Academic Journal of Entomology 11 (2): 29-35, 2018
ISSN 1995-8994

DOI: 10.5829/idosi.aje.2018.29.35

Radiation Effects on Adult Emergence, Longevity and Fertility in the Peach Fruit Fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae)

[1]*M. Nazim Uddin,* [2]*G. M. Saifur Rahman,* [3]*A. T. M. Fayezul Islam,*
[3]*M. Hasanuzzaman and* [3*]*Farzana Yesmin*

[1]Directorate of Secondary and Higher Education, Dhaka, Bangladesh
[2]Life and Earth Science Group, National University, Gazipur, Bangladesh
[3]Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Bangladesh Atomic Energy Commission (BAEC), Ganakbari, Savar, GPO Box 3787, Dhaka 1000, Bangladesh

Abstract: Radiation effects on adult emergence, longevity and fertility in the peach fruit fly, *Bactrocera zonata* (Saunders) at 3.5 Kr were studied in the laboratory condition to see the probabilities of sterile insect technique (SIT) for its fruitful application in field application. SIT is applied in integrated pest management program against tephritid fruit flies. In this paper, three parameters of irradiated *B. zonata* were evaluated for the possible use of SIT within the management of this pest. Pupae of *B. zonata* were irradiated at 3.5 Kr one day before emergence and corresponding control were kept as non-irradiated control group. A significant effect (F=5.12, df=1, P=0.04) on adult emergence on both male and female was observed with the irradiated group whereas some negative effects on longevity and fertility of the peach fruit fly were found. Mortality rate was higher in newly emerged adults. Maximum number of irradiated males were died in week 4 (Mean=5.00) following the week 3 (Mean=3.33) and week 5 (Mean=2.67). The female irradiated flies were died high in number in week 5 (Mean= 2.50). The average of longevity for the control groups was 90 days longer than the irradiated groups that took 56.16 days. The irradiated groups of *B. zonata* showed no fertility, *i.e.* no progeny where non-radiated control groups had positive response of fertility. The present study supports the possibility of *B. zonata* management/or eradication at radiation dose 3.5 Kr in SIT.

Key words: Radiation Dose · Fruit Flies · Tephritidae · *B. zonata* · Sterile Insect Technique (SIT)

INTRODUCTION

The Tephritid fruit flies (Diptera: Tephritidae) are the most devastating insect pests having a foremost impact on global agricultural products, effecting yield losses and decreasing the market value of horticultural crops. In addition, these flies are amongst the main persistent pest species of fruits and vegetables in the world due to direct and indirect economic malignity for their damaging effects on the specific crop species [1]. They are important pests of different cucurbit vegetables such as sweet gourd, ribbed gourd, snake gourd, bitter gourd, cucumber, kakrol, etc. grown in our country [2] where five species of *Dacus* (*Bactrocera*, tephritid fruit fly, Family- Tephritidae) attacking 16 host plants in Bangladesh [3]. Often more than 50 per cent of the vegetables are either partially or totally damaged and rendering them unfit for human consumption [4]. In Indian subcontinent, eighty seven species of the genus *Bactrocera* caused heavy damage to fruits and vegetables in Asia [5].

A preliminary survey showed that fruit fly infested a large amount of quality fruits including banana, mango, guava, papaya, citrus fruits, litchi, pineapple and some seasonal vegetables in Bangladesh [6]. A general estimate predicted that up to 10 to 15% of crops are destroyed by fruit flies every year [7].

The genus *Bactrocera* is regarded as a serious threat of horticultural crops because of the wide host range of its species and the invasive power of some species within the genus. Some of them have been introduced outside of their native Asian range [8]. *Bactrocera* spp.

Corresponding Author: Farzana Yesmin, Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Bangladesh Atomic Energy Commission (BAEC), Ganakbari, Savar, GPO Box 3787, Dhaka 1000, Bangladesh.

are of particular concern in most part of Asia and Australia, where they constitute a significant threat to agricultural resources [9, 10]. About 440 species of this genus is distributed principally in tropical Asia, South Pacific and Australia [11].

The peach fruit fly, *Bactrocera zonata* (Saunders), is a serious polyphagous pest that attacks over 50 cultivated and wild plants in many parts of the world [12, 13, 14]. This fruit fly is native to Asia and mainly occurs in Southeast Asia, India, Pakistan, Mauritius, the Maluku Islands, Sri Lanka and Thailand. This species was firstly reported as *Dacus zonatus* (sunders) infesting custard apple [15]. It was further reported as *D. zonatus* infesting apple from Bangladesh [16]. At present, it is a significant horticultural pest in India and Pakistan [17] and it primarily attacks peach, mango, guava, apricot, fig and citrus [12, 13]. In Egypt, B. zonata became a serious pest since 90s of the last century attacking a wide range of fruits that differ in their ripening time stage all over the year [18, 19]. Although the species has not been introduced to the European continent yet, it has been included in the A1 list of pests, which the European and Mediterranean Plant Protection Organization (EPPO) recommend to be regulated as quarantine pests [20].

Traditional chemical control measures using insecticides experience inconvenience such as residual problems and limited penetrate power of insecticides in the infested fruits to kill larvae [21]. The goal of SIT is to minimize the growth rate of target population by impregnating the wild females by releasing mass reared sterile males [22]. Gamma irradiation is currently the most common method used to sterilize mass reared males for SIT [23] and effectiveness of SIT depends greatly on the production of good quality sterile males that are released into target wild populations. The aim of our study is to analyse the effects of gamma radiation on three parameters of *B. zonata* i.e. adult emergence, longevity and sterility at radiation dose 3.5 Kr under laboratory condition.

MATERIALS AND METHODS

Fruit Fly Stock Culture: Laboratory cultures of *B. zonata* (Saunders) were maintained in the fruit fly laboratory, Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Savar, Dhaka. Adult flies were reared in a steel frame cage (12×10×8 cm) covered with nylon net. The culture was usually supplied with yeast extract and sugar (1:3) as adult food media and water as soaked cotton. Temperature and relative humidity (RH) of the rearing room were maintained at 25± 2°C and 65-70% respectively.

Pupae Collection and Irradiation: The larvae of *B. zonata* were kept in plastic bowl with saw dusts at the bottom for pupation. The saw dusts were sieved after pupation for the collection of dust free pupae. One hundred and eighty (180) fresh pupae of same age (6 day old/ one day before emergence) were transferred into test tubes and irradiated in a Co^{60} gamma irradiator of the Institute of Food and Radiation Biology (IFRB), AERE, Savar, Dhaka at 3.5 Kr. The dose was imposed in six replication groups in two different days (three replications in each day). Each replication group contained thirty pupae and six control batches were also maintained with thirty pupae in each batch.

Adult Emergence and Survival Counts: In control groups the pupae were reared in the same process but no radiation was applied. Each replication batch of pupae was placed in separate rearing cage. The emergence of adults was checked and their survival rates were recorded daily for consecutive seven days interval and also the number of dead fruit flies was recorded. The percentage and average of adult emergence was calculated based on the number of adults emerging from pupae and survival numbers were counted by calculating alive and dead adults in every week from each rearing cages.

Collection of Eggs and Fertility Test: In each cage, bananas were provided to facilitate the mature females to lay their eggs. After a certain period, bananas were in kept in bowl for further development.

Data Analysis: Data were analyzed by statistical software (Microsoft office, version 2007). Analysis of Variance (ANOVA) was calculated by using IBM SPSS software, version 24.

RESULTS AND DISCUSSION

Adult Emergence: The effect of radiation on adult emergence rate of peach fruit fly *B. zonata* has shown in the Figure 1. In non-irradiated control groups, 96% of adult had emerged and 90% of adult emerged from the irradiated pupae. There was a significance difference in case of adult emergence rate in both male and female (F=5.12, df=1, P=0.04) in irradiated fruit fly groups. The average emergence rate of control groups male and female

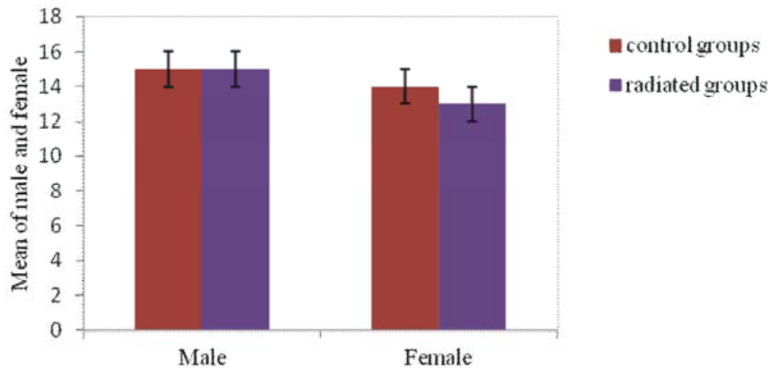

Fig. 1: Adult emergence from control and irradiated *B. zonata* (Bar graph shows the mean of adult emergence from the pupa).

was 49% and 46% where the irradiated groups male and female were 49% and 41% respectively, providing a positive result for SIT. It supports the result of Mahmoud *et al.* [24] and Zahran *et al*. [25].

Longevity: The longevity of peach fruit fly *B. zonata* was studied in terms of weekly and monthly mortality rates. Maximum number of irradiated males were died in week 4 (Mean=5.00) following the week 3 (Mean=3.33) and week 5 (Mean=2.67). The female irradiated flies were died high in number in week 5 (Mean=2.50) and in week 9 (Mean=2.17). In control groups, the highest number of dead male flies was recorded in week 6 (Mean=2.33) and female was in week 3 and in week 4 (Mean=1.67 for each week). The weekly mortality rate was highly significant in both irradiated male and female (male: F=6.35, df=11, P=0.00; female: F=3.82, df=11, P=0.00). The weekly mortality of control groups male and female flies were different in every weeks (male: F=3.20, df=14, P=0.00; female: F=1.91, df= 14, P= 0.03) (Table 1). Similar results were reported for irradiated *Anastrepha suspense* [26]. They observed that females treated with low radiation doses (15, 20 and 25 Gy) had higher or similar survival rates to the control whereas the higher radiation doses (30, 50 and 70 Gy) caused significantly more mortality.

Tukey HSD test showed that in weekly mortality, in case of control male week 6 and week 11 had the significant results (P=0.00 and P=0.01) respectively where as the control female flies demonstrated the non significant result in every weeks. On the other hand in irradiated groups the male flies manifested the significant mortality in week 3 and week 4 (P=0.01 and P=0.00) respectively and female flies recorded the same result in week 5 and week 9 (P= 0.00, P= 0.01). In control group mortality was high in week 6 and 11 in male flies where week 1 and 2 no flies were dead at all; on contrast irradiated male flies were died maximum in week 3, week 4 and week 5. The highest number of irradiated female was died in week 6 (Figure 2).

In monthly mortality, in case of irradiated male flies there were a significant difference in the month of September and October (F= 14.17, df=1, P=0.00) but in female the mortality showed the opposite result in both months (F=0.01, df=1, P=0.91) (Table 2). The maximum number of irradiated male flies died in September (Mean=2.88) but the female flies were in October (Mean=1.29) (Figure 3). On the other hand in control groups male flies showed the significant result in the month of September and November (F=2.98, df=2, P=0.05) and the female flies demonstrated the converse result in the whole three months (F=0.06, df=2, P=0.93) (Table 2). The greatest number of both male and female flies were died in the month of November (Mean=1.38 and Mean=1.04 respectively) (Figure 4). It is evident from the experiment that females lived longer than males. This was true for both control and irradiated flies.

The maximum longevity was 90.00 days in control groups where both male and female could alive in 87.66 days. In irradiated groups the average longevity was 56.16 days. The male flies in these groups were subsistent in 50.83 days and the female flies were stayed alive in 56.16 days. It followed the result of Nahar *et al*. [27]. They irradiated *B. cucurbitae* at different doses. In 3.00 Kr dose of radiation, the male and female mortality rate was 98% and 92% respectively where in 4.00 Kr dose the result was 96% and 94% respectively.

Sterility: Sterility determination of *B. zonata* at 3.5 Kr in both control groups and the irradiated groups mature adult (4 weeks in age) rearing cages were provided banana as larval natural food sources. After six hours the banana were removed and kept in plastic bowl covering a piece of

Table 1: Weekly mortality of *B. zonata* shows in the ANOVA table at 3.5 Kr

Name of groups		Sum of Squares	df	Mean Square	F	Sig.
Control	Male	30.667	14	2.190	3.200	.001
	Female	20.622	14	1.473	1.910	.038
Irradiated	Male	152.093	11	13.827	6.352	.000
	Female	41.476	11	3.771	3.826	.000

Table 2: Monthly mortality rate of irradiated and control groups *B. zonata* at 3.5 Kr

Name of groups	Sum of Squares	df	Mean Square	F	Sig.
Radiated male	58.521	1	58.521	14.171	.000
Radiated female	.021	1	.021	.013	.911
Control male	5.028	2	2.514	2.986	.057
Control female	.111	2	.056	.063	.939

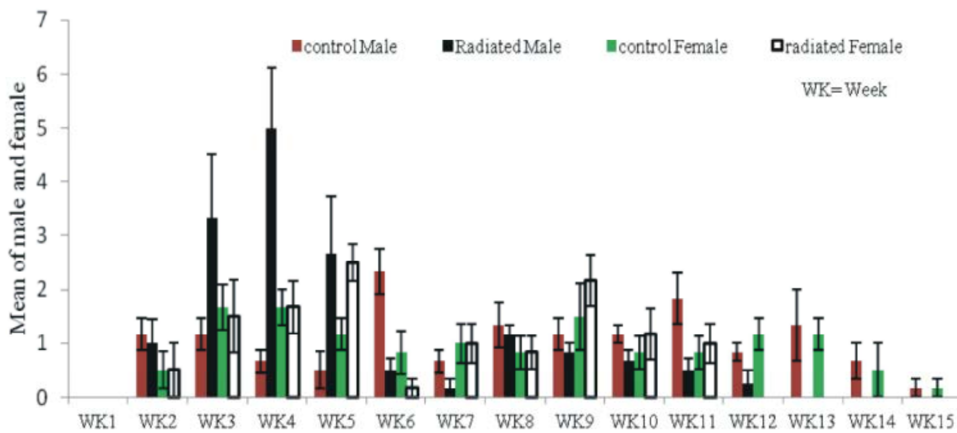

Fig. 2: Weekly mortality of male and female in both control and irradiated groups of *B. zonata* at 3.5 Kr (Bar graph shows the mean number of mortality)

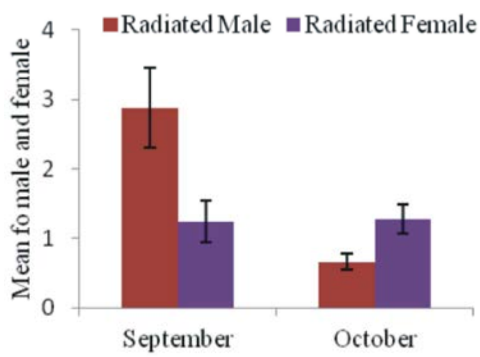

Fig. 3: Monthly mortality of radiated groups of *B. zonata* at 3.5 Kr

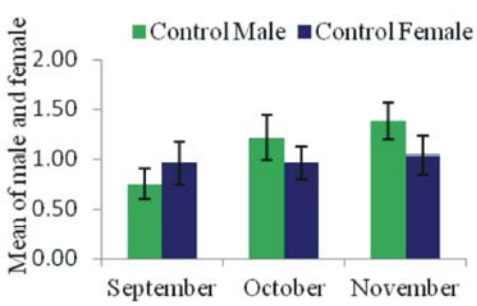

Fig. 4: Monthly mortality rate of control groups *B. zonata* at 3.5 Kr

white musline cloth. From the control cages viable eggs were found that hatched and emerged larva in due time but in case of irradiated adults no viable egg was found in any adult cages. Our result supported that a dose to induce total sterility of fruit fly males was a little lower ranging from 40-60 Gy, for example 40 Gy was recorded for *B. cucurbitae* [28] 50 Gy for *A. suspense* (Loew) [29] and *B. zonata* [30] or 60 Gy for *A. obliqua* (Macquart) [31]. In general, the sterility dose of males seems to differ from laboratory to laboratory. These differences may be due to a type of irradiator cells, methodology of assay, genus of flies, age of irradiated pupae, as well as fitness of laboratory strains tested. It also followed the result of Yesmin *et al*. [32] where they irradiated *B. cucurbitae* at the same dose and no progeny was found when they cross the irradiated male and female.

A dose of only 30 Gy resulted in completely sterile flies with minimal effects on quality or effectiveness [33]. Other authors also observed the lack of egg production in irradiated females, but radiation dosage was not the same for all of them, probably due to the variation of the dose rate used and/or different ages (Stages) of pupae for irradiation [26, 33, 34]. For many fruit fly species, optimal doses of gamma radiation were successfully determined for sterilization [35, 36]. However, in selecting an optimal sterilization dose for SIT, an equilibrium position is needed to reach between the levels of sterility and mating competitiveness of males [37, 38]. Insects that receive a too low dose are not sufficiently sterile and those that receive a too high dose may be uncompetitive. So augmenting the effectiveness of SIT it requires a greater number of sterile insects must be released. It appears to be a general consensus that the irradiation process negatively effects the total competitiveness of males [39] and that one simple way to lessen this impact and thereby to increase the effectiveness of SIT, is to reduce the sterilizing dose [40]. In general, data from our laboratory condition demonstrate that the effect of irradiation on peach fruit fly was consistent with the results for other tephritid fruit fly species.

Radiation effects on the developmental stages of *B. zonata* are less studied in Bangladesh. Irradiation is comparatively easy to study in pupal stage rather than other three stages of the life cycle of this fly. In this study, we applied 3.5 Kr radiation dose, because, in our laboratory [27, 32] 3.5 Kr is an established sterility dose for *B. cucurbitae* and also in another dipteran species, *Lucilia cuprina* [41].

CONCLUSION

The present study could contribute to the sterile insect technique (SIT) program against the peach fruit fly, *Bactrocera zonata* . The results indicate that similar to other dipteran species 3.5 Kr could be the appropriate dose of gamma radiation for sterilization program in terms of adult emergence, fertility and longevity of *B. zonata*. Further study is going on to optimize the radio-sensitivity of this pest in fruit fly lab of the institute (IFRB).

ACKNOWLEDGEMENTS

Fellowship to MNU from National University, Gazipur, Bangladesh is gratefully acknowledged. The study is undertaken under the TWAS Research Grant Scheme 16-062 RG/BIO/AS_I –FR3240293325. This project is running in the Radiation Entomology and Acarology Division of IFRB, AERE, Savar, Dhaka under FY as Principal Investigator.

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