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Irradiation of Star apple and cut flowers

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INTRODUCTION

Mekong Delta in Vietnam



Many kinds of fruits in Mekong delta

INTRODUCTION

16 Export Fruits of Vietnam have a good opportunity to export to US

According to its commitment in accession to the WTO and trade promotion program, The Ministry of Agriculture and Rural Development (MARD) has announced sanitary and phytosanitary standards (SPS) database of 16 kinds of fruits to be exported to the US

1. **Dragon (2008)**
2. **Rambutan (2011)**
3. **Longan (2014)**
4. **Litchi (2014)**
5. **Star apple (2017)**
6. **Mango (2017)**
7. **Pomelo**
8. **Banana**
9. **Pineapple**
10. **Watermelon.**
11. **Sapodilla**
12. **Durian**
13. **Guava**
14. **Plum**
15. **Jack-fruit**
16. **Rose-apple fruit**

INTRODUCTION

Star apple fruits (*Chrysophyllum cainito*) from Vietnam are allowed to be imported to US since July 2017 by USDA/APHIS.



Star apple fruits must be irradiated at 400 Gy minimum absorbed dose to quarantine .

- Famous star apple fruit: Lo Ren and purple
- Harvested time: December to March
- Rich of nutrients.



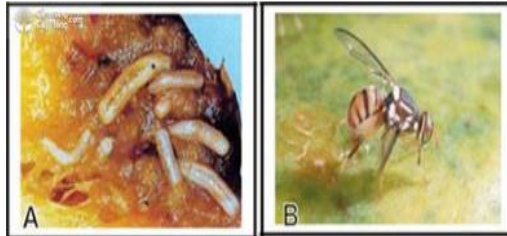
INTRODUCTION

Pest and diseases risk assessment of star apple fruit

Pests with highest risk potential (fruit borer)	Pests with high risk potential (fruit flies)	Pests with medium risk potential (mealybugs)	Diseases with high risk potential (fungi)
- <i>Nephopterix</i> sp. (<i>Pyralidae</i> – <i>Lepidoptera</i>)	- <i>Bactrocera dorsalis</i> (Hendel) (Diptera: Tephritidae) - <i>Bactrocera correcta</i> (Bezzi) (Diptera: Tephritidae)	- <i>Icerya</i> sp. (Homoptera: Margarodidae)	- <i>Lasiodiplodia theobromae</i>



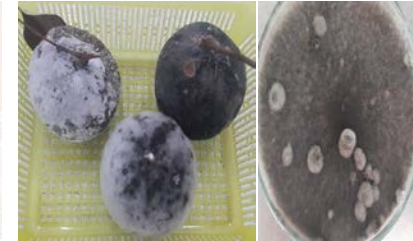
fruit borer larvae



Fruit fly larvae & adult



Mealybugs: *Icerya* sp.



Fungi

METHODS



- 1/ Effect of Gamma and EB irradiation on quality of star apple
- 2/ Effect of Gamma and EB irradiation on insects, fungi infested on star apples
- 3/ Determination of dose distribution on the carton of products
- 4/ Synergistic effect of combined treatment on Star Apple at trading condition

RESULTS AND DISCUSSION

Effect of Gamma and EB irradiation on quality of star apple after 6 days stored at room temperature (27°C±2, RH 70-80%)

Type of Irr.	Dose (kGy)	Lo Ren star apple			Purple star apple		
		Brix	Weight loss (%)	a*	Brix	Weight loss (%)	b*
EB	0	11.6±0.5 ^a	0.27±0.01 ^a	-5.39 ± 0.74 ^a	11.7 ± 0.4 ^a	0.23 ± 0.06 ^a	11.24 ± 1.17 ^a
	0.4	11.6±1.7 ^a	0.25±0.05 ^a	-5.00 ± 0.76 ^{ab}	11.0 ± 0.3 ^a	0.33 ± 0.06 ^{ab}	19.49 ± 1.20 ^b
	0.6	11.2±0.3 ^a	0.26±0.02 ^a	-5.99 ± 0.86 ^{ab}	11.5 ± 0.5 ^a	0.26 ± 0.1 ^{ab}	18.78 ± 1.25 ^b
	0.8	11.1±0.8 ^a	0.36±0.01 ^b	-3.56 ± 0.83 ^b	11.7 ± 0.6 ^a	0.32 ± 0.11 ^{ab}	18.32 ± 1.95 ^b
	1.0	11.3±1 ^a	0.37±0.09 ^c	-1.57 ± 0.89 ^c	11.7 ± 0.6 ^a	0.37 ± 0.22 ^{ab}	17.71 ± 2.50 ^b
γ ray	0	11.1±0.7 ^{ab}	0.31±0.06 ^a	-5.45 ± 1.34 ^a	11.9 ± 0.6 ^a	0.33 ± 0.04 ^a	9.78 ± 0.63 ^a
	0.4	12±1.3 ^{ab}	0.3±0.03 ^a	-5.65 ± 0.80 ^a	11.6 ± 1.2 ^a	0.29 ± 0.01 ^a	13.36 ± 1.88 ^b
	0.6	11.2±0.3 ^{ab}	0.33±0.03 ^{ab}	-6.43 ± 1.26 ^a	11.4 ± 1.7 ^a	0.33 ± 0.06 ^a	11.91 ± 1.94 ^{ab}
	0.8	11.5±0.9 ^{ab}	0.36±0.01 ^b	-4.69 ± 1.10 ^a	11.5 ± 2.3 ^a	0.32 ± 0.02 ^a	13.62 ± 0.82 ^b
	1.0	10.7±0.3 ^a	0.38±0.01 ^b	-3.79 ± 1.40 ^a	11.8 ± 0.3 ^a	0.35 ± 0.06 ^a	13.23 ± 1.01 ^b

The same letter in the column is insignificant difference (t-test, P= 0.0001).



EB



γ

Star apple after 9 days at room temperature



ray



EB



γ

ray

Lo Ren star apple after 1 day treatment by Irradiation and keep at room temperature (T=27±2°C; RH: 85±5%)



EB



γ ray

Purple star apple
after 1 day
treatment by
Irradiation and
keep at room
temperature
($T=27\pm 2^{\circ}\text{C}$; RH:
 $85\pm 5\%$)



RESULTS AND DISCUSSION

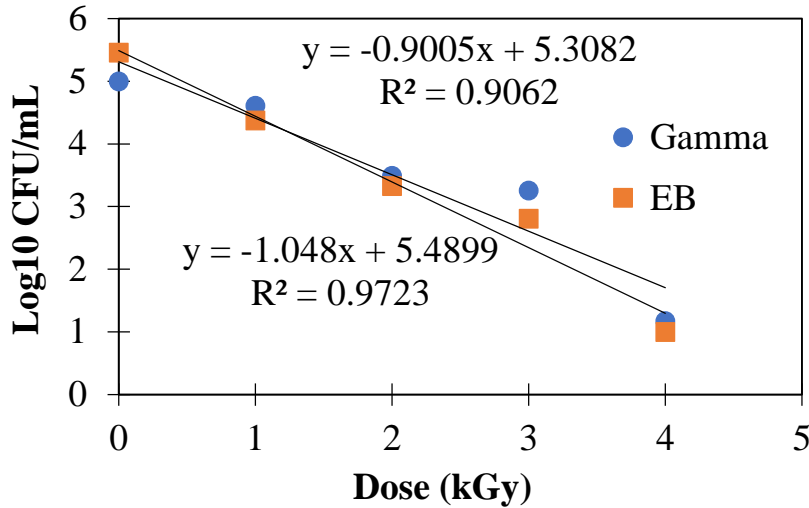
Effects of gamma and EB irradiation to pathogenic fungi and pest insects infesting on star apples

Subjects	Dose (kGy)	EB			γ ray		
		3d	6d	9d	3d	6d	9d
Pest insects	0 (Control)	-	+	++	-	+	++
	0.4	-	-	-	-	-	-
	0.6	-	-	-	-	-	-
	0.8	-	-	-	-	-	-
	1.0	-	-	-	-	-	-
Molds/fungi	0 (Control)	-	+	++	-	+	++
	0.4	-	+	++	-	+	++
	0.6	-	+	++	-	-	++
	0.8	-	-	++	-	-	+
	1.0	-	-	-	-	-	-

(-), (+), and (++) were not appearance, beginning appearance and a lot appearance, respectively

(15 fruits/observation time)

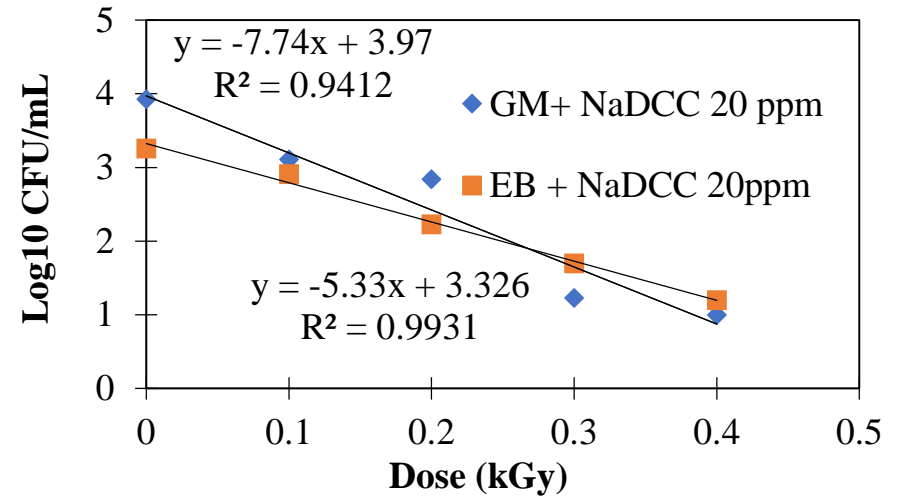
Comparison of resistance of fungal spores *Lasiodiplodia theobromae* isolated from fresh star apples to gamma and electron beam radiation.



Survival curves for conidiospores *Lasiodiplodia theobromae* following gamma and EB treatment



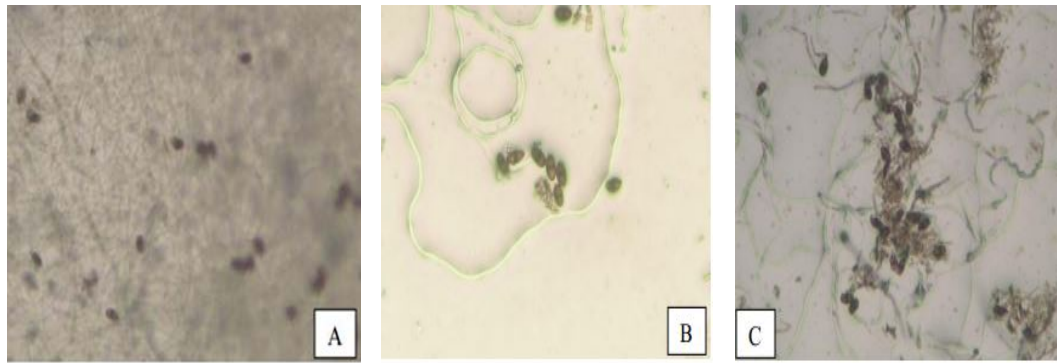
D_{10} value is 0.95 kGy and 1.1 kGy for gamma and EB respectively



Survival curves for conidiospores *Lasiodiplodia theobromae* following gamma and EB combined with NaDCC treatment



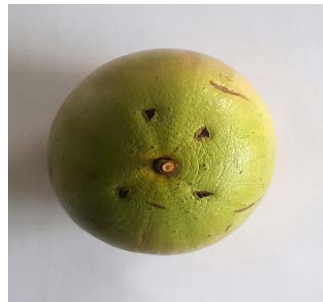
D_{10} value reduced to 0.13 kGy (for NaDCC + GI) and 0.19 kGy (for NaDCC + EbI) in combination



Spores and hyphae of *Lasiodiplodia theobromae* under microscope in combined treatment of irradiations and NaDCC: 20ppm NaDCC + 0 kGy (A); 20ppm NaDCC + 0.4 kGy Gamma irradiation (B) & 20ppm NaDCC + 0.4 kGy EB irradiation (C)



Control



NaD. 20ppm + 0 kGy



NaD. 20ppm + 0.4 kGy

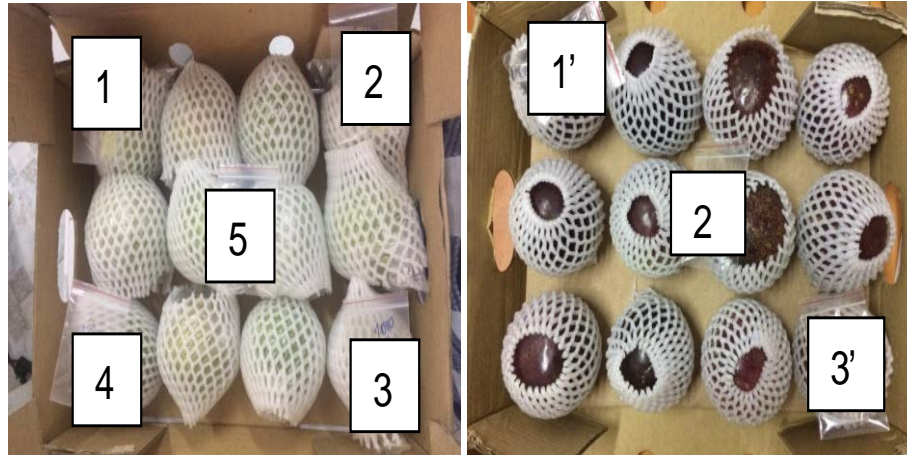


NaD. 20ppm + 0.6 kGy

Effect of combined treatment of EB irradiation and NaDCC 20ppm on *Lasiodiplodia theobromae* in vivo condition

RESULTS AND DISCUSSION

Determination of dose distribution on the carton of products (EB)



The carton dimension:
L49×W32×H12 cm

Gross weight: 4 kgs

Dose distribution on the carton of products (Lo Ren and purple star apple)

Parameter	Lo Ren star appele					Purple star aple		
Location	1	2	3	4	5	1'	2'	3'
Dose (Gy)	416	409	417	439	399	420	405	435
DUR (Dmax/Dmin)	1.1					1.07		

Distribution on carton of star apple is suitable for both kinds of star apples because DUR of 1.1 (Lo Ren) and 1.07 (purple).





5-7cm



8-10 cm

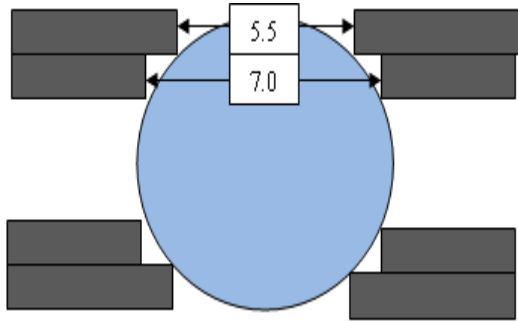


Hình 15: Dose distribution inside and outside star apple fruit

Vị trí	Purple		Lo Ren	
	Inside (kGy)	Outside (kGy)	Inside (kGy)	Outside (kGy)
1	2.5	1.8	1.9	1.8
2	2.2	2.0	2.0	1.8
3	2.3	1.9	1.9	1.9
4	3.3	1.9	2.1	1.9
5	4.0	2.4	2.0	1.9

DUR of Lo Ren star apple = 1.2

DUR of purple star apple = 2.2 → To assure the quality of irradiated purple star apples mdf wedges with 1 cm of thickness were suggested to put in the carton to get lower DUR.



Purple star apples using mdf wedges inside the carton

Dose uniformity ratio (DUR) for purple star apple before and after using mdf wedge

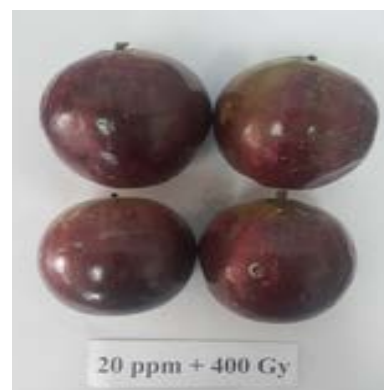
Location	Before		After	
	Inside of fruit (kGy)	Outside of fruit (kGy)	Inside of fruit (kGy)	Outside of fruit (kGy)
1	7.8	5.7	5.7	7.1
2	6.9	6.2	6.7	7.0
3	7.4	6.1	6.2	7.7
4	10.5	7.5	6.5	8.2
5	12.8	7.7	7.1	8.1
DUR	2.2		1.4	

DUR reduce form 2.2 to 1.4.

RESULTS AND DISCUSSION



Using 20 ppm NaDCC in pre-treatment before EB irradiation (dose of 0.4 – 0.6 kGy) extended shelf-life of star apple when keeping them under the trade conditions (7 days at 9°C in transportation by air to destination). The shelf-life of both types of star apples (13 days) was higher than the control (non- treatment. un-irradiation) (6 days) (Figure 4).



Star apple fruits after 13 days under trade conditions

Color and disease severity of star apple during time storage under trade conditions

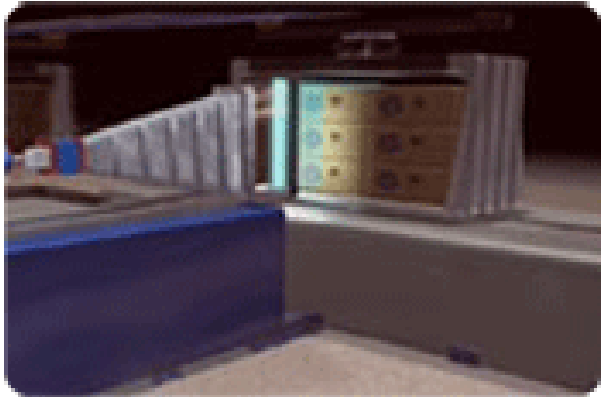
Parameter	Treatment	Lo Ren Star apple					Mean of dose
		0 d	7 d	10d	13 d	16 d	
L*	DC	61.03 ± 4.18	60.50 ± 4.13	60.30 ± 3.95	59.76 ± 6.33	54.42 ± 3.86	59.20B
	N - 0 Gy	64.05 ± 2.48	63.52 ± 2.52	62.98 ± 2.68	61.80 ± 2.30	59.42 ± 5.39	62.35A
	N - 400 Gy	62.41 ± 2.90	61.89 ± 2.91	62.32 ± 1.87	62.07 ± 2.28	48.65 ± 8.46	59.47B
	N - 600 Gy	61.60 ± 1.85	61.07 ± 1.91	61.65 ± 1.38	58.22 ± 2.17	48.05 ± 3.94	58.12B
	Mean of time	62.27a	61.74a	61.81a	60.46a	52.63b	
disease severity	DC	0.71	0.71	0.97 ± 0.51	1.24 ± 0.67	2.35 ± 0.00	1.19A
	N - 0 Gy	0.71	0.71	0.71	0.80 ± 0.29	1.43 ± 0.71	0.87B
	N - 400 Gy	0.71	0.71	0.71	1.00 ± 0.44	2.25 ± 0.12	1.07A
	N - 600 Gy	0.71	0.71	0.71	1.03 ± 0.49	2.30 ± 0.10	1.09A
	Mean of time	0.71a	0.71a	0.77a	1.02b	2.08c	
Purple star apple							
L	DC	45.22 ± 3.91	41.42 ± 3.48	37.65 ± 1.54	36.51 ± 2.12	30.11 ± 2.45	38.18A
	N - 0 Gy	47.10 ± 2.49	42.90 ± 2.21	41.83 ± 3.67	38.11 ± 0.51	36.28 ± 2.46	41.24B
	N - 400 Gy	48.34 ± 2.10	43.74 ± 2.49	40.56 ± 1.02	39.02 ± 1.69	34.68 ± 2.31	41.27B
	N - 600 Gy	47.73 ± 1.12	44.97 ± 2.10	40.89 ± 1.88	39.06 ± 1.74	33.84 ± 2.04	41.30B
	Mean of time	47.10a	43.26b	40.23c	38.17d	33.73e	
disease severity	DC	0.71	0.71	1.37 ± 0.72	1.69 ± 0.9	2.35	1.36A
	N - 0 Gy	0.71	0.71	0.71	0.71	1.81 ± 0.23	0.96B
	N - 400 Gy	0.71	0.71	0.71	0.71	2.3 ± 0.1	1.03B
	N - 600 Gy	0.71	0.71	0.71	0.71	2.3 ± 0.1	1.03B
	Mean of time	0.71a	0.71a	0.87ab	0.95b	2.19c	

Mean values followed by the same letter are not significant difference at $P < 0.05$

Data of disease severity was transformed to $(xi+0.5)^{1/2}$



Vietnam must prepare 10 years for exported star apple fruit to the US.



Status of Exported Lo Ren star apple fruits to US

- Starting from September 2017
- Exported Quantity: **238.36 tones** from December 26, 2017 to March 15, 2018 (transportation by airplane)

Area (province)	Export lot number	Exported quantity (tons)	Required phytosanitary treatment
Tien Giang	95	164.48	Irradiation
Can Tho	47	73.88	
Total	142	238.36	

Price in US market: 10 USD/kg

Phytosanitary irradiation of cut flowers by electron beams

- ❖ Status of export cut flowers in Vietnam
- ❖ EB irradiation of cut flowers for quarantine purpose
- ❖ Combination of pre-treatment and irradiation to prolongate flower's vase-life



Vietnam's cut flower export value to Japan is approximately 6.2 million USD per year, which constitutes 1.4% of Japan's total flower imports. In the next years, this figure could increase by more than USD 8 million.



❖ Insect pests infested on flowers



Fig. 1: thrip



Fig. 2: leafminers



Fig. 3: red mites

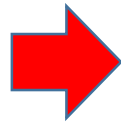


Fig. 4: green worm

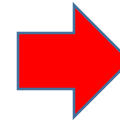
Treatment and irradiation cut flowers:



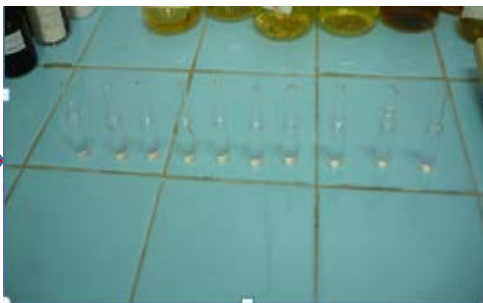
Cut flower



Pre-treated



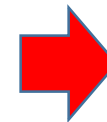
EB irradiation



Dosimeter: Fricke/Ag dicromat



Evaluate quality of cut flowers



Analyzed of variance (ANOVA) using Statgraphics 15.0 with the reliability $P = 0.05$.

Determination of dose distribution on the carton of products

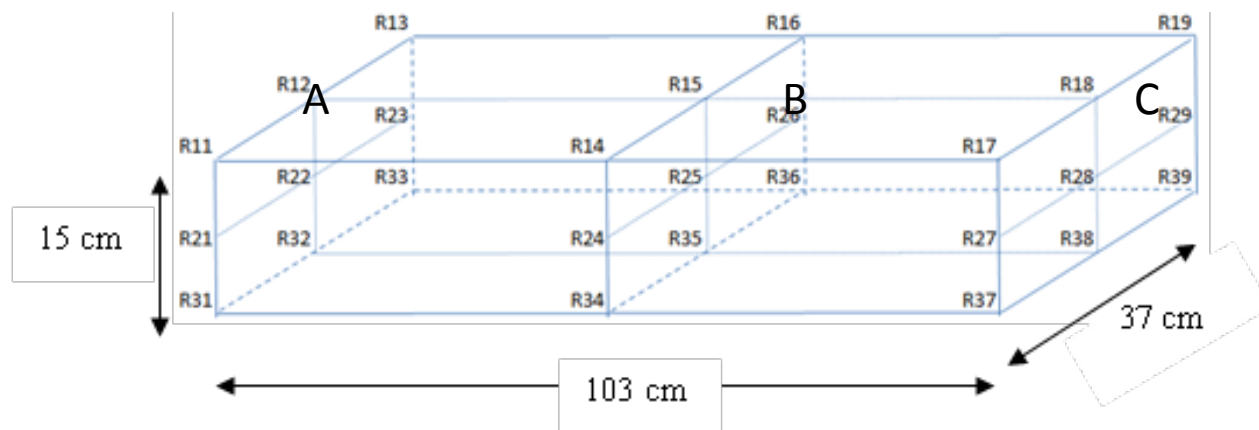


Diagram to fix dosimeters for determine dose distribution on the carton box of Chrysanthemum

Type of flower	Position of fixed dosimeters	Measured dose, Gy (Means)	DUR (Dmax/ Dmin)	Total DUR
Chrysathemums	A (Flower)	600 ÷ 730	1.22	1.7 (±0.15) (530 ÷ 870)
	B (Stem)	790 ÷ 870	1.10	
	C (Flower)	530 ÷ 680	1.28	
Carnations	A (Flower)	360 ÷ 430	1.19	1.27 (±0.05) (350 ÷ 440)
	B (Stem)	350 ÷ 420	1.20	
	C (Flower)	360 ÷ 440	1.22	

Effect of EB Irradiation on quality of cut flower

Effect of EB Irradiation on color, weight loss of chrysanthemum flower after 6 days at room temperature (T = 27°C±2, RH = 70-80%)

Parameters	Dose (Gy)	Color of flower (TB±SD)	
		Yellow	White
L	0	49.76±2.13a	65.79±2.16a
	200	50.36±7.88a	51.41±5.74b
	300	55.81±3.72a	51.14±2.97b
	400	48.56±1.45a	52.55±6.71b
a	0	-8.39±1.85a	-8.55±2.41a
	200	-7.32±2.13a	-11.95±1.19ab
	300	-7.19±0.82a	-13.71±2.73a
	400	-7.76±0.96a	-11.68±2.71ab
b	0	64.45±1.59a	19.66±4.87a
	200	58.64±6.56a	33.79±2.99ab
	300	59.68±1.51a	38.17±7.04b
	400	58.32±1.8a	30.71±12.19ab
Weight loss, %	0	11.81±6.7a	10.94±4.13a
	200	12.5±2.08a	15.1±3.29a
	300	13.89±2.41a	15.63±1.57a
	400	21.53±1.47b	26.54±1.67b

Mean of each parameter with the same letter in the column is insignificant difference (t-test, P= 0.0001).



Flower after 6 days at room temperature

Effect of EB Irradiation on color, rate of yellowed leaves of chrysanthemum after 6 days at room temperature (T = 27°C±2, RH = 70-80%)

Parameters	Dose (Gy)	Color of leaves (TB±SD)	
		Yellow	White
L	0	34.63±7.09a	32.99±1.59a
	200	28.41±1.20ab	29.54±4.97a
	300	24.37±2.76b	31.53±8.80a
	400	31.05±6.26ab	33.98±4.91a
a	0	-8.34±0.35a	-9.84±0.62a
	200	-8.00±1.75a	-9.05±0.96a
	300	-9.31±0.67a	-9.12±0.16a
	400	-6.87±3.12a	-9.72±0.57a
b	0	15.13±1.74ab	14.55±0.37a
	200	13.18±1.37b	14.48±1.28a
	300	17.57±0.23d	16.83±0.13b
	400	15.43±0.46c	18.01±2.01b
Rate of yellowed leaves, %	0	42.75±10.67a	7.55±5.04a
	200	41.1±51.01a	11.93±2.66ab
	300	47.57±19.1a	17.04±3.18bc
	400	47.43±30.21a	19.73±4.96c

Mean of each parameter with the same letter in the column is insignificant difference (t-test. P= 0.0001).



Leaves of *Chrysanthemum* after 6 days at room temperature



Effect of
EB Irradiation
on quality of
carnation after 6
days at room
temperature (T =
27°C±2. RH =
70-80%)

Parameters	Dose (Gy)	Red carnations (TB±SD)
L	0	32.90±2.78a
	200	26.34±1.48b
	300	31.97±0.44a
	400	31.87±1.90a
a	0	41.83±1.12a
	200	40.53±1.88a
	300	41.42±1.36a
	400	41.04±3.59a
b	0	17.50±2.15a
	200	16.16±2.21a
	300	15.13±0.80a
	400	18.16±1.92a
Rate of yellowed leaves. %	0	12.5±4.22a
	200	9.98±3.13a
	300	13.34±5.93a
	400	21.18±3.21a
Weight loss. %	0	5.55±0.94a
	200	5.56±0.9a
	300	5.56±0.9a
	400	7.78±0.59a

*Mean of each
parameter with
the same letter in
the column is
insignificant
difference (t-test.
P= 0.0001).*



Carnation after 6 days at room temperature

The pattern of tolerance to irradiation in red mites was eggs < 2nd instars (deutonymphs) < adults

Effect of irradiation on survival and reproduction of female adult after 15 days

Dose (Gray)	The number of red mites adults	Mortality rate (%)	Number of eggs/ female adult	Hatching rate of eggs (%)
0	58	16.49±4.31 ^a	2759 ± 23 ^a	93.6±1.46 ^a
100	45	55.33±7.92 ^b	256 ±12.53 ^b	63.68±5.78 ^b
200	47	77.71±7.45 ^c	187±10.15 ^c	41.5±2.08 ^c
300	53	100±0.00 ^d	81.67±9.02 ^d	4.25±2.91 ^d
400	57	100±0.00 ^d	43.33±4.73 ^e	0±0.00 ^d

Mean values within same stage followed by the same letter are not significant different at P=0.05.

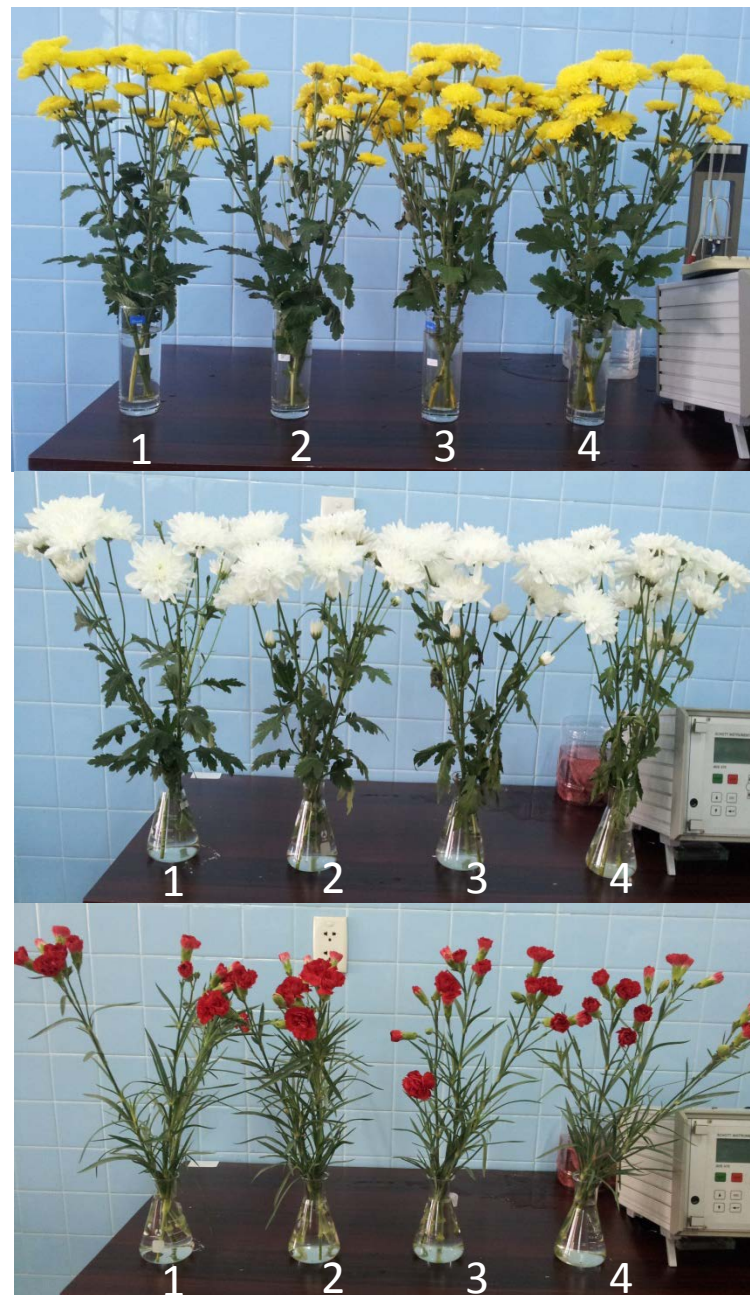
The mortality rate of female increased after 15 days and reached to 100% at dose 300. 400 Gy. Viability of eggs laid by irradiated females decreased with the increase of dose. Hatchability of eggs produced by treated red mite adults at dose 300 Gy was 4.25%. However, the number 1st instars (protonymphs) of F1 generation did not develop to 2nd instars during the observed time

➤ Using Glucose + STS to treat cut flowers before irradiation will increase their radio-tolerance when keeping under the trade conditions (5 days at 4-6°C in transportation).

➤ The vase-life of irradiated cut flowers is equivalent to the control (non-treatment. unirradiation) with 4 days for yellow chrysanthemum; 6 days for white chrysanthemum and 8-10 days for carnation (Figure 5).

1. control,
2. Glucose + STS + 0 Gy
3. Glucose + STS + 400 Gy
4. Glucose + STS + 600 Gy

STS: Sodium thiosulfate



A young woman with long dark hair, wearing a yellow long-sleeved shirt, is smiling and reaching up to touch a green apple hanging from a tree. The tree is filled with many green apples and lush green leaves. The scene is brightly lit, suggesting a sunny day in an orchard.

Thank you!