


---

OVICIDAL EFFECTS OF GAMMA RADIATION ON EGGS OF THE FULLER ROSE BEETLE, *PANTOMORUS CERVINUS* (COLEOPTERA: CURCULIONIDAE)

Susan A. Coats  
University of Florida, IFAS  
Citrus Research and Education Center  
700 Experiment Station Road  
Lake Alfred, Florida 33850

Mohamed A. Ismail  
Florida Department of Citrus  
Citrus Research and Education Center  
700 Experiment Station Road  
Lake Alfred, Florida 33850

ABSTRACT

Gamma radiation effects on Fuller rose beetle, *Pantomorus cervinus* (Boh.), eggs were evaluated. Two age ranges of 1-5 and 6-12 day-old eggs were subjected to irradi-
ation doses of 0.075, 0.150, and 0.300 kilo Gray (kGy). Three trials were replicated with
a minimum of 50 eggs per dose per age per trial. One hundred percent mortality of all
1-5 day-old eggs was affected by all three irradiation doses. No egg hatch was observed
for the 6-12 day-old eggs irradiated with 0.30 kGy. A statistically insignificant percent
of hatch of 6-12 day-old eggs irradiated with 0.075 and 0.150 kGy occurred (16.3 and
0.10%, respectively). Dose was highly correlated to mortality.

**Resumen**

Se evaluaron los efectos de radiación gama sobre huevos del escarabajo de la rosa,
*Pantomorus cervinus* (Boh.). Huevos de 1-5 y de 6-12 días de edad se sometieron a
dosis de radiaciones de 0.075, 0.150, y a 0.300 kilo Gray (kGy). Se replicaron tres
ensayos con un mínimo de 50 huevos por dosis por edad por ensayo. Un 100% de
mortalidad de todos los huevos de 1-5 días se obtuvo por las tres dosis de radiaciones.
No se observó eclosión de ningún huevo de 6-12 días de edad radiados con 0.30 kGy.
Ocurrió un porcentaje estadísticamente insignificante de eclosión de huevos de 6-12 días
de edad radiados con 0.075 y 0.150 kGy (16.3 y 0.10% respectivamente). La dosis estuvo
altamente correlacionada a la mortalidad.

The Fuller rose beetle, *Pantomorus cervinus* (Boheman), is widely distributed
throughout the world and has a wide range of hosts including citrus (Anonymous 1966).
The beetle has a propensity for laying the majority of its eggs under the calyx of citrus
fruit (Coats & McCoy 1989), which has created a major problem for the U.S. citrus
industry. Japan has refused to accept any infested fruit, establishing a zero tolerance
for viable rose beetle eggs on fresh fruit imported into their country by 1990. This policy
has necessitated the implementation of reliable, highly effective, quarantine treatments.
Fumigation by the Japanese at the port of entry with methyl bromide (MeBr) has
resulted in large monetary losses to the U.S. citrus industry. Not only is fumigation
costly, but MeBr phytotoxicity causes rapid fruit deterioration (Hancy et al. 1987,
Anonymous 1988). Furthermore, the use of chemical pesticides is not favorably received
by the consuming public. The U.S. Environmental Protection Agency banned ethylene
dibromide in 1987 and is requiring the re-registration of MeBr. There is currently no
quarantine treatment available to the U.S. citrus industry against Fuller rose beetle.

Numerous studies have shown radiation to be a reliable quarantine treatment for
control of insects in fruits and vegetables. Koidsumi (1930) first determined x-rays could
be successfully applied to effect mortality of insects in fruits in quarantine. Balock &
Christenson (1956) found both x-rays and gamma radiation to be effective in killing
fruit-infesting insects. Subsequent research detailed the dosages required to effect mor-
1984, McMullen & Yeager 1982). A range of 0.06-0.76 kilo Gray (kGy) (1 kGy = 100
kRad) was determined as the effective insect-disinfestation doses for almost all insects
(Kader 1986).

Major radiation costs are due to the transportation of the products to and from the
radiation facility, and the cost of irradiation itself is very dependent on the throughput.
Costs of a cobalt-60 facility operated for 8000 h/yr can be as low as $5 cents/kg of product
per 10 kGy dose and 1,000,000 tons of output, or as high as $3.50/kg for the same dose
and only 2,000 tons of output (Brynolfsson 1989). The feasibility of radiation is proven
by the fact that 38 operational facilities already exist in 24 countries, including four in
the U.S. The most extensive operation was established in Shihoro, Japan in 1973 and
currently has a monthly capacity to process 10,000 tons of potatoes (Matsuyama &
Umeda 1983).
Because gamma irradiation has been proven to be an effective, safe, and potentially economical quarantine treatment for fruit-infesting insects, the present study was designed to evaluate gamma radiation as an ovicidal treatment for Fuller rose beetle eggs.

**Materials and Methods**

Three separate radiation trials were completed. Because variable sensitivity of eggs has been demonstrated, 1 to 5 and 6 to 12 days old were used. These age ranges were chosen so the pre-hatch period of the Fuller rose beetle eggs could be evaluated. (Egg hatch generally begins on day 15 at 28°C and a buffer for earlier hatch at 13 and 14 days was allowed.) Also, because variable sensitivity of eggs has been demonstrated, at least two age ranges were necessary to evaluate this sensitivity in the Fuller rose beetle.

Three replications each consisting of a minimum of 50 eggs per dose per trial were used with each age. Eggs laid by adults on wax paper strips were collected, counted, and placed on a 20 ml screen mesh. This screen mesh was suspended above 1 cm of distilled water in presterilized 7 dram plastic vials. The vials were capped and irradiated at the U.S.D.A., A.R.S., Subtropical Horticultural Research Station in Miami, Florida. The eggs were subjected to three doses of gamma radiation from a cobalt-60 source by the application of a constant amount of radiation for a variable amount of time in minutes. Because the cobalt-60 source decayed over the period of the three tests, the 0.075, 0.150, and 0.300 kGy doses were accomplished by exposing the fruit to: 0.16927 kGy/min in test 1 on 28 September 1988 for 0.443 min, 0.886 min, and 1.772 min, respectively; 0.16742 kGy/in in test 2 on 20 October 1988 for 0.448 min, 0.896 min, and 1.792 min, respectively, 0.16397 kGy/in in test 3 on 29 June 1989 for 0.489 min, 0.978, and 1.956 min, respectively. These doses are equivalent to those received by carton fruit in commercial radiation facilities (von Windeguth & Ismail 1987). Two controls were used: A static control (CS), maintained at Lake Alfred, Florida and a mobile control (CM), transported with the treated eggs.

All eggs were maintained in an environmental growth chamber at 28°C, 24 h scotophase and 100% RH. Mortality was evaluated by counting the number of eggs that did not produce larvae within 3 weeks after the last of the larvae had emerged from the controls. The number of eggs that did not produce larvae were divided by the total number of eggs irradiated to give the mortality percentages. Significant differences among all treatment and control means were evaluated by general linear model procedures and Duncan's multiple range tests (SAS Institute 1988).

**Results and Discussion**

One hundred percent mortality of all eggs occurred with the use of 0.300 kGy (Table 1). There was also 100% mortality of all young (1–5 day) eggs subjected to either 0.075 or 0.150 kGy. Sixteen and 0.1% of older (6–12 day) eggs hatched after being irradiated with 0.075 and 0.150 kGy, but these amounts were insignificantly different for dose x age (F = 0.70, df = 4, Pr > F 0.60). Other research has revealed variable susceptibility among the different developmental stages of an insect species. Cornwell (1966) found this was true for Ceratitis capitata (Weid). Additionally, different ages of the same stage were found to be variably sensitive. One to 3-day-old eggs of Gibbium psyllids (Czenpinsk) were prevented from hatching by cobalt-60 irradiation with only 0.0175 kGy. However, 0.10 kGy were required for 100% mortality of 5-day-old eggs, and 0.40 kGy was necessary for 7-day-old eggs of the same species (Brower 1979).

There was a 75% hatch of controls in trial 3, but only a mean of 35% survival for controls in trial 1 and 2. However, general linear model procedures established signifi
TABLE 1. OVICIDAL EFFECTS OF GAMMA RADIATION ON FULLER ROSE BEETLE EGGS

<table>
<thead>
<tr>
<th>Dose (kGy)</th>
<th>Egg age (days)</th>
<th>No. eggs</th>
<th>No. emerging larvae</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (CS)*</td>
<td>1-5</td>
<td>539</td>
<td>829</td>
<td>39.0 a*</td>
</tr>
<tr>
<td></td>
<td>6-12</td>
<td>381</td>
<td>190</td>
<td>50.1 a</td>
</tr>
<tr>
<td>0 (UM)**</td>
<td>1-5</td>
<td>512</td>
<td>241</td>
<td>52.9 a</td>
</tr>
<tr>
<td></td>
<td>6-12</td>
<td>333</td>
<td>117</td>
<td>64.9 a</td>
</tr>
<tr>
<td>0.075</td>
<td>1-5</td>
<td>629</td>
<td>0</td>
<td>100.0 b</td>
</tr>
<tr>
<td></td>
<td>6-12</td>
<td>552</td>
<td>90</td>
<td>83.7 b</td>
</tr>
<tr>
<td>0.150</td>
<td>1-5</td>
<td>564</td>
<td>0</td>
<td>100.0 b</td>
</tr>
<tr>
<td></td>
<td>6-12</td>
<td>500</td>
<td>1</td>
<td>99.9 b</td>
</tr>
<tr>
<td>0.300</td>
<td>1-5</td>
<td>611</td>
<td>0</td>
<td>100.0 b</td>
</tr>
<tr>
<td></td>
<td>6-12</td>
<td>519</td>
<td>0</td>
<td>100.0 b</td>
</tr>
</tbody>
</table>

*Data are comprised of total amounts for three tests consisting of at least 50 eggs/replication and three replications/dose/age/trial except for controls which were replicated once in trial 1, and three times in tests 2 and 3.

**Average percent hatch of all controls = 66.6% (CS) and 42.4% (UM).

Employing Duncan's multiple range test (SAS Institute 1988), controls were significantly different statistically from dose for all three tests at 0.05 level.

Significant differences between treatments and controls for all three tests (F1 = 10.01, df = 4, Pr > F = 0.0033; F2 = 7.44, df = 4, Pr > F = 0.001; and F2 = 55.9, df = 4, Pr > F = 0.001 for tests 1, 2, and 3, respectively). The difference between dose and control for all three tests combined revealed a very significant difference (F = 28.46, df = 4, Pr > F = 0.0001). Mortality for gamma irradiated eggs showed no significant differences between tests (F = 0.29, df = 2, Pr > F = 0.75).

Research has not focused only on the effective dosages required for insect eradication, but also examined the phytotoxic effects of irradiation on foods. Certain trends have emerged: ripener fruits are less prone to injury whereas fruits containing the highest percentages of water are more susceptible. However, doses of 0.04-0.60 kGy, which are proven effective in causing 100% mortality of *C. capitata* in oranges (*Citrus sinensis*) (Fesus et al. 1981) and 0.10-0.30 kGy, which controls *Anastrepha suspensa* (Loew) in grapefruit (*Citrus paradisi* Macf.) (Burditt et al. 1981), do not significantly alter fruit quality. Hatton et al. (1982, 1984), quantified rind injury to grapefruit at 1, 4, and 9%, at doses of 0.075, 0.15, and 0.30 kGy, thus, allowing them to still be marketed. These results were also reported by von Windeguth (1982). With only a 0.300 kGy dose of gamma radiation necessary to affect 100% mortality in all ages of Fuller rose beetle eggs, phytotoxic effects on fruit should not be of concern with this dose also adequate for the simultaneous eradication of the Caribbean fruit fly in grapefruit (von Windeguth & Ismail 1987). These results indicate that gamma radiation is one solution for a safe quarantine treatment for Fuller rose beetle eggs on export citrus.

ACKNOWLEDGMENTS

The authors wish to thank D. von Windeguth for irradiating all three groups of FRD eggs, Barry Rogers for assistance in the transport and mortality counts of these eggs, and H. N. Nigg, C. C. Childers, and H. W. Browning for reviewing this manuscript. We also thank C. Evans, J. Morris, P. Hicks, B. Thompson, W. Tomlinson, and T. Hardy of the Word Processing Department for the typing and editing of this manuscript.
Coats & Ismail: Ovicidal Effects of Gamma Radiation 241

This research was supported by grants from the Florida Department of Citrus (#38044), the California Department of Food and Agriculture (#88-0622, and the California Citrus Research Board (CRB-256-73-550).
Florida Agricultural Experiment Stations Journal Series No. R-00161.

REFERENCES CITED

GAMMA IRRADIATION FOLLOWED BY COLD STORAGE AS A QUARANTINE TREATMENT FOR FLORIDA GRAPEFRUIT INFESTED WITH CARIBBEAN FRUIT FLY

DONALD L. VON WINEDEGUTH AND WALTER P. GOULD
Subtropical Horticulture Research Station
Agricultural Research Service
U.S. Department of Agriculture
1301 Old Cutler Road
Miami, Florida 33158

ABSTRACT

‘Marsh’ white grapefruit, Citrus paradisi (Mae.), infested with eggs and larvae of Caribbean fruit fly, Anastrepha suspensa (Loew) were subjected to ionizing radiation at several low doses followed by cold (1.1°C) storage for 0 to 8 days. Data analyses indicated that an irradiation dose of 50 Gray followed by 5 days of cold storage will give in excess of probit 9 level of quarantine security. A test involving more than 100,000 insects infesting grapefruit confirmed the efficacy of this treatment.

RESUMEN

Frutas del cultivar ‘Marsh’ de toronja blanca infestadas por huevos y larvas de la mosca frutal del caribe, Anastrepha suspensa (Loew) fueron sometidas a irradiación de ionización a varias dosis bajas, seguidas por almacenaje frío (1.1°C) por períodos de 0 a 8 días. Análisis de los datos indicaron que una dosificación de irradiación de 50 gray seguida por 5 días de almacenaje frío producirá un nivel en exceso de probit 9 de seguridad cuarentenal. Un ensayo que envolvió más de 100,000 insectos que infestaron las frutas de toronja confirmó esta observación.

Following the ban by the Environmental Protection Agency (Ruckelshaus 1984) of ethylene dibromide (EDB) as a fruit fly quarantine treatment for grapefruit, Citrus paradisi (Mae.), many different treatment methods have been investigated. Benschoter (1983, 1984, 1987, 1988) reported on the effect of low temperature alone or in combination with modified atmospheres or fumigants on immature stages of the Caribbean fruit fly (CFF), Anastrepha suspensa (Loew) infesting grapefruit. Benschoter & Witherell (1984) presented data on the lethal effects of suboptimal temperatures on CFF. Gould (1988) published on combining hot water and cold storage as a CFF quarantine treatment. Because some of the preceding authors had reported a synergistic or enhancing effect of a given treatment when followed by low temperature (about 1°C), we decided to determine if low dose radiation (<150 Gy) followed by low temperature storage for a