae formed, pupae formation and Adults, emergence were statistically analyzed separately.

**Effect of irradiation on 4 days old egg of *Callosobruchus maculatus***

Effect of gamma radiation on 4 days old eggs of *C. maculatus* are shown in Table- 2. The experiment showed that as the radiation doses increases, the percent eggs hatchability of *C. maculatus* decreased. It was found that the highest percent eggs hatched was recorded at zero exposure followed by 20Gy radiation dose by recording 25.33% while no eggs were hatched at 40, 60 and 80Gy doses of radiations. Significantly high number of larvae formed after eggs radiation at 0 (93.33%) and 20Gy (20.00%). The percent pupae formation after eggs radiation was significantly high at 0Gy (92.33%) while eggs treated with 20, 40, 60 and 80Gy showed no sign of pupae formation. Furthermore, the percent adult emergence after eggs radiation was noted maximum at 0Gy (90.00%).

**Table 2.** Effect of various doses of gamma irradiation on 4 days old eggs and other subsequent stages of *Callosobruchus maculatus*

| Treatments Gy | Egg hatching (%) | Larvae formed (%) | Pupa formed (%) | Adult emergence (%) |
|---|---|---|---|---|
| 0 | 96.66±1.76a | 93.33±2.40a | 91.33±1.33a | 90.00±1.15a |
| 20 | 25.33±2.90b | 20.00±2.30b | 0.00±0.00b | 0.00±0.00b |
| 40 | 0.00±0.00c | 0.00±0.00c | 0.00±0.00b | 0.00±0.00b |
| 60 | 0.00±0.00c | 0.00±0.00c | 0.00±0.00b | 0.00±0.00b |
| 80 | 0.00±0.00c | 0.00±0.00c | 0.00±0.00b | 0.00±0.00b |

Where, means carrying same letter in a column is not significantly different, the values are means of three replications ± standard error, eggs hatching, larvae formation, pupa formation and adult emergence were statistically analyzed separately.

**Effect of gamma radiation on 8 days old larvae of *Callosobruchus maculatus***

Data regarding the effect of various doses of gamma radiation on 8 days old larvae of *C. maculatus* is presented in Table- 3. The results revealed that with increasing radiation doses, the percentages of irradiated larvae mortality were found on increasing trend, the lowest larvae mortality (6.66%) was recorded at 0Gy while the highest larvae mortality (100%) was recorded at 80Gy which was significantly different from that of control. Similarly, the pupae formation from irradiate larvae was significantly lower at irradiation dose of 80Gy (0.00%) while highest pupae formation (93.33%) were recorded from larvae exposed to 0Gy. The percent pupae formation from larvae exposed to 20, 40, and 60Gy recorded 44.00%, 24.00% and 4.66% pupae respectively. Maximum adults emergence after larvae irradiation was recorded from 0Gy (90.66%).

**Table 3.** Effect of various doses of gamma irradiation on 8 days old larvae and other subsequent stages of *Callosobruchus maculatus*

| Treatment (Gy) | Larval mortality (%) | Pupa formation (%) | Adult emergence (%) |
|---|---|---|---|
| 0 | 6.66 ±1.33d | 93.33±1.3 a | 90.66±1.76a |
| 20 | 56.00 ± 3.4 c | 44.00 ±3.46b | 0.00±0.00b |
| 40 | 76.00±1.1b | 24.00± 1.15c | 0.00±0.00b |
| 60 | 95.33 ±1.76a | 4.66± 1.7d | 0.00±0.00b |
| 80 | 100.00 ±0.00a | 0.00 ±0.00d | 0.00 ±0.00b |

Where, means carrying same letter in a column is not significantly different, the values are means of three replications ± standard error, larval mortality, pupa formation and adult emergence were statistically analyzed separately.

**Effect of gamma irradiation on 12 days old larvae of *Callosobruchus maculatus***

Data regarding the effect of various doses of gamma radiation on 12 days old larvae of *C. maculatus* is presented in Table- 4. Mortalities of 12 days old *C. maculatus* larvae were found to vary directly with the radiation doses. Larval mortalities of 12 days old larvae following irradiation at 0, 20, 40, 60 and 80Gy were 13.5, 23.00, 55.00, 72.00 and 92 % respectively. The pupae formation from irradiate larvae was significantly lower at irradiation dose of 80Gy (7.5%) while highest pupae formation (86.004%) were recorded from larvae exposed to 0Gy. The percent pupae formation from larvae exposed to 20, 40, and 60Gy recorded 77.00, 45.00 and 28.00% pupae respectively. Maximum adults emergence after larvae irradiation was recorded from 0Gy (83.5%).

**Table 4.** Effect of various doses of gamma irradiation on 12 days old larvae and other subsequent stages of *Callosobruchus maculatus*

| Treatment (Gy) | Larval mortality (%) | Pupa formation (%) | Adult emergence (%) |
|---|---|---|---|
| 0 | 13.50 ± 0.95e | 86.00 ± 1.41a | 83.5 ± 1.25a |
| 20 | 23.00 ± 1.29d | 77.00 ± 1.29b | 0.00 ± 0.00b |
| 40 | 55.00 ± 1.29c | 45.00 ± 1.29c | 0.00 ± 0.00b |
| 60 | 72.00 ± 2.16b | 28.00 ± 2.1d | 0.00 ± 0.00b |
| 80 | 92.50 ± 1.50a | 7.50 ± 1.5e | 0.00 ± 0.00b |

Where, means carrying same letter in a column are not significantly different, the values are means of four replicates ± standard error, larval mortality, pupae formation and adult emergence were statistically analyzed separately.

**Effect of gamma irradiation on 15 days old pupae of *Callosobruchus maculatus***

Data regarding the effect of various doses of gamma radiation on 15 days old pupae of *C. maculatus* is presented in Table- 5. The data showed that the percent mortality of irradiated pupae increase as the irradiation doses increase, the percent mortality of pupae after irradiation was significantly high at 80Gy (95.33%) and significantly low (7.33%) at control (0Gy). Other treatments of gamma radiations i.e. 60, 40, and 20Gy resulted in 81.33%, 64.00% and 42.60% mean percent mortality respectively. The percent adult emergence after irradiation pupae was noticed significantly minimum at radiation treatment of 80Gy (4.66%) and significantly maximum when pupae were exposed at 0Gy (92.66%) while in other treatments it was 57.3% at 20Gy, 36.00% at 40Gy and 18.60% at 60Gy respectively.

**Table 5.** Effect of various doses of gamma irradiation on 15 days old pupae and other subsequent stages of *Callosobruchus maculatus*

| Treatments Gy | Pupa mortality (%) | Adult emergence (%) |
|---|---|---|
| 0 | 7.33±1.763a | 92.667±1.7a |
| 20 | 42.667±2.40b | 57.333±2.4b |
| 40 | 64.000±4.16c | 36.000±4.16c |
| 60 | 81.333±2.40d | 18.667±2.4d |
| 80 | 95.333±1.76e | 4.6667±1.76e |

Where, means carrying different letter in a column varied significantly different, the values are means of three replications ± standard error, pupa mortality and adult emergence were statistically analyzed separately.

**Effect of gamma irradiation on 18 days old pupae of *Callosobruchus maculatus***

Data regarding the effect of various doses of gamma radiation on 18 days old pupae of *C. maculatus* is presented in Table- 6. The result showed that there was significant difference among all doses. The data showed that the percent mortality of irradiated pupae increase as the irradiation doses increase. The percent pupal mortality was significantly high (88.50%) at 80Gy followed by 60 and 40Gy (63% and 58% respectively) while at 20Gy, 36.00% pupal mortality was recorded. The percent adult emergence after irradiation pupae was noticed significantly minimum at radiation treatment of 80Gy (11.50%) and significantly maximum when pupae were exposed at 0Gy (93.33%) while in other treatments it was 64.00% at 20Gy, 42.00% at 40Gy and 27.70% at 60Gy respectively.

**Table 6.** Effect of various doses of gamma irradiation on 18 days old pupae and other subsequent stages of *Callosobruchus maculatus*

| Treatments (Gy) | Pupa mortality (%) | Adult emergence (%) |
|---|---|---|
| 0 | 6.66 ± 1.33d | 93.33 ± 1.33a |
| 20 | 36.00 ± 4.16c | 64.00 ± 4.16b |
| 40 | 58.00 ± 8.00b | 42.00 ± 8.00c |
| 60 | 63.00 ± 7.00b | 27.00 ± 3.00cd |
| 80 | 88.50 ± 4.92a | 11.50 ± 4.92d |

Means in column followed by the same letters are not significantly different, the values are means of three replicates ± standard error, pupal mortality and adult emergence were statistically analyzed separately.

**Effect of Gamma irradiation on adults of *Callosobruchus maculatus***

Table- 7 shows the effect of gamma radiation on adult mortality of *C. maculatus* and fecundity after radiation at 0, 200, 400, 600 and 800Gy respectively. It was recorded that as the radiation doses increase, the percent adult mortality also increase and fecundity of adults decrease. Percentages of adults mortality at 0, 200, 400, 600 and 800Gy were 0.60, 18.00, 84.00, 94.00 and 100 % respectively. The percent adult mortalities at every dose after irradiations were found to be significantly different as compared to control. Furthermore, after irradiation dose, the percentage of eggs laid by females was significantly maximum (92.00%) at 0Gy while no eggs were laid after treated the adults at 200, 400, 600 and 800Gy respectively.

**Table 7.** Effect of various doses of gamma radiation on adult mortality and fecundity of *Callosobruchus maculatus*

| Treatments (Gy) | Adult mortality (%) | Fecundity (%) |
|---|---|---|
| 0 | 0.66 ±0.66e | 92.00±2.08a |
| 200 | 18.00 ±1.15d | 0.00±0.00b |
| 400 | 84.00 ±1.15c | 0.00±0.00b |
| 600 | 94.00 ±1.15b | 0.00±0.00b |
| 800 | 100 ±0.00a | 0.00±0.00b |

Where, means carrying different letter in a column varied significantly different, the values are means of three replicates ± standard error, adult mortality and fecundity were statistically analyzed separately.

## DISCUSSION

This research was conducted to study the effect of gamma irradiation on developmental stages of pulse beetle (*C. maculatus*) (Coleoptera; Bruchidae) at Plant Protection Division of Nuclear Institute for Food and Agriculture (NIFA) Peshawar. Five gamma radiation doses were tested on the egg, larvae, pupae and adult stages of *C. maculatus*. In the present experiment it was observed that 2 days old eggs of *C. maculatus* is highly susceptible to Cobalt 60 gamma radiation doses at 0, 20, 40, 60 and 80Gy as compared to 4 days old eggs. Hatchability of 2 days old and 4 days old eggs of *C. maculatus* were found to be varying directly with the increase in radiation doses. In this experiment, the percent eggs hatching and subsequent stages from 2 days old eggs of *C. maculatus* were completely ceased at 20Gy and higher dose, whereas 4 days old eggs required at least 40Gy to inhibit the percent eggs hatching, larvae formed, pupa formation and adults emergence. It was observed that 2 days old eggs of *C. maculatus* were highly susceptible to irradiation doses as compare to 4 days old eggs. The above conclusion was in agreement with Shivanna (2006) findings who reported that only 10 percent eggs of *C. maculatus* were hatched after treated with 5Gy while there were no eggs hatching at 10Gy and above. The present results were also in agreement with Ghogomu (1990), and Kansu (1989) findings, who observed that no eggs were hatched when 24-48 hours old eggs of *C. maculatus* were treated at doses higher than 10Gy.

Results on larval mortality and subsequent stages of *C. maculatus* on 8- and 12-days old larvae after gamma irradiation treatments showed that 12 days old larvae showed more radio-tolerance than 8 days old larvae after gamma irradiation treatments. For 8 days old larvae, the percent larval mortality of *C. maculatus* was significantly high (100%) at 80Gy and significantly low at 0Gy whereas 12 days old larvae showed a little more resistance than 8 days old larvae by recording 92.5% mortality at 80Gy. It was also observed that percent pupae formation and adult emergence from 8- and 12-days old larvae after irradiation was significantly low at 80Gy. Molin (2001) in his experiment also reported that 8-day old larvae were more sensitive to irradiation as compared to the 16-day old larvae. These findings were in agreement with Shivanna (2006) who reported that 6-8 days old larvae of *C. maculatus* when irradiated at 25Gy and above could not complete their developmental stage. Aye *et al*. (2006) reported that when fifth-instar larvae were irradiated at 0.25kGy, pupation did not occur. These results also showed similarity to those of the findings of Fontes *et al*. (2003) who investigated that improvement of *C. maculatus* adults from radiated pupae was absolutely control by 25Gy applied at a rate of 23.6Gy/min.

Our findings showed that with increasing irradiation doses, the percent pupal mortality of 15- and 18-days old pupae of *C. maculatus* increased. It was observed that the 18 days old pupae were more resistant to gamma irradiation doses as compared to 15 days old pupae of *C. maculates.* The percent pupal mortality of 15 days old pupae was significantly maximum at 80Gy (95.34%), whereas the percent pupal mortality of 18 days old pupae was significantly minimum than 15 days old pupae after irradiation at 80Gy (88.50%). It was further observed that from 18 days old the adult emergence after pupae irradiation was significantly low at 80Gy (88.50%) than 15 days old were (95.33%) at 80Gy. The results showed that 15 days old pupae were more susceptible to gamma irradiation than 18 days old pupae. Soumya *et al*. (2017) also stated that at a dose of 80Gy cause 95 percent mortality of four days old pupa of *C. chinensis*. These findings were also in agreement with Gill and Pajni (1991) findings, who reported that at a radiation dose of 35Gy caused 100 percent mortality of early stages pupae however older pupae from 14 to 18 days old, still not completely destroyed by treatment at dose of 8 Krad (80Gy) but make the pupa sterile and could not complete inhibition of adult emergence. For pupae to adults, emergence it was observed that the percent adult emergence was significantly high at 0Gy and significantly minimum at 80Gy. The exceeding conclusion were in agreement with Fontes *et al*. (2003), who investigated that the development of *C. maculatus* adults from irradiated pupa was completely control by 25Gy applied at a rate of 23.6Gy/min. Similar results, were also found by Kansu (1989) and Gill and Pajni (1991), who reported that by increase the gamma radiation dose the adult emergence from irradiated pupae were significantly decrease. They observed that when pupa, were irradiate at 100Gy the percent adult emergence was 7.4 percent respectively.

Data regarding the percent adult mortality of *C. maculatus* in Table-7 showed that the percentages of adult, mortality at 0, 200, 400, 600 and 800Gy were 0.6, 18.0, 84.0, 94.0 and 100 % respectively. As compared to control, the percent adult mortalities at every dose after radiation were found to be significantly different. Similar result was reported by Supawan *et al*. (2005) who showed that after irradiation a dose of 800Gy, the *C. maculatus* adult show 100 percent mortality. The present study was also an agreement with Sutantawong (1991) findings, who observed that a dose of 1000Gy *C. maculatus* show 100 percent mortality after irradiation.

It was also observed that various doses of gamma radiations significantly affect the fecundity of the adults. The percent adult fecundity was significantly high at 0Gy and no egg were laid by *C. maculatus* adult after a radiation dose of 200, 400, 600 and 800Gy respectively. The above result was an agreement with Supawan *et al*. (2005), who reported that a dose of 80Gy give 100% sterility in *C. chinensis*. Similar results were also recorded by Sutantawong (1991), who observed that at a dose of 60 to 80Gy irradiation is sufficient to make the *C. maculatus* female sterile. Similarly, Tandon *et al*. (2009) studied the effect of different doses of gamma irradiation against adults and immature stages of red flour beetle, *Tribolium castaneum* and reported that irradiation dose of 70Gy and above make the insect completely sterile. Our result also showed similarity with the finding of Bannu *et al*. (2006), who reported that, a dose of 15Gy caused infecundity in female and sterility in male of *Tribolium castaneum*. Costa and Arthur (2004) also studied the effect of gamma irradiation on different stages of *Ceratitis capitata* and found that a dose of 50Gy and above make freshly emerging adult of *Ceratitis capitata* uncapable of mating and laying egg.

## Conclusion

The results of our experiment revealed that Gamma irradiation can competently control the *Callosobruchus maculatus* infestation in mung bean. A dose of 80 and 100Gy were much better for disinfesting for all the developmental stages (egg, larvae, pupae). A dose of 800Gy was found effective against adults of pulse beetle, *C. maculatus* in mung beans after irradiation Based on our conclusion, it is recommended that gamma irradiation is an effective method in controlling the *Callosobruchus maculatus* infestation in mung bean and can be used against other stored grain insects pests.

**Conflict of interest statement:** The authors declare that they have no conflict of interest.

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