RADIIATION DISINFECTION OR DISINFESTATION OF NEMATODES, APHIDS, MITES, THRIPS, AND OTHER PESTS ON FOOD PLANT MATERIALS: EVALUATION FOR EFFECTIVENESS AND PRODUCT QUALITY

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Abstract

Many fresh herbs, ornamental plants, and several varieties of taro grown in Hawaii are infested with various pests such as aphids, mites, thrips, and nematodes. Finding an efficacious quarantine treatment for these commodities is difficult because most cannot tolerate heat or cold, and a suitable chemical treatment is lacking. Irradiation could be a feasible, practical alternative. Quality of these irradiated materials should be studied to help determine if irradiation is a suitable quarantine treatment. Of the ten fresh herbs irradiated with up to 0.70 kGy, five (rosemary, thyme, oregano, parsley, chives) are very tolerant, and show no difference from the controls after two to three weeks at 7 °C. Red ginger and four cultivars of heliconia, very attractive ornamental plants, can be irradiated at 0.75 and 0.50 kGy, respectively, and have a vase life of 10 days or more at 21 °C. Leafminer in bean plants cannot emerge when irradiated at 0.15 kGy. The nematode, *Meloidogyne javanica*, which infects taro and ginger, is prevalent in Hawaii. To cause mortality in second stage juveniles (J2), a gamma-radiation dose higher than 4.0 kGy is necessary. Suppression of hatching of egg masses requires doses of 2.0 kGy and above. Galling of tomato plants inoculated with J2 and egg masses decreases when J2 and egg masses were irradiated at 3.25 kGy and above. Heating J2 at 43 °C for 10 min before inoculating them into the plants effectively reduces root galling. Synergism was not found between heat treatment (49 °C for 10 or 20 min) and irradiation with up to 0.015 kGy, the dose above which sprouting of ginger rhizomes and taro cormels is inhibited. The results suggest that irradiation is promising as a quarantine treatment for selected fresh herbs and ornamental plants, but not for control of nematodes in root crops.

1. INTRODUCTION

In the past few years, the move to find alternatives to chemical fumigation of fresh commodities for disinfection or disinfestation has intensified. Participating member states at the Montreal Protocol have agreed that methyl bromide would be phased out for all uses by January, 2001. Thermal and cold treatments have been used on limited number of commodities as a quarantine treatment, but these treatments are commodity-specific in terms of the treatment regime. Treatment time are usually quite long, and product quality has been affected due to some biochemical changes in the commodity resulting from an overexposure to the applied time-temperature regime (heat or cold) [1]. Among its various potential applications, irradiation as a quarantine treatment is perhaps one of the most feasible and practical alternatives to chemical, heat, or cold treatment for fresh commodities [2]. Quarantine treatment with irradiation is simple because the dose applied to control a certain group of pests such as fruit flies is becoming generic; it is efficacious because it is both effective in meeting quarantine requirements totally and efficiently in terms of a short treatment time.

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2 Present address: Plant Pathology and Microbiology Division, Department of Agriculture, Chauchak, Bangkok, Thailand.
Irradiation is versatile because its application is broader than any other quarantine treatment method in terms of its applicability to many commodities and different species of pests.

Food plant growers and the floriculture industries in tropical and subtropical regions such as the Hawaiian islands are confronted with quarantine restrictions because their plant materials are often infested with melon thrips, aphids, mites, mealybugs, cockerell scale, other pests, or nematodes. Plant foods, cut flowers, and foliage plants shipped to the United States mainland or international destinations sometimes are not properly treated. Since 1988, over 4,000 floral plant shipments from Hawaii have been rejected at ports of entry in California alone when insects were found on the plant materials. Examples are dendrobium and red ginger. Elimination of these infestations by chemical or thermal means is difficult, and often with mixed results due to limited effectiveness in inactivating the pests and unwanted phytotoxicity to the plants.

When irradiation is applied as a quarantine treatment for fruit fly control, the concepts vary from causing sterility of the treated pest, to preventing adult emergence, to blocking the eggs from hatching. In the most recent publication of USDA-APHIS policy statements, the agency's expectation is that "... In those instances where pest organisms survive treatment, it is essential for quarantine purposes that the organism is unable to reproduce, and it is desirable for the organism to be unable to emerge from the commodity unless it can be easily distinguished from a non-irradiated pest of the same species." [3] A generic, minimum absorbed dose of 250 Gy is being proposed for treating papayas, lychees, and carambolas grown in Hawaii to prevent fruit fly spread. This is a modification of an earlier quarantine regulation on irradiation as a quarantine treatment of Hawaii grown papayas.

On pests other than fruit flies, the minimum effective dose for non-reproduction and non-emergence have been studied at various laboratories including those participating in this FAO/IAEA Research Coordinating Program. But the necessary minimum doses have not been defined or confirmed. At the same time, quality of commodities irradiated as a quarantine treatment to control those pests other than fruit flies need to be studied in order that their shelf or vase life, and marketability, are preserved. Determination of the upper dose for each commodity or a group of commodities, which can be called tolerance dose, is necessary to make the irradiation treatment practical. It has been observed that the tolerance dose of a given commodity should probably be 2 to 3 times higher than the minimum quarantine dose due to variations in dose rates in any given irradiator, package configuration, and product density.

The objective of our project was to explore the technical feasibility of using gamma irradiation alone or in combination with other means such as thermal treatment to disinfect or disinfest selected food and ornamental plant materials with pest problems that result in their being restricted in interstate and international shipments due to quarantine regulations.

Fresh herbs and a number of ornamentals grown in Hawaii have very good economic potential but are in need of a suitable quarantine treatment. Irradiation may just fit that need. Nematodes are another pest problem on root crops. With restrictions or unavailability of chemicals for nematode control, the possibility might exist for irradiation as an alternative quarantine treatment of plant materials for nematode control. The radiosensitivity of root-knot nematodes, *Meloidogyne* spp., has not been thoroughly documented. Irradiation doses required to kill or sterilize nematodes in all stages are unknown. Preliminary studies were carried out in Thailand of effects on second stage juveniles (J2) and egg masses of *M. incognita* exposed to gamma-radiation at 1.2 and 1.5 kGy, respectively. J2 stages were not killed in 14 days, and eggs were able to hatch (Chinnasri, unpubl.). Bioassays also showed that irradiated juveniles and juveniles from irradiated eggs induced galling and reproduced on tomato plants (Chinnasri, unpubl.). To understand the infection of plant materials by *Meloidogyne javanica*, which is prevalent in Hawaii, and whether or not irradiation is a feasible process, we need to know the effect of irradiation on J2 juveniles and eggs of *M. javanica*, and also the possibility of combining irradiation and heat treatment.
Our efforts have been mainly in these areas. We have intended to study the control of mites, thrips, aphids and other pests by irradiation. However, due to resource constraints, and lacking interested colleagues experienced in the rearing of these pests, this part of the study may be carried out at a later date.

2. MATERIALS AND METHODS

2.1. Irradiation of fresh herbs

Nine (9) herbs and taro leaves popularly grown in Hawaii were used as experimental materials. These included:

- Thyme (*Thymus vulgaris*)
- Rosemary (*Rosmarinus officinalis*)
- Oregano (*Origanum vulgare*)
- Parsley (*Petroselinum crispum*)
- Spearmint (*Mentha spicata*)
- Chives (*Allium schoenoprasum*)
- Arugula (*Eruca vesicaria ssp. sativa*)
- Dill (*Anethum graveolens*)
- Basil, Sweet, Thai and Opal (*Ocimum basilicum*)
- Taro leaves (*Colocasia esculenta cv. Bunlong*)

These fresh herbs and taro leaves were harvested from commercial farms on the island of Oahu, brought to the Food Technology Building, and irradiated at the Hawaii Research Irradiator either on the day of harvest or the next morning. The plant samples were irradiated with 0.25 to 0.70 kGy in replicates. After irradiation, they were kept in the refrigerators at 7 °C, except basil which was kept at ambient temperature (25-28 °C).

Evaluations of these plants were by visual inspections every two to three days up to three weeks. The irradiated samples were compared with controls in terms of color changes (discoloration), dehydration, wilting or curling of the leaves, and presence of burned or brown spots.

2.2. Irradiation of ornamentals

Popularly grown in Hawaii are two sizes of red ginger plants and four cultivars of Heliconia used in this study:

- Red ginger (*Alpinia purpurata*)
- Heliconia (*Heliconia orthotrica*)
- Heliconia (*Heliconia caribaea*)
- Heliconia (*Heliconia spathocircinata x psittacorum*)

Replicate irradiation experiments were conducted with doses varying from 0.25 to 0.75 kGy. After irradiation, the flower samples were kept in water in containers at 21 °C. Evaluations were also by visual inspections every two to three days up to two weeks. Irradiated samples were compared with controls in quality factors somewhat similar to fresh herbs indicated above. Any appearance of wilting/curling, softening (loss of turgidity) or burnt/brown spots would be on petals and small stems.

2.3. Irradiation of leafminer (*Liriomyza trifolii*) in bean plants

Beans plants infested with leafminer were irradiated up to 0.75 kGy to determine the minimum dose needed for non-emergence. Leafminers also infest many of the fresh herbs mentioned above.

2.4. Irradiation of root-knot nematode (*Meloidogyne javanica*)

2.4.1. Propagation of *Meloidogyne javanica*

*M. Javanica* populations were propagated on Rutgers tomato plants (*Lycopersicon esculentum*) in a greenhouse at 30 °C. Egg masses or juveniles were collected from 15-day-old cultures. Two experiments were conducted in the laboratory and the greenhouse.
2.4.2. Irradiation of M. javanica

For mortality tests, approximately 100 one-day-old J2s were placed in vials containing sterile water and irradiated at 2.0, 4.0, 6.0, 7.0, 7.5, and 8.0 kGy. Controls were not irradiated. Dose rate for these experiments was 9.93 Gy/min. Triplicate runs were made. J2s were characterized as dead when they were observed to lay motionless, their bodies swelled, or they turned brown. Juveniles were observed daily, and the number of dead J2s were counted and recorded.

To determine the effect of irradiation on hatch, egg masses collected from females on 45-day-old tomatoes plants were placed individually into vials containing sterile water and irradiated at 2.0, 3.0, 4.0, 5.0, 6.0, 6.25, and 6.5 kGy besides the control. Irradiated egg masses were transferred from vials into 5-cm-diam. Petri dishes filled with sterile water and incubated at 22-25 °C. These egg masses in the Petri dishes were examined daily and the number of J2 counted. At day-15, the gelatinous matrix covering the eggs was dissolved with sodium hypochlorite [4], and the unhatched eggs were counted. The total number of eggs per egg mass was determined by combining the total number of J2 with the number of unhatched eggs. This number was used to compare the percentage of hatch among treatments. There were three replicates per irradiation dose.

2.4.3. Bioassay

For bioassay, approximately 5,000 one-day-old J2s or 20 egg masses were placed in vials containing sterile water and irradiated at 1.0, 2.0, 3.0, 3.25, 3.75, 4.0, 4.25, and 4.5 kGy. Controls were not irradiated. The dose rate for these experiments was 9.71 Gy/min. Irradiated juveniles were then inoculated onto 5-cm-tall Rutgers tomato seedlings in 10-cm-diam. clay pots. Irradiated egg masses were observed under a microscope to insure that there was no contamination by any newly-hatched juveniles. The egg masses were then transferred into another vial containing sterile water and inoculated onto a 5-cm-tall Rutgers tomato seedling transferred in a 10-cm-diam. clay pot. Inoculated tomato plants were arranged in a randomized complete block (RCB) with five replicates per treatment, two plants per replicate, and maintained in the greenhouse. Forty-five days after inoculation, the tomato roots were rated for galling where 0 = no galling, 1 = trace infections with a few small galls, 2 = < 25%, 3 = 25-50%, 4 = 50-75%, and 5 and above = > 75% of roots galled [5]. Eggs were extracted from tomato roots with a sodium hypochlorite technique [4], and the number of eggs per gram of wet root weight was calculated.

2.5. Combined heat treatment and gamma-radiation of root-knot nematode

Two 4 x 4 factorial experiments were conducted: one on J2s and the other on egg masses. Approximately 5,000 one-day-old J2s or 20 egg masses were placed in 10-ml vials containing sterile water. The vials were immersed in a water bath at either 43 °C for 10 min, 49 °C for 10 min, 49 °C for 20 min, or maintained at room temperature (25 °C) as control. Immediately after the hot water treatment, the J2s or egg masses were exposed to gamma-radiation with 0.005, 0.01, or 0.015 kGy. Controls were not irradiated. The hot water-treated and irradiated juveniles and egg masses were then inoculated onto 5-cm-tall Rutgers tomato seedlings transferred in 1-cm-diam. clay pots and transferred into the greenhouse. The treatments were triplicated, with two plants per replicate. All tomato plants were harvested 45 days after inoculation. Roots were rated for galling as indicated above, and eggs were extracted from roots with sodium hypochlorite. The number of eggs per gram of wet root weight was calculated.

2.6. Radiation source

The Hawaii Research Irradiator with 100 60Co capsules of the U.S. National Brookhaven Laboratory design, located in the Food Technology Building, University of Hawaii at Manoa, was used as the gamma radiation source for all the experiments. During the experimental period, the
activity of the $^{60}$Co source was 4,943 to 4,832 Ci ($1.83 \times 10^{14}$ to $1.79 \times 10^{14}$ Bq). The dose rates were 9.93 to 9.71 Gy/min, and the maximum to minimum dose rates was 1.09.

3. RESULTS AND DISCUSSION

3.1. Shelf/Vase life as indicator of tolerance of fresh herbs and ornamental plants to irradiation

3.1.1. Fresh herbs

Evaluations of fresh herbs and taro leaves after irradiation were carried out mainly by R. Hamasaki who is very knowledgeable and experienced in the cultivation and quality of herbs. From replicate runs, the observed results are expressed in Table I. These nine herbs and taro leaves seem to fall into three categories in terms of their tolerance to gamma-radiation: quite tolerant (at 0.60 to 0.70 kGy); moderately tolerant (about 0.45 to 0.50 kGy); and not tolerant (0.25 kGy and below).

<table>
<thead>
<tr>
<th>Days quality was retained</th>
<th>Quite Tolerant @ 0.60 - 0.70 kGy</th>
<th>Moderately Tolerant @ 0.45 - 0.50 kGy</th>
<th>Not Tolerant @ 0.15 - 0.25 kGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Rosemary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Thyme</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Oregano</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Parsley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Chives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Spearmint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Taro leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Dill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Basil (Sweet, Thai, Opal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Arugula</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observations of tolerance to gamma-radiation in terms of quality retention were as follows:

1. Rosemary (Rosmarinus officinalis) - Tolerates irradiation very well. At 21 days, irradiated samples (0.25 to 0.70 kGy) were as good as the control.
2. Thyme (Thymus vulgaris) - Tolerates irradiation to 0.60 kGy up to 14 days without any difference from the control.
3. Oregano (Origanum vulgare) - Can tolerate irradiation up to 0.70 kGy quite well. At 14 days, most samples were as good as the control, except one or two showing necrosis in young leaves, and a few older leaves turning black. At 21 days, most samples (0.25 - 0.70 kGy) were in fair condition.
4. Parsley (Petroselinum crispum) - Tolerates irradiation up to 0.60 kGy up to two weeks. The leaves begin to turn yellow after two weeks.
5. Chives (Allium schoenoprasum) - Tolerates irradiation to 0.60 kGy up to 14 days, and shows no difference from the control.
6. Spearmint (Mentha spicata) - Those treated up to 0.50 kGy appear to tolerate irradiation.
quite well up to about 10 days. At 14 days, all samples including the control have their lower leaves turning brown or black.

(7) Taro leaves (Colocasia esculenta cv. Bunlong) - Used as one type of Hawaiian foods, taro leaves can tolerate irradiation to 0.45 kGy up to 10 days.

(8) Dill (Anethum graveolens) - Sensitive to irradiation. Can tolerate 0.25 kGy for one week with acceptable quality. Irradiation at 0.50-0.60 kGy causes yellowing of stems and leaves.

(9) Basil, Sweet, Thai and Opal (Ocimum basilicum) - Probably the most sensitive to irradiation among the group of fresh herbs tested. Judged acceptable three days after irradiation at 0.25-0.60 kGy, the stems and leaflets begin to show yellowing at 25 °C. By the seventh day, they become unmarketable. In general, the shelf life of untreated basil is rather limited. Lowering the storage temperatures, and keeping the plants in water may help prolong the life of cut basil.

(10) Arugula (Eruca versicaria spp. sativa) - This herb appears very sensitive to irradiation, even at the low dose of 0.15 kGy. Irradiation causes arugula to turn yellow much faster than the control.

3.1.2. Red ginger and Heliconia

(1) Red Ginger (Alpinia purpurata) - These are medium to large red ginger plants, which are very attractive ornamentals. The cut plants used in the experiments are mostly about 50 to 55 cm tall. Samples were irradiated at 0.25, 0.50, and 0.75 kGy and kept in water at 21° C after irradiation. There appears to be some differences between those grown in the summer months and those grown in the cooler months (spring and fall). Experimental samples collected in June had a vase life of about 10 - 12 days with no observed differences between the controls and those irradiated with up to 0.75 kGy. Those sampled in cooler months (March and October) had 4 to 5 days of additional vase life.

(2) Heliconia - Several cultivars of Heliconia were collected and their tolerance to gamma-radiation evaluated. The names of the cultivars were given above. They were irradiated with 0.25, 0.50, and 0.75 kGy. It was observed that some sensitivities were exhibited by these plants at various doses, such as softening, bending, and some browning or burning of the tips. Overall results show that heliconias irradiated up to 0.50 kGy were comparable to the control for up to 7 - 10 days when keep in water at 21°C.

3.2. Irradiation to cause non-emergence of leafminer

Six replicate experiments were conducted to determine the minimum dose for non-emergence of the leafminers which infest many plants in Hawaii. The highest dose used was 0.75 kGy. It was found that 0.15 kGy was sufficient to cause non-emergence of the leafminers.

3.3. Effects of irradiation on root-knot nematode, Meloidogyne javanica

3.3.1. Mortality of J2 and hatch of egg masses

There was minimum effect on the J2s up to 15 days with treatment of up to 4.0 kGy. There was no significant difference in mortality between the control and those irradiated with up to 4.0 kGy (P = 0.01). After irradiated with 6.0 kGy, mortality of J2s began to increase after 5 days, reaching 80% at 15 days. With a dose of 7.0 kGy, death of J2s was observed by the second day and increased rapidly until all were dead by day 5 after exposure. Mortality was 100% on the day following exposure to 7.5 and 8.0 kGy.

Overall, hatching decreased with increasing radiation doses. Irradiation at doses of 2.0 and 3.0 kGy affected hatching. The number of J2 hatching from egg masses irradiated at 4.0 to 6.0 kGy was very low throughout 15 days of the experiment. Doses of 6.25 and 6.5 kGy completely inhibited egg hatch.
3.3.2. Bioassay

Bioassay proved to be a more sensitive indicator of the effect of irradiation on *M. javanica* juveniles and egg masses than the observations of mortality or hatch. A dose as low as 2.0 kGy resulted in a reduction of root galling by J2s and in the number of eggs per gram of root (Table II). Egg masses were less sensitive to irradiation than the J2s. A reduction in galling and in the numbers of eggs/g root did not occur below doses of 3.25 kGy. Exposure of J2s and egg masses to 4.25 kGy or greater resulted in no galling and no reproduction as measured by eggs/g root (Table II).

3.4. Effects of combined heat and irradiation on root-knot nematode, *M. javanica*

Irradiation treatments did not affect galling or numbers of egg/g root on tomato plants by J2s or eggs as compared to the nonirradiated nematodes (*P > 0.05*). Heat treatments, however, reduced galling and nematode reproduction on tomato plants (Table III). Additionally, there was no interaction between irradiation and heat treatment (*P > 0.05*). Reproduction was completely inhibited by heat treatment of 49 °C for 10 or 20 min (Table III). The J2s were adversely affected by heat treatment at 43 °C for 10 min as measured by subsequent reduction in root gall index (Table III). In contrast, heat treatment at 43 °C for 10 min was insufficient to inactivate eggs, resulting in a greater number of egg production than the eggs that were not exposed to heat (Table III).

| TABLE II. ROOT GALL INDEX AND NUMBER OF EGGS/ g ROOT OF MELOIDOGYNE JAVANICA ON TOMATO AFTER IRRADIATION OF J2 AND EGGS OF THE NEMATODE. |
| --- | --- | --- | --- |
| Root gall index | Eggs/g root |  |
| (kGy) | Irradiation dose | J2 | Eggs | J2 | Eggs |
| 0 | 5.0 a | 4.4 a | 5.3 a | 5.3 a |
| 1 | 5.0 a | 4.8 a | 5.2 a | 4.9 ab |
| 2 | 4.0 b | 4.5 a | 5.0 b | 5.0 ab |
| 3 | 3.4 c | 4.6 a | 4.4 c | 4.5 b |
| 3.25 | 2.7 d | 2.3 b | 3.0 d | 3.9 c |
| 3.75 | 1.8 e | 1.4 c | 2.7 e | 2.3 d |
| 4 | 1.0 f | 0.5 d | 2.2 f | 1.5 e |
| 4.25 | 0 g | 0 d | 0 f | 0 f |
| 4.50 | 0 g | 0 d | 0 f | 0 f |

Means in columns followed by the same letter are not different (*P < 0.05*), according to Duncan’s multiple-range test performed on log10-transformed data.

4. DISCUSSION

It is interesting and encouraging to note that five out of ten fresh herbs including taro leaves were found to be quite tolerant to gamma-radiation up to 0.70 kGy. The rest are moderately tolerant to radiation (around 0.50 kGy), or not tolerant to radiation (below 0.25 kGy). Those that are very tolerant to radiation would be good candidates to be irradiated as a quarantine treatment to control pests other than fruit flies, though the minimum dose required to control these various pests remains to be defined.
The two ornamental plants, red ginger and heliconia, also appear to be good candidates for irradiation as a quarantine treatment for export markets. Growers spend considerable time and efforts in washing to get rid of pests that might be on the plants before packing them for shipments. Yet it is not a complete assurance that all pests are washed off the plants. That is the reason for rejection of many shipments from Hawaii of cut flowers at the port of entry in California. If irradiation is used, the floriculture industry should see an improvement in their postharvest handling of cut flowers and having a suitable quarantine treatment which should be readily acceptable to the public.

Plant-parasitic nematodes are often quarantine pest subject to importation bans. The infestations are particularly difficult to eliminate when the infested material is vegetative propagation materials, such as seed potatoes, ginger rhizomes, taro cormel, or bulbous crops. Currently, disinfestation procedures rely upon hot water treatments, chemical dips or combinations of the two [6]. Irradiation has proven to be an effective method to disinfect many processed and perishable foodstuffs of bacteria, fungi, and insects [7,8]. It may also have applicability for disinfection and disinfestation of nematodes.

One of the most important considerations for the control of nematodes with irradiation is the effect of irradiation on plants [9]. The treatment must not adversely affect the growth of the plant, and should be based on the inability of nematode to reproduce rather than its immediate death. Applicability of irradiation on crops such as ginger rhizomes or taro cormels for disinfestation of *Meloidogyne javanica* is dependent upon the quality of the rhizomes and the cormels after treatment. The sprouting of ginger rhizomes and taro cormels is inhibited by radiation doses of 0.025 kGy and below [10 and Chinnasri, unpubl.]. Higher doses would cause adverse effects on the rhizomes and cormels.

Disinfestation does not require the elimination of the nematode from the plant material, but only prevention of subsequent reproduction. Sublethal doses of irradiation did affect the viability of *M. javanica*. To enhance the efficacy of sublethal exposures, the nematodes were stressed with heat prior to irradiation. However, the heat stress was sufficient in itself to kill the nematodes and did not bring about any synergistic effect with irradiation.

**TABLE III. EFFECT OF HOT WATER TREATMENT ON REPRODUCTIVE CAPABILITY OF J2s AND EGGS OF *MELOIDOGYNE JAVANICA* AS MEASURED BY ROOT GALL INDEX AND NUMBER OF EGGS/g WET ROOT WEIGHT**

<table>
<thead>
<tr>
<th>Hot water treatment</th>
<th>J2 Root gall index</th>
<th>Eggs/g root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5 a</td>
<td>24,815 a</td>
</tr>
<tr>
<td>43°C for 10 min.</td>
<td>3.9 b</td>
<td>18,920 a</td>
</tr>
<tr>
<td>49°C for 10 min.</td>
<td>0 c</td>
<td>0 b</td>
</tr>
<tr>
<td>49°C for 20 min.</td>
<td>0 c</td>
<td>0 b</td>
</tr>
</tbody>
</table>

Means in columns followed by the same letter are not different ($P<0.05$), according to Duncan's multiple range test.
5. CONCLUSIONS

(1) Results from this study of applying gamma-radiation to a number of fresh herbs and cut flowers show that some are quite tolerant to radiation up to about 0.75 kGy which is an encouraging sign that irradiation could be used as a quarantine treatment for these plant materials for controlling pests other than fruit flies.

(2) A low dose (0.15 kGy or less) required to prevent the emergence of leafminers is another encouraging sign that this pest, which invades a number of herbs and ornamental plants, could be controlled by irradiation. Between 0.15 kGy and the tolerance dose of the plants indicated above (0.50 to 0.75 kGy), a factor of 3 to 5 in the minimum required vs the maximum tolerable should be very feasible for the industry to adopt.

(3) Nematodes appear to be a very radiation-resistant pest. The doses required for non-hatching of the egg masses and mortality of the second stage juveniles are much too high for any plant material to tolerate. Since nematodes seem to be quite heat sensitive, further research to find a suitable combination treatment using heat, irradiation, and/or other means to achieve a synergistic effect of causing non-reproduction of nematodes in plant materials would be very useful.

ACKNOWLEDGEMENTS

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REFERENCES