EFFECTS OF GAMMA IRRADIATION ON THE MORTALITY OF THE CARIBBEAN FRUIT FLY IN GRAPEFRUIT

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Additional index words. Anastrepha suspensa, commodity treatment, quarantine-treatment.

Abstract. Three irradiation tests were conducted in the winter and spring of 1982 on Caribbean fruit fly infested 'Marsh' white grapefruit. Infested fruit were transported from Miami via Orlando, FL, to the Department of Energy, Sandia Laboratories, in Albuquerque, New Mexico. There the fruit were irradiated in a cesium137 pilot plant sewage sludge irradiator. Following return of the irradiated fruit to Miami the fruit was held in bioassay towers to determine the effects of the irradiation on the immature flies infesting the fruit. In all three replicates of the test, immature (pupae) were recovered from fruit following irradiation at 15 and 30 kilorads. No insects were recovered from fruit irradiated at 60 and 90 kilorads. Two adults emerged from the recovered pupae, one male at 15 krad and one female at 30 krad, both died before reproducing.

Grapefruit (Citrus paradisi Macf.) and other subtropical fruits grown in Florida are susceptible to infestation with immature stages of the Caribbean fruit fly, Anastrepha suspensa (Loew). Those fruits, when shipped to Arizona, California, Hawaii, Texas, Japan and some other areas, are presently fumigated with ethylene dibromide (EDB). Gamma irradiation is one of several treatments being investigated as a replacement for EDB fumigation.

Balock in 1956 (1) proposed the use of gamma irradiation on fruit shipped from Hawaii to U.S. mainland. Ionizing radiation has been investigated and reported on by Balock et al. in 1963 (2), Benschoter and Telich in 1964 (3), Shipp and Osborne in 1968 (10), Cava11oro and Delrio in 1971 (6), and Hatton et al. in 1973 (9), as well as many others. These researchers have shown that low dose levels of gamma irradiation are capable of killing or adversely affecting development of immature fruit flies.

A critical factor in the use of any treatment for the control of insects within a commodity is whether the treatment adversely affects the commodity. The effect may be only cosmetic, or it may influence shelf life, palatability or nutritive value. Phytotoxicity of gamma irradiation on grapefruit has been reported by Burditt et al. in 1981 (5) and Hatton et al. in 1982 (7).

In 1979 small scale tests were performed on infested grapefruit containing populations of ca. 1000 immature fruit flies per irradiation dose rate in a low dose Gammarad® irradiator. This irradiator had a capacity of only 2 medium size grapefruit at a time and a dose rate of ca. 1.2 krad/min at that time. Because of the apparent success of the 30 krad rate in these small scale tests we decided to transport large numbers of infested fruit to the Department of Energy's (DOE) Sandia National Laboratories and irradiate them in their cesium137 sludge irradiator. Following irradiation, fruit were transported back to Miami where they were held in bioassay towers for recovery of irradiated insects.

Materials and Methods

'Marsh' white grapefruit to be infested with fruit fly immatures and then irradiated were picked up at a packing house in the central Florida citrus region and brought to Miami about 1 wk before being transported to the irradiation site in New Mexico. In Miami, the fruit were removed from their cartons and placed in a screened outdoor infestation cage, containing ca. 100,000 gravid fruit flies. The grapefruit were laid out on wire racks and exposed to the ovipositing flies for ca. 6 days. The day before leaving for Orlando (en route to Albuquerque) the fruit were removed from the cage, cleaned and reboxed in shipping cartons. The ventilation slots in the sides, top and bottom of the cartons were covered with 32 mesh saran screening to prevent larvae from crawling out in the event that elevated temperatures speeded up larval development and some emerged from the fruit before returning to Miami. Upon arriving in Orlando the infested fruit were transferred to a special insulated compartment constructed in the rear of the refrigerated truck. The larger forward area, where the fruit for phytotoxicity study were transported, was maintained at a temperature of 50°F. The insect infested fruit had to be held at a temperature of about 70°F. At lower temperatures larval development would be delayed or halted; at higher temperatures insect development would be accelerated (8), and larvae would exit the fruit prior to irradiation or the return to Miami. To maintain a rear compartment temperature of 70°F, a fan forced resistance heater and/or heat lamps were added. These were powered by a converter during transit, or standard voltage through an extension while parked. To determine how much insect mortality or decrease in yield was due to handling and transport conditions of the trip, two sets of untreated controls were maintained. One set was retained in Miami in the bioassay towers. The other set went along on the truck and with the exception of not being irradiated, was handled the same as the fruit for irradiation.

The irradiator used in these tests is located at the Sandia Laboratories DOE facility. It is a pilot plant built for the irradiation of sewage sludge and consists of an endless chain of steel buckets (ca. 1 bushel capacity each) that makes a double pass over and under a 1 megacurie source of cesium137 located in an underground vault. In order to limit variation in gamma exposure it was necessary to irradiate the fruit in a single layer of no more than 8 grapefruit located in the center of the bucket. Dose variability was held to ca. ±15% (Table 1, standard deviation). For irradiation, the fruit were removed from the cartons and manually placed in the buckets. Following passage through the irradiator they were removed from the buckets and repacked in the cartons. Control fruit were sent through the irradiator at the 15 krad bucket speed with the cesium source withdrawn into its shielded cavity. The dose rate of the grapefruit was controlled by the speed of the bucket past the source. We had intended to irradiate at 7.5 krad as well as the higher doses, but because of gearbox problems and drive motor overheating we were unable to drive the buckets any faster than the speed required for 15 krad fruit exposure (2600 gearbox rpm, 164.8 inches/min bucket speed). The
higher dose rates of 50, 60 and 90 krad required the appropriate reduction in the bucket speed past the source (95.0, 47.5 and 31.7 inches/minute respectively). On several occasions the 15 krad bucket speed caused the motor to overheat, tripping the motor overload switch and causing the buckets to stop. Through indexing of the visible bucket numbers we were able to determine which buckets were in the irradiation field at the time of the stoppage. Fruit in these were discarded since they had been overdosed.

Dosimetry was performed using thermoluminescent dosimeters (TLD’s). The first 8 fruit to be irradiated at each of the 4 levels were cut in half, TLD’s inserted in the middle and the fruit taped back together. These fruit were then placed in the center 16 inches of the bucket (2 rows of 4 fruit) and the bucket drive was started. Dosimetry for all tests was provided by Sandia National Laboratories.

Fruit irradiation (both infested fruit and the phytotoxicity test fruit) generally required 2 days. Travel time from Miami to Albuquerque and back required a total of 7 days. After return to Miami, pupae surviving irradiation and control pupae were collected from their respective pupation boxes beneath the fruit holding towers once a week for at least 6 wk.

Results and Discussion

Initially, we had intended to irradiate 8 cartons of size 32 grapefruit (256 fruit) at each of the five dose rates (7.5, 15, 30, 60 and 90 krad). Before the first test we were informed that the bucket drive could not handle the speed necessary for a 7.5 krad irradiation so those fruit intended for that rate were added to those treated at 15 krad (Table 1, test 1). At all other dose rates we had fewer than 256 fruit for bioassay. Some fruit were lost when buckets inverted while inside the irradiator making removal impossible, also, we had to discard any fruit that were in the irradiation field when the motor overheated. When temperatures inside the trucks rose to 80°F or more, some fruit succumbed to mold and bacterial degradation and had to be destroyed in New Mexico. Pupae recovery data in Table 1 include only pupae from larvae that emerged from the fruit after returning to Miami. During the second trip, temperatures in the truck rose into the 80°F range and insect development was speeded up enough to allow larvae to crawl out of the fruit and pupate enroute.

Comparison of insect yield in the mobile versus the static control indicates that the trip conditions and handling of the fruit caused a reduction in the insect population available for irradiation and the bioassay procedure. The first and third trip had a 33% and 32% reduction respectively. On the second trip we recovered 5,789 insects from the static control compared to 702 from the mobile control, an 81% reduction due to high temperatures encountered on the trip.

Insect reduction due to irradiation is calculated by the mean pupae yield per fruit at each irradiation level compared to the mean number of pupae per fruit recovered from the mobile control. The data reported in these tests at the 15 and 30 krad dose rate are in close agreement with the results obtained by Burditt et al. in the 1981 tests (5). In those tests there was a 94% reduction in pupae yield at 15 krad and 100% reduction at 30 krad. Although the 1981 tests had no survivors at 30 krad, only 183 insects were irradiated. In this series of tests, 9,707 insects were irradiated at the 30 krad level and 4 pupae recovered, giving a weighted mean mortality rate of 99.87% for the 30 krad treatments. One female adult emerged from the recovered pupae and it died within a week without laying any eggs. One hundred forty-nine pupae were recovered from the 13,225 insects irradiated at 15 krad giving a weighted mean mortality rate of 98.22% for these three replicates. Only one male emerged from one of the three pupae and it died the first day. There were no survivors at the 60 and 90 krad irradiation rates. Because of the close proximity of the insect

Table 1. Caribbean fruit fly infested grapefruit irradiated at 4 dose rates in the \[^{13}C\]E irradiator at Sandia Laboratories, Albuquerque, New Mexico.

<table>
<thead>
<tr>
<th>Control or treatment (Test #)</th>
<th>Fruit irradiated (no.)</th>
<th>Insects (no.)</th>
<th>Insects per fruit (no.)</th>
<th>Insect reduction (%)</th>
<th>Adults emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 March</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static control</td>
<td>264</td>
<td>7357</td>
<td>27.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile control[w]</td>
<td>241</td>
<td>4943</td>
<td>20.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.4 krad ± 2.1[w]</td>
<td>449</td>
<td>9209</td>
<td>28</td>
<td>0.06</td>
<td>99.71</td>
</tr>
<tr>
<td>30.2 krad ± 3.5</td>
<td>236</td>
<td>4840</td>
<td>1</td>
<td>0.004</td>
<td>99.98</td>
</tr>
<tr>
<td>60.9 krad ± 7.2</td>
<td>299</td>
<td>4902</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>94.8 krad ± 10.1</td>
<td>248</td>
<td>5086</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2 April</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static control</td>
<td>256</td>
<td>3789</td>
<td>14.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile control</td>
<td>180</td>
<td>702</td>
<td>3.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.5 krad ± 2.6</td>
<td>192</td>
<td>749</td>
<td>14</td>
<td>0.07</td>
<td>98.21</td>
</tr>
<tr>
<td>30.0 krad ± 3.4</td>
<td>142</td>
<td>554</td>
<td>2</td>
<td>0.014</td>
<td>99.64</td>
</tr>
<tr>
<td>57.8 krad ± 6.4</td>
<td>159</td>
<td>620</td>
<td>0</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>85.9 krad ± 11.4</td>
<td>140</td>
<td>546</td>
<td>0</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>#3 May</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static control</td>
<td>256</td>
<td>6279</td>
<td>24.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile control</td>
<td>224</td>
<td>4207</td>
<td>19.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.5 krad ± 1.5</td>
<td>172</td>
<td>3368</td>
<td>107</td>
<td>0.62</td>
<td>96.75</td>
</tr>
<tr>
<td>29.1 krad ± 2.7</td>
<td>227</td>
<td>4313</td>
<td>1</td>
<td>0.004</td>
<td>99.98</td>
</tr>
<tr>
<td>55.9 krad ± 3.7</td>
<td>192</td>
<td>5648</td>
<td>0</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>83.2 krad ± 7.0</td>
<td>192</td>
<td>2308</td>
<td>0</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Based on insect yield per treated fruit compared to insect yield per mobile control fruit.

These fruit remained at the Miami, FL station and were not subjected to transportation conditions.

These fruit went with the fruit transported to the irradiation facility.

Wand standard deviation of 8 thermoluminescent dosimeters in first fruit irradiated at each dose level.

mortality rates in the two treatments where we had survival and a lack of lower treatment levels (7.5 krad or less) no statistically valid dose/mortality rates can be projected from these data.

No sterilizing dose has been established for Caribbean fruit fly when irradiated as an egg or larvae, but Lopez tested pupae and adults in the 3-10 krad range (4). He found that 8 krad exposure sterilized both male and female flies when irradiated as 10 and 12 day-old pupae or 1 day-old adults. Tests on eggs and larvae (unpublished data) in our low dose irradiator have indicated that the radio-sensitivity of the fly is greater in its earlier stages of development. If so, then levels of less than 15 krad delivered to the physical location of the immature fly within the fruit should assure that any fly surviving to adult emergence would be sterile.

Literature Cited


POSTHARVEST CREASING OF 'ROBINSON' TANGERINES

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Additional index words. Citrus reticulata Blanco, post-harvest losses, maturity, storage, calcium.

Abstract. Creasing, characterized by random grooves in citrus peel, intensified on 'Robinson' tangerines during 2-wk storage at 70°F. This condition has previously been reported to be related to climatic and nutritional factors, but has not been reported to increase during storage of the fruit. Peels were analyzed for sodium, potassium, calcium, magnesium and zinc contents; only calcium showed a significant reduction between the two harvest dates of October 14 and October 26.

Creasing is an imperfection of citrus peel, and is depicted by the appearance of irregular grooves on the surface of the fruit. Depressions in the peel are caused by separations in the tissue (albedo) underlying the outer-most peel tissue (flavedo). Creasing tends to worsen as fruit matures; changes (cell wall degradation) within the compact albedo tissue are evidenced by separation of cells and by a decrease in tissue strength (9). The development of creasing in oranges is associated with high pectolytic activity, high contents of water-soluble pectins and an enhanced incorporation of amino acids into proteins (9). Factors causing this disorder are not well understood; a degree of control has been associated with certain preharvest conditions and treatments. Most reports of creasing (1, 2, 3, 8, 9, 10) relate the disorder to nutritional or climatic conditions. Generally, creasing is reported to decrease with treatments of higher potassium, nitrogen and phosphorus (1, 2, 3, 9). Others have found the proportion between nitrogen and potassium to be important (6, 12). Gibberellin has also been reported to decrease the incidence of creasing (2, 5, 9).

Peel creasing has been reported on orange and mandarin cultivars (1, 3, 4, 8, 10, 16) from citrus-growing areas throughout the world. The importance of this disorder is indicated by a report from Israel where 14 to 25% of the 'Valencia' orange crop once had to be discarded because of creasing (9). The occurrence of this disorder in Florida and elsewhere is not consistent, making controlled repeated tests difficult to conduct (6).

Creasing is reported not to increase after harvest (5, 15). The grading tolerances for creasing of citrus in South Africa (only a trace amount allowed) is identical to the European Common Market regulations, and creasing has not been observed to develop during transportation and subsequent handling (5). Unlike creasing, puffing is known to increase after harvest (14). In this study, we investigated the effects of storage on postharvest creasing and, secondly, we studied the mineral contents of peel for possible correlation to creasing proneness.

Materials and Methods

'Robinson' tangerines (Citrus reticulata Blanco) were harvested from 10 trees randomly selected from a commercial grove on October 14 and October 26, 1981. This particular grove was selected because we noted increased creasing during storage with fruit sampled from this grove the prior year (1980). Although designated and marketed as a tangerine, 'Robinson' is a complex hybrid, i.e., 'Clementine' mandarin x 'Orlando' tangelo ('Duncan' grapefruit x 'Dancy' tan-