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Inherited sterility in Mediterranean flour moth *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae): Effect of gamma radiation on insect fecundity, fertility and developmental period

Abdurrahman Ayvaz*, Sevil Albayrak, Aydın Ş. Tunçbilek

Science and Art Faculty, Department of Biology, Erciyes University, 38039 Kayseri, Turkey

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Abstract

The effects of gamma radiation on the fecundity, fertility, longevity, development and level of inherited sterility in the Mediterranean flour moth *Ephestia kuehniella* were determined. Newly emerged virgin Mediterranean flour moth adults were irradiated with 100, 200, 400 and 600 Gy in a ^{60}Co irradiator with a source strength of ca. 3811 Ci and a dose rate of ca. 1 Gy/min. Laboratory studies revealed that radiation did not effect the longevity of irradiated male and female adults. Inherited deleterious effects of gamma radiation were observed in the F_1 and F_2 generations. Fecundity and the daily egg laying pattern of irradiated and unirradiated females mated to irradiated males was not significantly different from untreated controls. Adverse effects of gamma radiation were observed in the percentage egg hatch and rate of development. Levels of sterility in the P_1, F_1 and F_2 generations were higher than that of untreated controls. The doses of radiation also had a significant effect on the time from oviposition to larval eclosion or adult emergence. Mortality increased with radiation dose. The incidence of larval and pupal mortality was higher in the F_2 than in the F_1 generation.

Keywords: *Ephestia kuehniella*; Inherited sterility; Gamma radiation; Sterile insect technique

1. Introduction

The use of sterile insect release technique (SIRT) has been proposed as a means of controlling phycitine moths that attack stored agricultural products (Brower, 1974, 1975; Brower and Tilton, 1975), and many advantages for its successful use to control isolated populations within storage structures have been enumerated. Inherited sterility was discovered by Proverbs (1962) in the codling moth and has since been documented in many lepidopterous pests of economic importance (Saour and Makee, 1997). Lepidopteran females generally are much more sensitive to radiation than males of the same species. This may allow the dose of radiation to be adjusted so that treated females are completely sterile and males are partially sterile (Carpenter et al., 2001). When partially sterile males are outcrossed with wild fertile females, the adverse radiation-induced effects are inherited by the F_1 generation. As a result, egg hatch is reduced and the F_1 offspring produced are both highly sterile and predominately male. The lower dose of radiation used in this technique increases the quality and competitiveness of the released moths (North, 1975). Not only is the sterility effect increased, but the production of F_1 sterile offspring can enhance the build-up of native natural enemies that attack the insect pest (Carpenter et al., 1996). The potential for using F_1 sterility as a component of regional management of lepidopteran pests has been suggested by Knipling (1970) and LaChance (1985), and numerous laboratory-based studies on pests around the world have demonstrated the effectiveness of the technique (LaChance, 1985). An alternative to using completely sterile moths in SIRT is the use of partly sterile males. The resulting F_1 progeny are more sterile than the irradiated parent moths and the males are more competitive than completely sterile males as a result of receiving a lower dose of radiation (Seth and Sharma, 2001). It is

*Corresponding author. Tel.: +90 352 4374937/33068; fax: +90 352 4374933.
E-mail address: ayvaza@erciyes.edu.tr (A. Ayvaz).

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reported that population suppression by release of partially sterilized females only is probably ineffective, but if both partially sterilized males and females are released, control would be as good as or better than that obtained from the release of treated males alone (Brower, 1981). The study presented here was designed to evaluate the effect of releasing either partially sterilized males alone or both partially sterilized male and female parents on the reproductive performance of the Mediterranean flour moth (MFM) *Ephestia kuehniella* Zeller.

2. Materials and methods

2.1. Insect culture

The MFM culture was obtained from the Department of Plant Protection, Faculty of Agriculture, Ankara University. *Ephestia kuehniella* larvae were reared using a mixture consisting of 1 kg wheat flour, 55 g yeast and 30 g wheat germ (Marec et al., 1999). Throughout the experiments, insect cultures were maintained at constant temperature ($27 \pm 1\,^{\circ}C$), 14L:10D photoperiod and $60 \pm 5\%$ relative humidity (r.h.).

2.2. Irradiation of E. kuehniella adults

Newly emerged virgin adults were segregated by sex and aged 24 h before irradiation. A ^{60}Co irradiator (Theratronics 780 C) with a source strength of ca. 3811 Ci and a dose rate of ca. 1 Gy/min was used to administer doses of 0, 100, 200, 400 and 600 Gy.

2.3. Effect of gamma radiation on MFM

Immediately after treatment, test adults were transferred to plexiglas cylinders and mated in two combinations, treated male × treated female (TM × TF) and treated male × untreated female (TM × UF). Untreated males and females were mated to serve as controls. Three replicates (each of 10 pairs) were used for each dose level and controls in P and F_1 generations to assess effects on fecundity, fertility, adult emergence, sex ratio and longevity. An additional 15 pairs of TM × TF and TM × UF were set up to investigate the effect of irradiation on the daily egg laying pattern of females mated with irradiated males. The moths were allowed to mate and lay eggs in special plexiglas cylinders until their deaths were recorded. Eggs were collected in Petri dishes placed under the cylinders. After oviposition, eggs from each combination were placed in glass Petri dishes that had a centre well made by ringing a central area with glue and allowing the glue to dry. Rearing medium to provide food for the newly emerged larvae was placed in the Petri dish around the centre well. Egg hatch was counted daily until it dropped to zero and the food containing hatched larvae was then transferred to 300 ml glass jars containing ca. 150 g of rearing medium, which were incubated at the rearing conditions. The number and sex of emerging F_1 adults were determined daily until no more adults emerged from the diet. The growth index (% adult eclosion/total developmental period) for each treatment was calculated. Three replicates of 10 pairs of the emerged F_2 adults were set up to ascertain their fecundity (total number of eggs laid) and percentage hatch of eggs.

2.4. Statistical analysis

Data from the experiments (number of eggs laid, egg hatch, adult emergence, developmental period, growth index) were subjected to analysis of variance (ANOVA) using SPSS (2001) for Windows. Percentage data were transformed using arcsine $\sqrt{x}$ before ANOVA. Means were separated at the 5% significance level by the least significant difference (LSD) test.

3. Results

3.1. Effects of gamma radiation on fecundity, fertility, adult emergence and sex ratio of TM × UF crosses

The fecundity of adult females mated to treated males was not significantly affected by the radiation dose in the P, F_1 and F_2 generations (for P, $F = 1.027$, df = 8; $P = 0.452$; for F_1, $F = 0.720$, df = 3, $P = 0.568$ and for F_2, $F = 0.156$, df = 2, $P = 0.859$) (Table 1). Fertility (i.e. the proportion of eggs that hatched) decreased with increasing doses of radiation in P, F_1 and F_2 generations when treated (T) males were mated to untreated (U) females (for P, $F = 261.432$, df = 4, $P < 0.001$; for F_1, $F = 220.060$, df = 2, $P < 0.001$ and for F_2, $F = 29.056$, df = 2, $P < 0.001$). These results suggest that the deleterious effects from treatment in the P generation were still present in the F_2 population. However, the radiation-induced sterility in the F_2 generation was generally lower than in the F_1 at the 100 Gy dose, indicating partial recovery of fertility.

Percentage hatch of eggs laid by untreated females mated to irradiated males decreased from 92.0% in the untreated control to 8.3% at 400 Gy. All irradiated male adults were completely sterile at 600 Gy (Table 1). When percentage egg hatch for the *P* generation was corrected using Abbott's formula (Abbott, 1925), sterility values became 13.4%, 32.6% and 91.0% for males treated with 100, 200 and 400 Gy, respectively. The percentage of F_1 and F_2 progeny that survived to adulthood was inversely related to the dose of radiation administered to the male parent. Decreased adult emergence was more evident in the F_2 than in the F_1 generation ($F = 39.685$; df = 4; $P < 0.001$) (Table 1). The corrected mortality values were 10.0%, 46.6% and 100% for the F_1 generation when males were treated with 100, 200 and 400 Gy, respectively. Although the sex ratio of F_1 adults shifted from 1.06:1 (male:female) in untreated controls to 1.52:1 and 1.29:1 in favour of males at 100 and 200 Gy, respectively, a male-biased sex ratio was not observed in F_2 adults (Table 1).