XA9950289

TOLERANCE OF CUT FLOWERS TO GAMMA-RADIATION

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Abstract

Cut flowers were gamma-irradiated with doses of 0, 200, 400, 600, and 1000 Gy. *Dianthuscaryophyllus* (Caryophyllaceae), *Gypsophila paniculata* (Caryophyllaceae), *Freesia* sp (Iridaceae), *Limonium sinuatum* Mill. (Plumbaginaceae), *L. latifolium* Kuntze (Plumbaginaceae), *Narcissus tazetta* L. (Amaryllidaceae), *Helichrysum bracteatum* Andr. (Compositae) and *Rhodanthe manglesii* Lindl (Compositae) were tolerant up to 1000 Gy, without visible negative changes after irradiation and during the vase-life. *Callistephus chinensis* (Compositae) and *Lilium longiflorum* Thunb. (Liliaceae) were moderately tolerant, but were modified by high doses. *Anthurium* sp (Araceae), *Strelitzia* sp (Musaceae), *Matthiola incana* R. Br. (Cruciferae), *Aechmea distichanta* (Bromeliaceae), *Consolida ajacis* Niew (Ranunculaceae), *Ranunculus* sp (Ranunculaceae), *Dendrobium phalenopsis* (Orchidaceae) and *Gerbera* sp (Compositae) were not tolerant to a dose of 200 Gy. The most adequate flowers to be submitted to irradiation treatment for disinfestation purpose were those of the Caryophillaceae family and those which can be used as dried flowers, such as members of the *Rhodanthe*, *Helichrysum* and *Limmonium* genera.

1. INTRODUCTION

Brazil has a huge diversity of exotic flora that includes flowers and other ornamental plants of commercial value. Some of these plants have great potential to be explored and expanded to the international market. However, fresh products have to be submitted to a phytosanitary inspection when exported to other countries. The tropical climate of Brazil favors infestation by many pest organisms that do not exist in non-tropical regions. Radiation could be an effective treatment against insects that will prevent their reproduction in the host country. The radiation treatment could be also an alternative to substitute for chemical fumigation with methyl bromide, which destroys the ozone layer of the Earth.

The cut flower is alive and in some cases it continues developing during its vase-life. It can be composed of one or many flowers, and may include leaves and stem, or only flower and stem. Some are harvested as bud and others after the blossom. The vase-life varies with the species or cultivar. Handling and environmental conditions during the vase-life can also affect flower vigor. Infestation by pests can damage drastically the final product, so that it can be considered commercially unsuitable. Flowers do not differ from other biological organisms in that they can be damaged by radiation, depending on the dose. Some authors have irradiated cut flowers with gamma-radiation [1-5], while others have used electron beams [6, 7] for disinfestation.

To avoid the deleterious effects of radiation, cut flowers can be supplied with preservative or holding solutions containing sugar [1, 4, 5]. Unfortunately, this procedure also must be adopted by the florist and the final consumer to assure continued flower quality during the vase-life.

The problem of insects or other arthropods infesting live plants, such as cut flowers, foliage, or cacti is perhaps the most limiting factor to increased international trade. Currently disinfestation by insecticides that are sprayed or dipped is a necessity. However, due to the architecture of flowers, there are many parts of the flower on which an application of the correct amount of pesticide is almost impossible or very difficult. Besides, because misapplication and other biological factors occur, there may be a significant increase of resistance by the pests rendering pesticide application more and more inefficient, if not useless. Moreover, handling or maintaining plants with a potentially toxic residue in their homes could be a nightmare for housewives [2, 8-15].

This paper presents the tolerance and the sensitivity of some cut-flowers to gamma-radiation, and indicates those more suitable for disinfestation by radiation.

2. MATERIALS AND METHODS

2.1. Plant materials

Cut flowers were obtained in the São Paulo city flower market, about 4 km from the laboratory. The stems of the flowers were cut and soaked in tap water for about 15 hours before irradiation in order for the flowers to recover their turgidity.

The following cut flowers were irradiated: *Dianthus caryophyllus* (Caryophyllaceae), *Gypsophila paniculata* (Caryophyllaceae), *Freesia* sp (Iridaceae), *Rhodanthe manglesii* Lindl (Compositae), *Limonium sinuatum* Mill. (Plumbaginaceae), *L. latifolium* Kuntze (Plumbaginaceae), *Narcissus tazetta* L. (Amaryllidaceae), *Helichrysum bracteatum* Andr. (Compositae), *Callistephus chinensis* (Compositae), *Lilium longiflorum* Thunb. (Liliaceae), *Anthurium* sp (Araceae), *Strelitzia* sp (Musaceae), *Matthiola incana* R. Br. (Cruciferae), *Aechmea distichanta* (Bromeliaceae), *Consolida ajacis* Niew (Ranunculaceae), *Ranunculus* sp (Ranunculaceae), *Dendrobium phalenopsis* (Orchidaceae) and *Gerbera* sp (Compositae).

2.2. Irradiation of flowers

Two sources of irradiation were used as follows: a Panoramic cobalt-60 source (Yoshizawa Kiko Co. Ltd.) (205-493Gy/h) or a Gammacell 220 (Nordion International Inc.) (338.0-418.1Gy/h). The flowers were irradiated with the stems soaked in water.

2.3. Maintenance of flowers

After irradiation, the flowers were maintained in holding solutions at room temperature of 24-30°C in summer (December to March), 15-24°C in winter (June to September), 19-27°C in spring (September to December) and autumn (March to June), and light exposure for 9 or 10 hours.

The compositions of the holding solutions were:
- Solution A: 0.02% 8-hydroxyquinoline sulfate, 0.01% citric acid, 25ppm silver nitrate;
- Solution B: 0.02% 8-hydroxyquinoline sulfate, 0.001% ampicillin, 0.001% streptomycin.

3. RESULTS

3.1. Tolerant flowers (tolerant up to 700Gy or more)

3.1.1. Plant material

Dianthus caryophyllus (Caryophyllaceae)

Irradiation source: Gammacell 220

Doses: 0, 300, 600, and 900 Gy (418.1 Gy/h)

Holding solution: A

Carnations were not modified by gamma-radiation if they were irradiated in the developed flowering stage, and they toleratied doses up to 900 Gy. In the irradiated samples there was no new shoot formation as in the control ones. However, this fact did not compromise the commercial value of the irradiated carnations.

Gypsophila paniculata (Caryophyllaceae)

Irradiation source: Gammacell 220

Doses: 0, 200, 400, 600, 800, and 1000 Gy (342 Gy/h)

Holding solution: A

The leaves and opened flowers were not affected by radiation. Bud opening was inhibited, but it did not affect the product value because the majority of the flowers are normally commercialized as semi or totally opened flowers.

Freesia sp (Iridaceae)

Irradiation source: Gammacell 220

Doses: 0, 200, 400, 600, and 800 Gy (342 Gy/h)

Holding solution: A

Bud opening was not inhibited by radiation. The number of opened flowers reached the maximum between 2 - 5 days after irradiation in all samples (Figure 1A) and the number of buds decreased similarly in all doses (Figure 1B), indicating that the inflorescence continued developing even after irradiation. However, flowers originating from buds irradiated with 800 Gy had pale coloration.

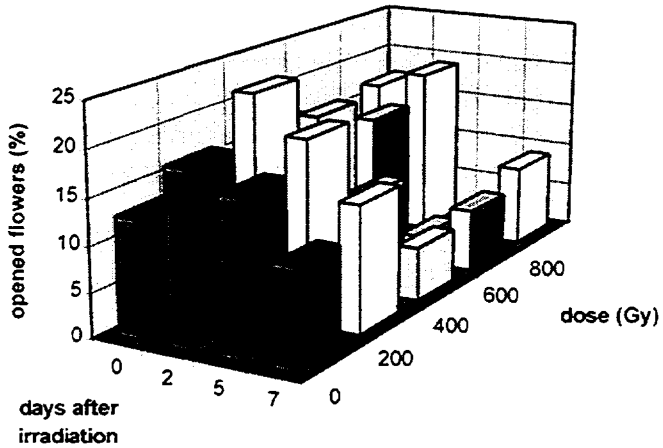

FIG. 1A. Percentage of Freesia opened flowers after gamma-irradiation.

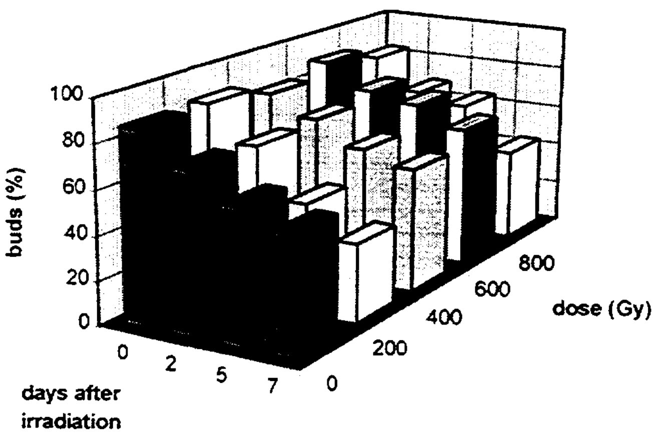

FIG. 1B. Percentage of Freesia *buds after gamma-irradiation.*

Rhodanthe manglesii Lindl (Compositae)

Irradiation source: Gammacell 220

Doses: 0, 200 400, 600, 800, and 1000 Gy (338 Gy/h)

Holding solution: A

Rhodanthe was very resistant to irradiation, without visible alterations. The flower coloration was not affected and the leaves also continued green as did the control ones.

Limonium latifolium Kuntze *and L. sinuatum* Mill. (Plumbaginaceae)

Irradiation source: Panoramic cobalt-60 source

Doses: 0, 200, 400, 600, 800 and 1000 Gy (206 Gy/h)

Holding solution: B

Bud opening of *Limonium* was inhibited by radiation. Thus, only the control samples presented new flowers during 4 or 5 days. However, the main visual aspect of *L. sinuatum* is the colored bracts, which are dry, and these were not modified by radiation. *L. latifolium* also did not lose their commercial value, because they are used as a complement to a flower arrangement and bud color was not affected by the treatment, in spite of the opening inhibition. The leaves of both cultivars were also tolerant to radiation.

Narcissus tazetta L. (Amaryllidaceae)

Irradiation source: Panoramic cobalt-60 source

Doses: 0, 200, 400, 600, 800, and 1000 Gy (206 Gy/h)

Holding solution: B

Gamma-radiation up to 1000 Gy did not inhibit bud opening (Figure 2A) and the percentage of opened flowers increased similarly in all samples (Figure 2B). However, there was a delay in the opening process of irradiated buds, which consequently slowed the wilting process of the flowers, and the decrease in fresh weight of irradiated flowers during the vase-life was lower than values for control flowers (Table I).

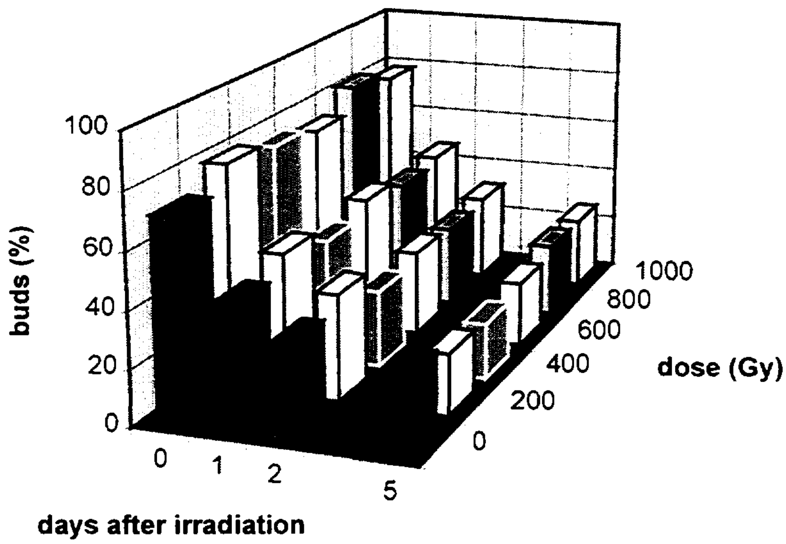

FIG. 2A. Percentage of Narcissus *buds after gamma-irradiation.*

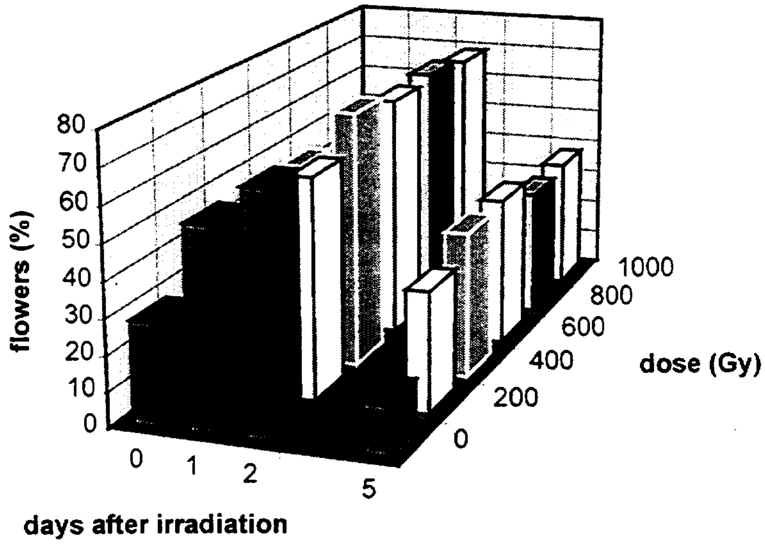

FIG. 2B. Percentage of Narcissus *flowers after gamma-irradiation.*

TABLE I. *Narcissus tazetta* FRESH WEIGHT (%) AFTER GAMMA-IRRADIATION. NUMBER OF STEMS BY DOSE, N=9.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	92.36±4.63	95.38±8.93	94.12±5.24	96.13±7.35	100.85±3.60	95.45±1.48
5 days	80.64±3.00	87.23±13.28	88.90±4.54	92.64±9.71	95.64±5.31	92.66±2.53

Helichrysum bracteatum Andr. (Compositae)

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (205 Gy/h)
Holding solution: B

In spite of the fresh weight decrease with doses above 400 Gy (Table II), the irradiated samples were not visually modified comparing to the control ones. The development of the inflorescence was not inhibited by any of the doses used.

TABLE II. *Helichrysum bracteatum* FRESH WEIGHT (%) AFTER GAMMA-IRRADIATION. NUMBER OF STEMS BY DOSE, N=9.

Dose (Gy)	0	200	400	600	800	1000*
0 day	100	100	100	100	100	100
2 days	98.90±0.73	99.49±0.72	97.99±3.81	97.81±1.38	96.45±1.15	93.83±1.45
5 days	93.52±4.28	94.97±1.56	85.68±5.90	87.25±0.30	82.75±4.61	82.21±5.22
7 days	87.32±9.78	88.91±4.67	76.93±2.22	80.74±1.96	72.99±6.89	73.88±5.35
9 days	78.88±17.6	81.16±6.84	67.25±0.62	73.19±0.30	63.50±8.28	65.93±4.44
12 days	57.88±21.77	63.11±17.82	49.00±1.80	54.58±4.94	46.84±4.21	47.56±5.71

*N=8

3.2. Moderately tolerant flowers (tolerant up to 500 Gy)

3.2.1. Plant material

Callistephus chinensis (Compositae)
Irradiation source: Gammacell 220
Doses: 0, 200, 400, 600, 800, and 1000 Gy (234 Gy/h)
Holding solution: A

Doses over 400 Gy caused wilting of leaves. Doses of 600, 800, and 1000 Gy also were deleterious, damaging the inflorescence and decreasing vase-life. The fresh weight of irradiated samples decreased significantly 5 days after irradiation (Table III).

TABLE III. FRESH WEIGHT (%) OF *Callistephus chinensis*, AFTER GAMMA-IRRADIATION. NUMBER OF INFLORESCENCE BY DOSE, N=5.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	103.09±1.42	102.40±0.12	99.81±1.11	101.47±0.96	100.10±0,15	101.08±0.48
5 days	101.44±2.59	95.47±2.19	93.51±1.32	90.30±1.74	93.54±3.49	94.06±0.98

Lilium longiflorum Thunb. (Liliaceae)
Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (208 Gy/h)
Holding solution: B

The *Lilium* samples were irradiated in the bud or in semi-opened flower development stages. The buds opened normally up to 400 Gy. With higher doses at the bud stage, flower development reached only the semi-opened stage. When the semi-opened flower was irradiated, however, the opened stage was reached.

3.3. Flowers with low tolerance (below 250 Gy)

3.3.1. Plant material

Anthurium sp (Araceae)
Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, and 600 Gy (236.6 Gy/h)
Holding solution: A

Anthurium was very radiosensitive, presenting discolored spots in the spathe (colored bract) 2 days after irradiation. After 5 days, black dots also appeared in those spots. Fresh weight decreased similarly in all samples up to 5 days after the treatment (Table IV).

TABLE IV. *Anthurium* sp FRESH WEIGHT (%) AFTER IRRADIATION. NUMBER OF FLOWERS BY DOSE, N=5.

Dose (Gy)	0	200	400	600
0 day	100	100	100	100
2 days	100±0.00	99.93±0.10	99.69±0.27	99.31±0.15
5 days	98.28±2.22	99.37±0.51	98.28±1.74	94.73±2.34

Strelitzia sp (Musaceae)

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200,400, 600, and 800 Gy (236.6 Gy/h)
Holding solution: A

Strelitzia was not tolerant to gamma-radiation. The vase-life was shortened by radiation (Table V) and processes of discoloration and wilting were observed. The fresh weight did not modify notably due to the treatment (Table V).

TABLE V. *Strelitzia* FRESH WEIGHT (%) AFTER GAMMA-IRRADIATION AND VASE-LIFE. NUMBER OF FLOWERS BY DOSE, N=5.

Dose (Gy)	0	200	400	600	800
0 day	100	100	100	100	100
2 days	101.27±0.28	98.32±0.90	98.83±0.50	97.76±1.01	98.48±0.49
5 days	96.70±1.98	94.64±2.45	96.65±0.41	95.39±2.60	95.02±0.42
7 days	91.97±3.43	91.06±3.28	-	-	-
vase-life (days)	8	6	5	5	5

Matthiola incana R. Br. (Cruciferae), white and wine color cultivars.

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (234 Gy/h)
Holding solution: A

Matthiola flowers were radiosensitive even at a dose of 200 Gy, presenting bud opening inhibition. Development of the inflorescence was stopped in irradiated samples, while control buds continued generating new flowers. Vase-life was shortened by only one day compared to the controls (Table VI).

TABLE VI. *Matthiola incana* VASE-LIFE (DAYS) AFTER GAMMA-IRRADIATION. NUMBER OF INFLORESCENCE BY DOSE, N=5.

Dose (Gy)	0	200	400	600	800	1000
wine color	6	5	5	5	5	5
white color	7	6	6	6	6	6

Aechmea distichanta (Bromeliaceae)

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (234 Gy/h)
Holding solution: A

Doses of 800 and 1000 Gy caused discoloration of the inflorescence 2 days after irradiation. This was observed later with 200, 400, and 600 Gy, also. The inflorescence discoloration was followed by a decrease of the fresh weight with doses of 600, 800, and 1000 Gy (Table VIII).

TABLE VII. *Aechmea distichanta* FRESH WEIGHT (%), AFTER GAMMA-IRRADIATION. NUMBER OF INFLORESCENCE BY DOSE, N=5.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	99.46±0.38	100.63±1.47	99.11±3.05	96.65±0.11	98.39±4.34	96.31±0.04
5 days	90.92±1.30	95.85±3.79	90.67±4.96	86.51±3.34	87.76±11.77	81.37±6.74

Consolida ajacis Niew (Ranunculaceae)

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (234 Gy/h)
Holding solution: A

Coloration of *Consolida* flowers was not altered by irradiation. However, the leaves were not tolerant even to 200 Gy, presenting an accelerated chlorosis and wilting. Wilting of the flowers was evident at a dose of 400 Gy 5 days after irradiation.

Ranunculus sp (Ranunculaceae)

Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (206 Gy/h)
Holding solution: B

The main negative quality change of irradiated *Ranunculus* flowers was the stem bending (Table VIII). All samples were not viable 5 days after irradiation, including the control ones, due to the wilting of the petals. The fresh weight decrease was more accentuated on irradiated samples (Table IX).

TABLE VIII. NUMBER OF STEM BENDING OF *Ranunculus* FLOWERS, 5 DAYS AFTER GAMMA-IRRADIATION. NUMBER OF FLOWERS BY DOSE, N=10.

Dose (Gy)	0	200	400	600	800	1000
No. of flowers	2	5	5	7	7	10

TABLE IX. *Ranunculus* FLOWERS FRESH WEIGHT (%) AFTER GAMMA-IRRADIATION. NUMBER OF FLOWERS BY DOSE, N=10.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	94.18±6.20	90.30±2.43	89.67±2.59	92.59±5.39	88.30±1.18	91.79±8.86
5 days	80.03±9.60	77.10±5.30	73.29±6.67	76.17±4.33	66.48±5.32	71.14±5.37

Dendrobium phalenopsis (Orchidaceae)
Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (234 Gy/h)
Holding solution: A

There was bud opening inhibition with all doses, but 200 Gy did not cause visible damages when the irradiation was done on opened flowers. Doses of 800 and 1000 Gy were definitely damaging because they caused flowers to drop.

Gerbera sp (Compositae), small size cultivar - light rose and wine colors; normal size cultivar - light rose color.
Irradiation source: Panoramic cobalt-60 source
Doses: 0, 200, 400, 600, 800, and 1000 Gy (208 Gy/h)
Holding solution: B

The irradiated *Gerbera* negative quality changes included stem bending, flower discoloration, curling of petal, and wilting of the flower. Fresh weight decrease after irradiation was a good parameter of measurement related with the visual quality loss of the flowers (Tables X-XII).

TABLE X. *Gerbera* FRESH WEIGHT (%), AFTER GAMMA-IRRADIATION. SMALL SIZE, LIGHT ROSE COLOR CULTIVAR. NUMBER OF INFLORESCENCE BY DOSE, N=4.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	101.57±0.06	99.79±2.11	100.02±1.15	101.36±0.61	101.50±1.34	95.54±2.41
5 days	98.75±0.38	96.00±1.57	86.33±12.81	95.48±1.00	93.86±3.75	85.47±3.53
7 days	95.20±1.54	90.66±0.32	74.11±21.07*	83.04±3.76	85.20±4.48	76.28±2.87
9 days	90.71±4.51	87.58±1.09	83.04±3.76*	80.87±5.95	79.82±4.64	66.90±4.26
12 days	85.76±4.58	83.17±3.18	75.45±2.62*	-	-	-

*N=3

TABLE XI. *Gerbera* FRESH WEIGHT (%), AFTER GAMMA-IRRADIATION. SMALL SIZE, WINE COLOR CULTIVAR. NUMBER OF INFLORESCENCE BY DOSE, N=4.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	101.81±0.40	100.24±0.48	100.62±0.01	98.21±0.65	99.27±0.36	98.45±3.42
5 days	93.93±1.25	89.46±4.45	86.80±2.58	81.16±1.41	81.14±0.41	79.38±2.74
7 days	87.13±1.14	82.66±4.43	78.87±5.30	73.03±0.84	70.94±2.31	69.45±0.66
9 days	82.59±1.22	78.83±3.32	75.25±6.63	68.73±1.53	67.46±3.65	65.89±0.37
12 days	78.67±0.15	74.64±3.53	-	-	-	-

TABLE XII. *Gerbera* FRESH WEIGHT (%), AFTER GAMMA-IRRADIATION. NORMAL SIZE, LIGHT ROSE COLOR CULTIVAR. NUMBER OF INFLORESCENCE BY DOSE, N=6.

Dose (Gy)	0	200	400	600	800	1000
0 day	100	100	100	100	100	100
2 days	100.77±1.60	94.05±8.69	100.30±3.94	99.24±2.00	95.14±0.08	100.08±0.66
5days	92.56±3.30	79.16±11.22	88.96±6.38	83.65±4.10	78.83±0.96	86.30±4.93

4. CONCLUSIONS AND DISCUSSION

Radiation could be an effective treatment against insects in some cut-flowers such as carnations (*Dianthus*) and *Gypsophila*, (Caryophillaceae), *Limonium* (Plumbaginaceae) and *Narcissus* (Amaryllidaceae). These flowers were tolerant to doses up to 900 or 1000 Gy, without negative alterations that could compromise the commercial quality of the flowers. *Dianthus* and *Gypsophila* also were reported as tolerant to a gamma-radiation dose of 500 Gy by Wit and van de Vrie [3]. Tanabe and Dohino [7] reported that *Gypsophila* was tolerant to 400 Gy electron beam irradiation, but had slightly withered petals with 600 Gy. *Limonium sinuatum* cv.'Sophia Soft Pink' was tolerant to 600 Gy electron beam radiation, but *L. sinuatum* cv. 'New Blue' had slight chlorosis of leaves and stems [7]. The *Limonium sinuatum* samples we irradiated were constituted by rose and blue colors, both tolerant to gamma-radiation.

The response to gamma-radiation varied by genus in the Compositae family. *Rhodanthe* and *Helichrysum* were tolerant and *Callistephus* was moderately tolerant. On the other hand, *Gerbera* was not tolerant, and neither was *Chrysanthemum* [4, 5]. *Callisthephus* was reported as tolerant to 500 Gy by Wit and van de Vrie [3] and *Gerbera* was tolerant to 400 Gy electron beam radiation [7], but not tolerant to 100 Gy gamma-radiation [3]. Because the Compositae is the most abundant family of the Angiospermae division, comprising about 19,000 species of plants [16], it could justify the variable response observed in this work. It would be interesting to examine why some genus/species are tolerant to radiation and others are sensitive.

Rhodanthe (Compositae), *Helichrysum* (Compositae) and *Limonium* (Plumbaginaceae) are used as dried flowers and have naturally low water content. Possibly low water content could be one of the reasons for tolerance to radiation.

The tropical plants, *Strelitza* (Musaceae), *Dendrobium phalenopsis* (Orchidaceae) and *Aechmea distichanta* (Bromeliaceae), were sensitive to gamma-radiation. *Strelitza* and *Aechmea* have a high level of water content, which may promote radiosensitivity.

Anthurium was very sensitive to gamma [3] and electron beam [7] radiation, and cannot be irradiated even with low doses, as observed in this work.

Fresh weight was a good parameter of measurement to evaluate the radiation effect in some cases, as with *Narcissus tazetta, Callistephus chinensis, Aechmea distichanta, Ranunculus sp* and *Gerbera sp.* However, it is necessary to develop predictive tests and quantitative measures of internal quality of the cut-flowers to evaluate the product [17].

Intercontinental trade of flowers and other ornamental plants is increasing significantly. Tropical exotic plants are very coveted by North American, Japanese, and European markets, the three major world flower markets. Quality improvement of flowers and quality control are being considered as important goals to the floricultural products world trade [17]. The improvement of the quality of some radiosensitive flowers can be a step to increase the tolerance to the radiation and to other kinds of stress that shorten the vase-life of the cut-flowers.

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