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Effect of high-temperature pre-irradiation on reproduction and mating competitiveness of male *Sitotroga cerealella* (Olivier) and their F_1 progeny

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Abstract

Pupae of the Angoumois grain moth*,* *Sitotroga cerealella* (Olivier) were irradiated with substerilizing doses of 150, 180 and 210 Gy of gamma radiation. Inherited deleterious effects due to irradiation of P males irradiated as pupae were recorded for F_1 progeny. The radiation damage increased when pupae were kept at high temperature (32.5 °C) for 24 h before irradiation, where a marked reduction in fecundity and egg hatch was obtained among P males and their F_1 progeny. This reduction was significantly increased by increasing the dosage. F_1 progeny were more sterile than the irradiated parent generation, though F_1 males were more sterile than F_1 females. Also, the combination of high temperature and irradiation applied to parental male pupae decreased larval survival and percentage of F_1 female progeny, whereas it did not affect the mating frequency among P males and F_1 progeny at the tested doses. Laboratory mating competitiveness indicated that parental males heat-treated with 32.5 °C and irradiated with 150, 180 and 210 Gy and their F_1 progeny were fully competitive with their untreated siblings.

Keywords: *Sitotroga cerealella*; Temperature; Gamma irradiation; Inherited sterility; Competitiveness

1. Introduction

The Angoumois grain moth, *Sitotroga cerealella* (Olivier) is a serious pest of grains and causes damage in the field and during harvest and storage. Two important factors that contribute to the pest status of the moth include its ability to develop resistance to insecticides and the tendency of larvae to feed inside grains, thus achieving an additional measure of protection from direct contact with insecticides. These considerations highlight the need for effective new methods to control *S. cerealella*. Among these are physical control measures such as high temperature or gamma radiation (Cogburn et al., 1966; White, 1981; Boshra, 1983; Alrubeal, 1987).

Knipling (1970) first demonstrated the potential advantage of inherited sterility over the sterile male technique. Al-Taweel et al. (1993) and Pransopon et al. (2000), studied the effects of substerilizing doses of radiation and inherited sterility in lepidopterous pests. The combined effect of high temperature and gamma irradiation on sterility of treated insects was studied by Singh (1973), North (1975) and Al-Zahaby et al. (1997).

The aim of the present study was to determine the effects of substerilizing doses of irradiation at the pupal stage on reproduction in *S. cerealella* and on the mating competitiveness of P (parental) males of *S. cerealella* irradiated as pupae and their F_1 progeny. In addition, the effect of high temperature (32.5 °C) applied for 24 h before irradiation to pupae on reproduction and mating competitiveness of P males and F_1 progeny was assessed.

2. Materials and methods

Test moths were obtained from laboratory cultures reared on wheat at 26 ± 1 °C and 85 ± 5% r.h. Pupae of Angoumois grain moth (48 h before emergence) were selected according to Boshra (1983) and were irradiated

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with 0, 150, 180 and 210 Gy from a 60 Co-irradiator with a dose rate of 0.33 Gy/s. Each kernel containing a pupa was kept separately in small glass tube and held at the rearing conditions. After emergence irradiated (I) males were paired with unirradiated (U) females (I × U), also unirradiated (U) males with unirradiated (U) females (U × U). Five replicates were used for each combination with three pairs for each replicate. Each jar contained a black zigzag paper as an oviposition site and was covered with muslin secured with rubber band. The eggs deposited in each replicate were collected daily, counted, recorded and placed on black paper circles in separate Petri dishes containing rearing medium for determining percentage egg hatch. After 7 days, each female was dissected to determine the number of spermatophores in its bursa copulatrix (mating frequency).

F_1 newly hatched larvae from each treatment were kept in groups of 100 in glass jars provided with wheat. Rearing continued until pupation when each kernel containing a pupa was removed and kept separately in a glass tube until adult emergence. The newly emerged males and females of F_1 progeny were paired with untreated adults of the opposite sex or with each other according to the following combinations, UM × UF (0, control), $F_1M \times UF$, $UM \times F_1F$, $F_1M \times F_1F$. Five replicates of three pairs were set up for each combination as described above. The effects on larval survival, sex ratio, fecundity, egg hatch and mating frequency were estimated.

For studying the combination effect of high temperature and gamma irradiation treatments, full grown pupae were exposed to high temperature (32.5 ± 1 °C) for 24 h inside controlled incubators and were then irradiated with 0, 150, 180 and 210 Gy. The same number of pupae were treated only with high temperature at 32.5 ± 1 °C for 24 h before transfer to 26 ± 1 °C, and another group of unirradiated pupae were held continuously in an incubator at 26 ± 1 °C and 85 ± 5% r.h. as a control. In these tests each kernel containing a pupa was kept separately in a small tube. Newly emerged adult males resulting from the treatments of pupae with high temperature and/or irradiation were paired with unirradiated females, and also unirradiated males and females were mated together as a control. The same steps were used in each case to estimate fecundity, egg hatch and mating frequency in P males and the F_1 progeny. Also F_1 larval survival and sex ratio were recorded. The data obtained were statistically analyzed by Duncan's multiple range test.

For studying mating competitiveness of irradiated P males and their F_1 progeny, pupae were irradiated with 150, 180 and 210 Gy. After adult emergence, irradiated (I) and unirradiated (U) males were caged with unirradiated (U) females in ratios of IM:UM:UF, 0:1:1 control, 1:0:1, 1:1:1 and 5:1:1. The same ratios were used for F_1 males in the combination F_1M:UM:UF and to study F_1 female competitiveness using F_1 females instead of F_1 males, F_1F:UF:UM. Each group was replicated 15 times and egg hatch was recorded.

To determine the combined effect of irradiating heat-treated pupae with substerilizing doses of gamma irradiation on the mating competitiveness of the resulting P males and F_1 progeny, pupae were exposed to 32.5 °C and then irradiated at 150, 180 and 210 Gy. The same combination and ratios as for the irradiation treatment were used to study the mating competitiveness of the resulting P males, F_1 males and F_1 females. Expected egg hatch and competitiveness values (CVs) were computed according to Fried (1971). CVs near to 1.0 indicate full competitiveness and those higher than 0.75 indicate good competitiveness.

3. Results and discussion

A significant reduction in egg hatch occurred when pupae were irradiated, and the reduction was most obvious when the P males was irradiated as pupae with 210 Gy (50% sterility). The high dosage also decreased the number of eggs laid per female, although the average number of spermatophores per female was not significantly affected (Table 1). The percentage of F_1 larvae that survived to the adult stage was significantly decreased as the dose applied to P males increased. The sex ratio of the emerging F_1 adults was skewed in favor of males (Table 2). The effect of irradiation in the F1 generation was evidenced by a significant reduction in fecundity and egg hatch (Table 3), indicating lower reproductive activities than those of the parental cross, although the number of spermatophores at the three tested doses did not differ from the control. The greatest effect of irradiation was expressed with F_1 female × F_1 male or with F_1 male × U female from a P I male × U female at 210 Gy. A similar result was reported by Carpenter et al. (1989) on *Heliothis zea* (Boddie),

Table 1
Effects of gamma irradiation on reproduction of P male adults when *S. cerealella* were irradiated as pupae

Dose (Gy)	Crosses (Male × female)	Eggs/female (% of control)	Egg hatch (% of control)	Av. no. of spermatophores/female
0	U × U	100 a	100 a	2.48 ± 0.35 a
150	I × U	95.24 a	66.16 b	2.72 ± 0.59 a
180	I × U	69.40 b	54.86 b	2.50 ± 0.41 a
210	I × U	74.61 b	50.07 c	2.31 ± 0.48 a

0, control; I, irradiated; U, unirradiated.
Means followed by the same letter in each column are not significantly different ($P > 0.05$; Duncan's multiple range test).