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Article

Effect of using microwave, UV and gamma rays on the morphological and chemical characteristics of the tuberose plant

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Abstract: Flowers are an integral part of our life due to their diversity in form, color and fragrance. Tuberose is a marketable ornamental species and considers as one of the most important ornamental flowers grown mainly due the long flowering period, which is an important aspect whether grown as cut flowers or landscaping. The aim of the experiment was to study the effect of using microwaves, UV rays and gamma rays on the growth and flower quality of tuberose plant. Data revealed that irradiation of Tuberose bulbs with microwaves for 10 and 20 seconds significantly improved the growth and flower quality parameters while the time from planting to harvest increased compared to the control. For UV-C rays, 1 and 2 hours exposure increased Tuberose growth and flower quality with superiority of 2 hour exposure except for the time from planting to harvest where 1 hour was superior to 2 hour exposure as the time from planting to harvest was similar to the control. Gamma irradiation of bulbs enhanced growth and flower quality parameters with preference of dose of 5 Gy, however, the time from planting to harvest increased with all doses compared to the control. In conclusion, irradiation of Tuberose bulbs with microwave for 20 seconds, UV-C for 2 hours and gamma rays at dose of 5 Gy could be effective treatments for improved production of Tuberose with enhanced growth and flower quality. The most important indicators, which reflect the economic efficiency of transactions of microwaves, UV rays and gamma rays to tuberose (*Polianthes tuberosa* L.) plants, are average productivity, total return, the net return, benefit-cost ratio, cost of florets, and cost of corms, profitability, and return on the invested pound of feddan.

Key words: Ornamentals, bulbs, radiation, vase life, spike.

1. Introduction

Flowers are prized as object of great beauty and diversity and are commercially valuable and highly perishable **(O'Donoghue, 2006)**. Tuberose is popular flowering plant worldwide, uses usually as cut flower or garden decoration in pots, beds, borders, and for extraction of essential oil. Tuberose is popular among flowers loving people because of its sweet and pleasant fragrance and long vase life **(Singh and Shanker, 2011)**. Furthermore, tuberose produces attractive and fragrant white flowers which occupy very selective and special position among the ornamental bulbous plants, it is an important flower which has both aesthetic as well as economic value **(Sood and Nagar, 2005)**. The term growing medium or substrates are used usually to describe the materials used to grow plants in containers. The good substrate should have some characteristics such as provide adequate amounts of aeration and water, allow for maximum root growth and support the plant. Substrates are often being single materials as inorganic or organic substrates, also substrate mixture or growing media are often formulated from a mix of different substrates in order to achieve the correct balance of air availability.

Gamma radiation it is used for their simple method, having short wavelength with high penetrable power, high mutation frequency and not harmful to health than chemical mutagens **(Khan *et al.*, 2000)**. Gamma irradiation is a technology that could enhance growth and quality of plants, for their high mutation frequency and can affect morphology, anatomy, biochemistry and physiology of the plants **(Chahal and Gosal, 2002)**. reover, it is a method, which began to use early in 20th century, plays a vital role in the development of plants **(Kharkwal, 2012)**. Because they are non-toxic and do not require detoxification after implementation, therefore, the ease of treatment plays an important role on global spreading of the technique **(Mba, 2013)**. Furthermore, gamma rays showed a positive response in terms of germination speed and vigor index of *Terminalia Arjuna* at lower doses of 25 Gy **(Akshatha *et al.*, 2013).** The application of different types of radiation such as UV and gamma rays is considering non-invasive methods that are eco-friendly and enhance the germination rate and the growth of seeds **(Thakur *et al.*, 2022)**.

Ultraviolet radiation is an electromagnetic radiation with shorter wavelengths than the visible light, but longer than X - rays **(Shetta and Areaf, 2009).** UV-A radiation has valuable effects on plant metabolic and morphological processes, such as photosynthesis, biomass production, and synthesis of pigments and antioxidant compounds **(Verdaguer *et al.*, 2017).** In addition, seed treated with UV at low levels is environmentally safe to improve plant productivity, and induced tolerance of plants to biotic stresses **(Forges *et al.*, 2018).** Furthermore, it has been shown to stimulate plant growth, improve stress tolerance, and enhance crop productivity in various plant species by the induction of the production of antioxidants, phytohormones **(Foroughbakhch *et al.*, 2019).** Besides, the ultraviolet irradiation on seeds, raise the permeability of membranes of cells changes, which leads to stimulation of the initial growth processes **(Shaazizov and Shukurov, 2020)**.

The Economic evolution of the experiments generally depends on the set of economic indicators that must be taken into consideration when conducting the economic evolution. To estimate or predict the economic viability of microwaves, UV rays and gamma rays to Tuberose (*Polianthes tuberosa* L.) plants, these indicators are average productivity, total return, the net return, benefit-cost ratio, cost of florets, and cost of corms, profitability, and return on the invested pound of feddan. as these indicators usually reflect the economic efficiency of transactions **(Guirguis, 2002).**

Therefore, the aim of the experiment was to study the effect of using microwaves, UV rays and gamma rays on the growth and flower quality of tuberose plant.

2. Materials and Methods

This investigation was carried out during the two successive seasons of 2022 and 2023, at open field in the nursery of Ornamental plants and Gardening Landscape Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.

The bulbs of *Polianthes tuberosa* L.were obtained from horticulture research station at al-kanater El-khaireya. Microwave treatment involves exposure of Tuberose bulbs to128 waves for 10, 20, 40 or 60 seconds. The used microwave was single phase, 220 V., 1.3 kW, output at a frequency of

2450 MHz (Model 129 Mo6T). Ultraviolet treatment involves exposure of Tuberose bulbs to UV-C of 30 watt for 1, and 2 hours. The lamp was 90 cm long and placed at the height of 40 cm from the bulbs. Gamma irradiation treatment involves exposure of Tuberose bulbs to 5, 100, and 200 Gy. Exposure of bulbs to microwave and UV-C were held at Ornamental plants and Gardening Landscape Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt. Bulbs gamma irradiation were held at the National Center for Radiation Research and Technology, Egyptian Atomic Energy Authority, Cairo, Egypt using a Gamma cell unit (^{60}Co) at dose rates of 0.58 and 0.50 for 2022 and 2023, respectively. Bulbs are used by direct planting in permanent soil. The physical and chemical properties of the soil used are shown in Tables (1) and (2).

Table (1). Physical properties of sand and clay used in plantation

Soil texture	Coarse sand %	Fine Sand %	Clay sand %	Silt %
Sandy	88.04	3.21	0.72	8.03
Clay	1.20	22.6	21.7	54.50

Table (2). Chemical properties of sand and clay used in plantation

Soil texture	S.P.	PH	E.C (dS/m)	Cations (mg/l)				Anions (mg/l)		
				Cu++	Mg++	Na+	K+	HCO_3-	Cl --	SO_3 -
Sandy	21.07	7.75	3.46	13.46	4.98	20.40	0.62	2.41	14.5	22.56
Clay	42.30	7.40	1.51	2.94	1.29	3.89	2.30	3.54	4.33	

All the recommended cultural practices namely, irrigation and fertilizer, were carried out during the plant's growth and flowering period. The fertilizers were supplied for each treatment as recommended, Irrigation was done with tap water according to the needed amount of water, and weeding was carried out by hand as the soil needed.

Different measurements have been recorded during the experimental time; vegetative growth measurements such as: plant height (cm), number of leaves/ plant, leaves fresh and dry weights (g/plant). Flowering and flower quality measurements such as: number of florets/spike, number of days from planting to harvest (days), spike length (cm), spike fresh weight (g) and vase life (days). Chemical measurements such as: total chlorophyll was determined in leaf samples in mg/ 100g fresh weight according to **(Wellburn and Lichtenthaler, 1984).** The elements content was measured in leaves including nitrogen% via Kjeldahl method **(Bremner and Mulvaney, 1982)**, phosphorus% via spectrophotometer **(Olsen and Sommers, 1982)**, and potassium% via flame photometer **(Jackson 1970)**. Elements were calculated as a percentage of dry matter.

All data recorded were statistically analyzed using a one-way Analysis of Variance (ANOVA) for a complete randomized design **(Gomez and Gomez, 1984)** utilizing the “MSTAT-C” computer software package **(MSTAT, 1989).** The means of all treatments were assessed using Duncan’s multiple range tests at a 5% level of probability **(Waller and Duncan 1974).**

For Economic evaluation, descriptive and quantitative statistical analysis methods have been applied as simple statistical methods such as percentages and arithmetic, in addition to a set of developments in economic indicators, as these indicators usually reflect the economic efficiency of transactions. The most important of these indicators are average productivity, total return, the net return, benefit-cost ratio, cost of florets, and cost of corms, profitability, and return on the invested pound of feddan.

3. Result and Discussion

The results in Table (3) demonstrate the effect of microwave, UV, and gamma rays on plant height, vase life and number of leaves/plant of Tuberose. Irradiation of Tuberose bulbs with microwaves up to 20 sec significantly increased plant height, vase life and number of leaves/plant, after that the effect reversed compared to the control. Irradiation of Tuberose bulbs with UV-rays significantly increased plant height, vase life and number of leaves/plant. Exposure of Tuberose bulbs to gamma rays at dose of 5Gy significantly increased plant height, vase life and number of leaves/plant. Doses of 100 and 200 Gy decreased plant height, and vase life while induced a non-significant increase in the number of leaves/plant compared to the control. The highest values of plant height, and vase life were obtained with 20 sec of microwave irradiation (35.00-37.00 cm, 7.5-7.75 days) and 2 hr. of UV irradiation (35.00-36.00 cm, 7.25-7.5 days). The highest number of leaves/plant was obtained with dose of 5Gy gamma radiation (46.00 in both seasons) and 2 hr. of UV irradiation (44.00-45.00).

The enhancing effect of microwave radiation at exposure time of 20 sec on Tuberose and the negative effect of higher exposure times (40 and 60 sec) was also reported on Gladiolus where 10 and 20 sec exposure to microwave increased plant height, and number of leaves/plant with superiority of 10 sec whereas exposure time of 30sec decreased both plant height, and number of leaves/plant **(Moustafa *et al*., 2018)**. Moreover, exposure of Freesia hybrida plants to 15 sec of low and medium intensity microwave radiation significantly increased the plant height compared to the control. On the other hand, exposure times of 5, and 20 sec induced non-significant increase in plant height. The positive effect of low dose gamma radiation (5 Gy) on plant height, and the number of leaves/plant was also reported by **Mounir *et al*. (2022)** on Jerusalem artichoke (*Helianthus tuberosus* L.) where dose of 5 Gy was superior to 2,5 and 10 Gy. The inhibitory effect of gamma radiation at high doses was also confirmed by **El-Khateeb *et al*. (2016)** who found that irradiation of stem cuttings of Philodendron scandens at doses of 20-80 Gy significantly decreased the plant height, and the number of leaves/plant. Another study on Gladiolus revealed that irradiation at doses of 20 and 40 Gy induced a significant increase in plant height, and number of leaves/plant with preference to 20 Gy while dose of 80 Gy decreased plant height, and number of leaves/plant **(Moustafa *et al*., 2018).**

Table (3). Effect of microwave, UV, and gamma rays on plant height, vase life and number of leaves/plant of Tuberose (*Polianthes tuberosa* L.)

	Plant height (cm)		Vase life (days)		Number of leaves/plant	
Season	1st	2nd	1st	2nd	1st	2nd
Cont.	30.00 d	32.00 d	5.50 e	6.25 d	35.00 e	37.00 e
MV 10 sec.	32.00 b	35.00 b	5.80 d	6.50 c	37.00 d	40.00 c
MV 20 sec.	35.00 a	37.00 a	7.50 a	7.75 a	41.00 c	43.00 b
MV 40 sec.	29.00 d	28.00 e	6.80 b	7.00 b	33.00 f	41.00 bc
MV 60 sec.	25.00 f	24.00 f	6.00 c	6.25 d	31.00 g	37.00 e
UV 1 hr.	31.50 c	32.00 d	6.25 c	6.50 c	37.00 d	39.00 c
UV 2 hr.	35.00 a	36.00 ab	7.25 a	7.50 a	44.00 a	45.00 a
GM 5 Gy	35.00 a	33.00 c	6.50 b	6.70 c	46.00 a	46.00 a
GM 100 Gy	27.00 e	29.00 e	5.70 d	5.80 e	42.00 b	42.00b
GM 200 Gy	25.00 f	24.00 f	5.50 e	5.60 e	36.00de	38.00 d

Means with different letters indicates significant difference at $p < 0.05$.

The enhanced plant growth in response to low gamma doses could be related to altering the hormonal signaling network and increased cells' anti-oxidative capacity **(Kim *et al*., 2004).** Also, gamma irradiation causes modifications in transcriptional control of genes related to signal transduction, transcription factors, antioxidant system, phytohormones, metabolism transport, energy, morphogenesis and cell cycle **(Gicquel *et al*. 2012 and Gudkov *et al*. 2019).** The positive impact on the photosynthetic process related to stimulation of the Rubisco enzyme, a central component of the

CO_2 fixation process (Singh *et al*. 2013). Another cause of overall enhanced growth and flower quality is stimulated antioxidant activities such as peroxidase (Ling *et al*. 2008), superoxide dismutase (Kim *et al*. 2004) and ascorbate peroxidase and glutathione reductase **(Macovei *et al*., 2014)** as well as stimulated cell division.

The effect of microwave, UV, and gamma rays on florets/spike, number of days from planting to harvest and spike length of Tuberose was illustrated in Table (4). Irradiation of Tuberose bulbs with microwaves significantly increased florets/spike, number of days from planting to harvest and spike length compared to the control with superiority of 20 sec exposure time followed by 10 sec and then 40 and 60 sec. Irradiation of Tuberose bulbs with UV-rays significantly increased florets/spike, number of days from planting to harvest and spike length compared to the control except 1 hr. exposure where the number of days from planting to harvest was similar to the control. Exposure of Tuberose bulbs to gamma rays significantly increased florets/spike, number of days from planting to harvest and spike length compared to the control with superiority of 5 Gy followed by 100 Gy and then 200 Gy. The highest value of florets/spike was obtained with 20 sec of microwave irradiation (27.25-27.50), while the least number of days from planting to harvest was obtained by the control (106.25 and 106.50 days) and 1 hr. of UV irradiation (106.5 and 107.2 days).

Table (4). Effect of microwave, UV, and gamma rays on number of florets/spike, number of days from planting to harvest and spike length of Tuberose (*Polianthes tuberosa* L.)

	No of florets/spike.		No of days from planting to harvest (days)		Spike length (cm)	
	1st	2nd	1st	2nd	1st	2nd
Cont.	22.20 e	22.5 e	106.25 e	106.50 d	74.25 d	75.24 d
MV 10 sec.	25 .15 b	25.75 b	107.25 d	107.75 c	75.25 c	77.50 c
MV 20 sec.	27.25 a	27.50 a	109.50 a	110.25 a	76.25 b	80.25 a
MV 40 sec.	24.00 c	24.75 c	108.25 b	109.10 b	77.10 a	79.50 ab
MV 60 sec.	23.75 cd	23.75 d	107.75 c	108.00 c	76.25 b	77.25 c
UV 1 hr.	23.50 d	24.75 c	106.50 e	107.20 cd	75.50 bc	76.25 cd
UV 2 hr.	25.10 b	25.50 b	108.25 b	108.75 b	76.25 b	77.00 c
GM 5 Gy	24.50 bc	25.50 b	109.25 a	110.10 a	77.50 a	78.25 bc
GM 100 Gy	23.75 cd	24.25 c	108.50 b	109.10 b	76.25 b	76.50 cd
GM 200 Gy	22.25 e	23.50 d	107.25 d	108.00 c	75.50 bc	75.70 d

Means with different letters indicates significant difference at $p < 0.05$.

The highest number of leaves/plant was obtained with dose of 5Gy gamma radiation (46.00 in both seasons) and 2 hr. of UV irradiation (44.00-45.00). The highest value of spike length obtained with 40 sec of microwave irradiation and 5 Gy gamma rays at the 1^{st} season and with 20 and 40 sec of microwave irradiation in the 2^{nd} season. The increased spike length of Tuberose in response to microwave or gamma rays irradiation was also reported on Gladiolus where gamma irradiation at doses 20-80 Gy as well as microwave exposure for 10 and 20 sec significantly increased spike length compared to the control **(Moustafa *et al*., 2018).** The stimulative effect of low doses of gamma rays irradiation on growth may be due to the increase of cell length or cell number and size shifting in metabolism which promoted the stimulating effect of phytohormones on biosynthesis of nucleic acids. It has been suggested that gamma rays treatment also activates enzyme activity and protein formation, cell reproduction, photochemical activity, respiration rate, and nucleic acid content (Patel *et al*., 2018).

Data on the effect of microwave, UV, and gamma rays on leaves fresh and dry weights, and spike fresh weight of Tuberose was demonstrated in Table (5). Irradiation of Tuberose bulbs with microwaves significantly increased leaves fresh and dry weights with no significant differences between different exposure times compared to the control except for exposure time of 10 sec where the leaves fresh and dry weights was similar to the control. Irradiation of Tuberose bulbs with UV-rays significantly increased leaves fresh and dry weights compared to the control with superiority of 1 hr. exposure time. Exposure of Tuberose bulbs to gamma rays significantly increased leaves fresh and dry weights compared to the control with superiority of 5 Gy followed by 100 Gy and then 200 Gy. The highest value of leaves fresh and dry weights was obtained with dose of 5Gy gamma radiation (160.25, 160.50, 45.25, and 46.25, respectively) followed by 5Gy gamma radiation (158.50, 159.25, 44.50, and 46.50, respectively). For spike fresh weight, microwaves irradiation significantly increased spike fresh weight with preference to 20 sec and then 40 sec. exposure time of 10 and 60 sec increased spike fresh weight in the 1st season only. Irradiation of Tuberose bulbs with UV-rays for 2 hr. significantly increased spike fresh weight while 1 hr. exposure decreased spike fresh weight in the 2nd season.

Table (5). Effect of microwave, UV, and gamma rays on leaves fresh weight, leaves dry weight and spike fresh weight of Tuberose (*Polianthes tuberosa* L.)

	Leaves fresh weight (g/ plant)		Leaves dry weight (g/ plant)		Spike fresh weight (g)	
	1st	2nd	1st	2nd	1st	2nd
Cont.	130.25 d	134.25 f	33.25 d	34.50 e	70.50 f	75.25 f
MV 10 sec.	135.45 d	140.25 e	35.50 d	36.25 de	73.25 e	73.50 g
MV 20 sec.	145.25 c	145.00 d	37.75 c	38.25 d	76.75 d	76.90 d
MV 40 sec.	144.50 c	144.15 d	36.50 c	37.25 d	75.25 e	75.60 e
MV 60 sec.	143.75 c	143.90 d	36.25 c	37.50 d	74.50 e	74.75 f
UV 1 hr.	145.25 c	145.75 d	40.25 b	41.25 c	72.50 f	73.25 g
UV 2 hr.	147.50 b	149.50 c	43.25 ab	45.50 b	77.25 d	77.50 d
GM 5 Gy	160.25 a	162.50 a	45.25 a	46.25 a	80.25 a	86.50 a
GM 100 Gy	158.50 ab	159.25 b	44.50 a	46.50 a	79.50 b	79.75 b
GM 200 Gy	157.25 b	157.50 b	44.10 a	45.50 b	79.15 c	79.50 c

Means with different letters indicates significant difference at $p < 0.05$.

Exposure of Tuberose bulbs to gamma rays significantly increased spike fresh weight compared to the control with superiority of 5 Gy followed by 100 Gy and then 200 Gy. The highest value of spike fresh weight obtained with 5 Gy of gamma rays, followed by 100 Gy gamma rays and then 200 Gy gamma rays. The increased spike fresh weight of Tuberose in response to microwave or gamma rays irradiation was also reported on Gladiolus where gamma irradiation at doses 20 and 40 Gy as well as microwave exposure for 10 and 20 sec significantly increased spike fresh weight compared to the control **(Moustafa *et al*., 2018).** Low dosages of gamma irradiation also accelerated cell division and nucleic acid synthesis **(Asare *et al.*, 2017)** and enhanced the potential of antioxidants, which affect growth characteristics **(Wi *et al.*, 2007).**

The experimental data in Tables (5) and (6) demonstrate a significant physiological response of Tuberose (*Polianthes tuberosa* L.) to physical mutagens, including microwave (MV), ultraviolet (UV), and gamma (GM) radiation. The application of ionizing and non-ionizing radiation significantly enhanced the vegetative biomass compared to the control. The lowest dose of gamma radiation (**5 Gy**) achieved the highest significant increase in leaves fresh weight (160.25 g) and spike fresh weight (80.25 g) in the first season. This phenomenon, known as **Radiostimulation**, is often attribute to the activation of enzymatic and hormonal systems at low doses **(Hameed, 2008).**

Table (6). Effect of microwave, UV, and gamma rays on number of corms/experimental unit, corm fresh weight, corm dry weight and corm circumference of Tuberose (*Polianthes tuberosa* L.)

	number of corms/experimental unit (corms yield)		Corms fresh weight (g)		Corms dry weight (g)		Corms circumference (cm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Cont.	2.00 de	2.33 ef	5.72 h	6.45 h	3.08 bc	3.37 bc	4.42 h	5.50 h
MV 10 sec.	2.50 cd	2.75 de	6.50 fg	6.75 gh	3.15 b	3.90 a	6.50 de	6.75 de
MV 20 sec.	3.00 b	3.25 bc	9.75 a	9.95 a	3.50 a	4.25 a	9.75 a	9.95 a
MV 40 sec.	2.25 d	2.50 e	9.25 b	9.30 b	2.80 cd	2.80 d	9.25 b	9.40 b
MV 60 sec.	2.05 de	2.10 f	8.50 c	8.75 c	2.50 de	2.50 e	8.50 c	8.95 c
UV 1 hr.	2.33 d	2.67 de	6.72 f	9.38 b	3.10 bc	3.40 bc	6.12 f	6.38 f
UV 2 hr.	2.60 c	2.85 d	7.25 e	7.50 f	3.30 ab	3.65 b	7.25 d	7.60 d
GM 5 Gy	3.50 a	4.00 a	7.25 e	7.75 e	3.50 a	4.00 a	7.25 d	7.50 d
GM 100 Gy	3.25 ab	3.30 b	6.75 f	6.85 g	3.25 ab	3.30 c	6.15 f	6.50 fg
GM 200 Gy	3.10 b	3.15 c	6.40 g	6.50 h	3.10 bc	3.15 c	6.05 f	6.10 g

Means with different letters indicates significant difference at $p < 0.05$.

Extending UV exposure to **2 hours** significantly improved the leaves dry weight (43.25–45.50 g), showing superiority over most microwave treatments according to **Krizek (2004).**

Microwave Response: The **20-second** microwave treatment was the most effective duration for leaf biomass. However, longer durations (40–60 sec) showed a stabilizing or diminishing effect, suggesting a threshold for beneficial thermal or non-thermal microwave influence according to **Khalafallah and Sallam (2009).**

The treatments exerted a differential impact on the reproductive organs of the plant. Gamma radiation at **5 Gy** significantly maximized the number of corms per unit (3.50 and 3.75 in both seasons). This suggests that low-dose gamma rays enhance the sink capacity of the plant, leading to increased daughter corm formation. Interestingly, the highest quality corms in terms of weight and size were obtained from the **20-second microwave** treatment. It recorded the maximum corm fresh weight (8.75–8.90 g) and circumference (6.75–6.95 cm). While gamma rays favored the *quantity* of corms, microwave radiation at specific intervals improved the *physical vigor* of individual corms according to **Sardoei (2014).**

The effect of microwave, UV, and gamma rays on total chlorophyll, nitrogen %, phosphorus% and potassium% of Tuberose was presented in Figure (1). Irradiation of Tuberose bulbs with microwaves for 10, 40 and 60 sec significantly increased total chlorophyll content compared to the control with superiority of 20 and 40 sec exposure time. Irradiation of Tuberose bulbs with UV-rays for 1 and 2 hr. significantly increased total chlorophyll content compared to the control with no significant difference between 1 and 2 hr. exposure. Exposure of Tuberose bulbs to gamma rays significantly increased total chlorophyll content compared to the control with superiority of 5 Gy followed by 100 Gy and then 200 Gy**. Beyaz *et al*. (2016)** exposed the seeds of *Lathyrus chrysanthus* to irradiation at doses of 0, 50, 100, 150, 200, and 250 Gy. Their findings indicated that lower doses, specifically up to 150 Gy, resulted in increased seedling lengths, fresh weight, dry matter content, and total chlorophyll content in the leaves. This enhancement can be attributed to the stimulatory effect of electromagnetic waves on enzyme activities involved in chlorophyll biosynthesis, as noted by **Dhawi *et al*. (2009).**

For nitrogen percentage, all used radiation types and exposure duration significantly increased N% compared to the control. The highest value was obtained with 2 hr. of UV irradiation (2025 and 2.77), followed by 20 and 40 sec of microwave irradiation and dose of 5Gy gamma rays. For phosphorus and potassium percentages, exposure of Tuberose bulbs to microwaves had no significant effect on P% and K% compared to the control. Exposure of Tuberose bulbs to either UV-rays or gamma rays significantly increased P% and K% compared to the control. The highest value of P% and K% was obtained with all doses of gamma rays followed by 2 hr. UV irradiation. The positive impact on the photosynthetic process related to stimulation of the Rubisco enzyme, a central component of the CO_2 fixation process **(Singh *et al*., 2013).** Another cause of overall enhanced growth and flower quality is stimulated antioxidant activities such as peroxidase **(Ling *et al*., 2008)**, superoxide dismutase **(Kim *et al*., 2004)** and ascorbate peroxidase and glutathione reductase **(Macovei *et al*., 2014)** as well as stimulated cell division. The increase in potassium percentage following irradiation, particularly with gamma rays, may be attribute to the stimulation of physiological processes and enhanced mineral uptake efficiency in the tubers **(Kovács and Keresztes, 2019).**

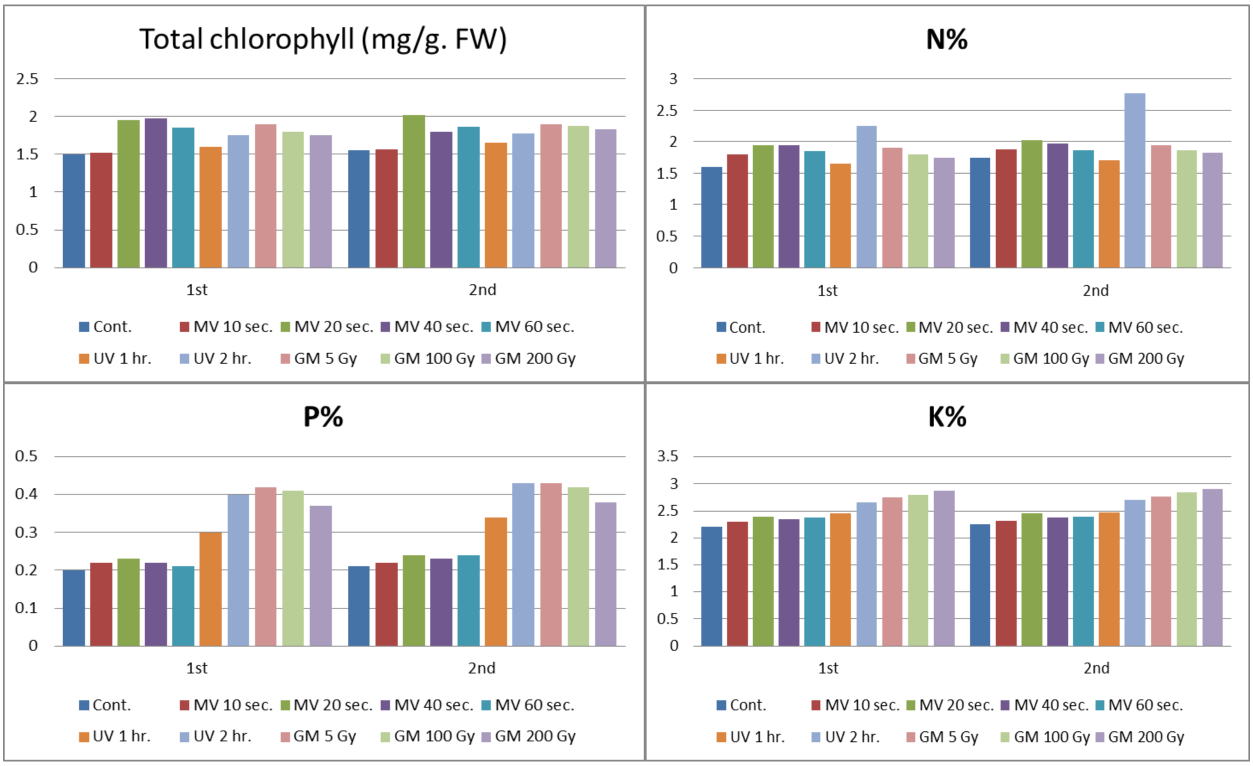

Figure (1). Effect of microwave, UV, and gamma rays on total chlorophyll, nitrogen %, phosphorus% and potassium% of Tuberose (*Polianthes tuberosa* L.)

Economic evaluation

The Economic evolution of the experiments generally depends on those that have been applied, carried out at research stations and in field experiments across different production areas. According to the results of experiments related to the addition of Microwave, UV, and Gamma at different levels to Tuberose (*Polianthes tuberosa* L.), and that was during two consecutive agricultural seasons 2022 and 2023. In addition, there are set of economic indicators that must be taken into consideration when conducting the economic evolution. To estimate or predict the economic viability of Microwave, UV, and Gamma to Tuberose (*Polianthes tuberosa* L.), as these indicators usually reflect the economic efficiency of transactions. The most important of these indicators are average productivity, total return, the net return, benefit-cost ratio, cost of florets and corms profitability, and return on the invested pound of faddan.

The data in Table (7) shows an increase in productivity in Tuberose (*Polianthes tuberosa* L.) treated with Microwave compared to untreated plants. The highest increase in productivity of main product (florets) was observed at a concentration of Micro 20 sec, reaching approximately 80,838.93 florets/faddan, equivalent to 18.36% of the untreated plants.

Table (7). Economic indicators of the effect Microwave, UV, and Gamma treatment compared to untreated (control) of Tuberose (*Polianthes tuberosa* L.) for the average of the 2022 and 2023 seasons

Transactions		Total cost pound/fad.	Main product.		Secondary product.		Total Return pound/fad.	Net Return pound/fad.	Return /cost ratio	cost of florets pound/ florets	cost of corms pound/ corms	Profitability %	Return per pound invested
			productivity florets	Main return.	productivity corms	Secondary return.							
Control		1,154,400	66,000.00	5,151,960.00	165,000.00	2,475,000.00	7,626,960	6,472,560	6.61	17.49	7.00	84.86	5.61
Micro 10sec.	value	1,154,411	76,040.27	5,935,703.36	200,057.74	3,000,866.05	8,936,569	7,782,158	7.74	15.18	5.77	87.08	6.74
	Deviation from control	11	10,040.27	783,743.36	35,057.74	525,866.05	1,309,609.41	1,309,598.41	1.13	-2.31	-1.23	2.22	1.13
	%Deviation from control	0.0010	13.20	13.20	17.52	17.52	14.65	16.83	14.65	-15.21	-21.25	2.55	16.83
Micro 20sec.	value	1,154,422	80,838.93	6,310,286.58	238,163.97	3,572,459.58	9,882,746	8,728,324	8.56	14.28	4.85	88.32	7.56
	Deviation from control	22	14,838.93	1,158,326.58	73,163.97	1,097,459.58	2,255,786.16	2,255,764.16	1.95	-3.21	-2.15	3.45	1.95
	%Deviation from control	0.0019	18.36	18.36	30.72	30.72	22.83	25.84	22.82	-22.48	-44.34	3.91	25.84
Micro 40sec.	value	1,154,433	71,979.87	5,618,748.32	181,004.62	2,715,069.28	8,333,818	7,179,385	7.22	16.04	6.38	86.15	6.22
	Deviation from control	33.00	5,979.87	466,788.32	16,004.62	240,069.28	706,857.61	706,824.61	0.61	-1.45	-0.62	1.28	0.61
	%Deviation from control	0.0029	8.31	8.31	8.84	8.84	8.48	9.85	8.48	-9.06	-9.70	1.49	9.84
Micro 60sec.	value	1,154,466	70,134.23	5,474,677.85	158,140.88	2,372,113.16	7,846,791	6,692,325	6.80	16.46	7.30	85.29	5.80
	Deviation from control	66	4,134.23	322,717.85	-6,859.12	-102,886.84	219,831.02	219,765.02	0.19	-1.03	0.30	0.42	0.19
	%devotion from control	0.0057	5.89	5.89	-4.34	-4.34	2.80	3.28	2.80	-6.26	4.16	0.50	3.28
UV1H	value	1,154,422	71,241.61	5,561,120.13	190,531.18	2,857,967.67	8,419,088	7,264,666	7.29	16.20	6.06	86.29	6.29
	Deviation from control	22.00	5,241.61	409,160.13	25,531.18	382,967.67	792,127.80	792,105.80	0.69	-1.29	-0.94	1.42	0.69
	%deviation from control	0.00	7.36	7.36	13.40	13.40	9.41	10.90	9.41	-7.94	-15.47	1.65	10.90
UV2H	value	1,154,444	74,711.41	5,831,972.62	207,678.98	3,115,184.76	8,947,157	7,792,713	7.75	15.45	5.56	87.10	6.75
	Deviation from control	44	8,711.41	680,012.62	42,678.98	640,184.76	1,320,197.37	1,320,153.37	1.14	-2.04	-1.44	2.23	1.14
	%Deviation from control	0.0038	11.66	11.66	20.55	20.55	14.76	16.94	14.75	-13.19	-25.86	2.56	16.94
GMA 5G	value	1,157,400.0	73,825.50	5,762,818.79	285,796.77	4,286,951.50	10,049,770	8,892,370	8.68	15.68	4.05	88.48	7.68
	Deviation from control	3,000.00	7,825.50	610,858.79	120,796.77	1,811,951.50	2,422,810.29	2,419,810.29	2.08	-1.81	-2.95	3.62	2.08
	%deviation from control	0.26	10.60	10.60	42.27	42.27	24.11	27.21	23.91	-11.57	-72.76	4.09	27.02
GMA 100G	value	1,157,400.0	70,798.66	5,526,543.22	249,595.84	3,743,937.64	9,270,481	8,113,081	8.01	16.35	4.64	87.52	7.01
	Deviation from control	3,000.00	4,798.66	374,583.22	84,595.84	1,268,937.64	1,643,520.87	1,640,520.87	1.40	-1.14	-2.36	2.65	1.40
	%devotion from control	0.26	6.78	6.78	33.89	33.89	17.73	20.22	17.51	-6.99	-50.88	3.03	20.01
GMA 200G	value	1,157,400.0	67,550.34	5,272,979.19	238,163.97	3,572,459.58	8,845,439	7,688,039	7.64	17.13	4.86	86.92	6.64
	Deviation from control	3,000.00	1,550.34	121,019.19	73,163.97	1,097,459.58	1,218,478.78	1,215,478.78	1.04	-0.36	-2.14	2.05	1.04
	%Deviation from control	0.26	2.30	2.30	30.72	30.72	13.78	15.81	13.55	-2.08	-43.97	2.36	15.59

* The price of the florets in Egyptian pounds (78.06) was calculated based on a florets price of approximately $2 and an average exchange rate of approximately 39.03 Egyptian pounds per dollar for the 2022and2023 seasons.
** The price of the corms was (15) pounds**,** Exchange rate of approximately 39.03 Egyptian pounds per dollar for the 2022and2023.
Net Return = Total return - Total costs cost of florets and corms = Total costs / productivity Profitability (Producer Profit Margin Percentage) % = (net return / Total return) × 100
Return per pound invested = net return / Total costs
Source: Results of field study data analysis of the average of Season 2022and2023.

The highest increase in productivity of Secondary product (corms) was observed at a concentration of Microwave 20 sec, reaching approximately 238,163.97 corms/faddan, equivalent to 30.72% of the untreated plants.

This resulted in 25.84% increase in net return, 22.82% increase in the benefit - cost ratio, 22.84% decrease in florets costs, 44.34% decrease in corms costs, 3.91% increase in profitability, and 25.84% increase in return on investment per faddan compared to untreated plants.

In addition, data in Table (7) shows an increase in productivity in Tuberose (*Polianthes tuberosa* L.) treated with UV compared to untreated plants. The highest increase in productivity of main product (florets) was observed at a concentration of UV2H, reaching approximately 74,711.41florets/feddan, equivalent to 11.77% of the untreated plants.

The highest increase in productivity of Secondary product (corms) was observed at a concentration of UV2H, reaching approximately 207,678.98 corms/feddan, and equivalent to 20.55% of the untreated plants.

This resulted in 16.94% increase in net return, 14.75% increase in the benefit - cost ratio, 13.19% decrease in florets costs, 25.86% decrease in corms costs, 2.56% increase in profitability, and 16.94% increase in return on investment per feddan compared to untreated plants.

Data in Table (7) shows an increase in productivity in Tuberose (*Polianthes tuberosa* L.) treated with Gamma compared to untreated plants. The highest increase in productivity of main product (florets) was observed at a concentration of GMA 5G, reaching approximately 73,825.50 florets/feddan, equivalent to 10.60% of the untreated plants.

The highest increase in productivity of Secondary product (corms) was observed at a concentration of GMA 5G, reaching approximately 285,796.77 corms/feddan, and equivalent to 42.27% of the untreated plants.

This resulted in 27.15% increase in net return, 23.38% increase in the benefit - cost ratio, 10.80% decrease in florets costs, 71.58% decrease in corms costs, 4% increase in profitability, and 26.45% increase in return on investment per feddan compared to untreated plants.

4. Conclusion

Data revealed that irradiation of Tuberose bulbs with microwaves for 10 and 20 seconds, UV-C rays for 1 and 2 hours and gamma irradiation at doses 5, 100 and 200 Gy significantly improved the growth and flower quality parameters while the time from planting to harvest increased compared to the control except for 2 hour exposure to UV-C where the time from planting to harvest was similar to the control. The best results were obtained using microwave radiation at a rate of 20 seconds, UV radiation at a rate of 2 hours, and gamma radiation at a rate of 5 Gray. This was evident in the morphological characteristics and chemical analyses of the tuberose plant.

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تأثير استخدام أشعة الميكروويف والأشعة فوق البنفسجية وأشعة جاما على الخصائص المورفولوجية والكيميائية لنبات التبروز

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تُعدّ الأزهار جزءًا لا يتجزأ من حياتنا لما تتميز به من تنوع في الشكل واللون والعبير. يُعتبر مسك الروم من الأنواع الزينة الرائجة، ويُصنّف ضمن أهم أزهار الزينة المزروعة، ويعود ذلك أساسًا إلى طول فترة إزهاره، وهو جانب بالغ الأهمية سواءً استُخدمت الأزهار للقطف أو لتزيين الحدائق. هدفت التجربة إلى دراسة تأثير استخدام الميكروويف والأشعة فوق البنفسجية وأشعة جاما على نمو وجودة أزهار مسك الروم. أظهرت البيانات أن تعريض أبصال مسك الروم للميكروويف لمدة 10 و20 ثانية حسّن بشكل ملحوظ من نموها وجودة أزهارها، بينما زاد الوقت من الزراعة إلى الحصاد مقارنةً بالكنترول. أما بالنسبة للأشعة فوق البنفسجية من نوع C، فقد أدى التعرض لها لمدة ساعة وساعتين إلى تحسين نمو مسك الروم وجودة أزهارها، مع تفوق مدة ساعتين، باستثناء الوقت من الزراعة إلى الحصاد حيث كانت مدة ساعة واحدة أفضل من ساعتين، إذ كانت المدة مماثلة للمجموعة الضابطة. كما حسّن تعريض الأبصال لأشعة جاما من نموها وجودة أزهارها، مع افضلية جرعة 5 جراي، إلا أن الوقت من الزراعة إلى الحصاد زاد مع جميع الجرعات مقارنةً بالكنترول. في الختام، يمكن أن يكون تشعيع ابصال مسك الروم باشعة الميكروويف لمدة 20 ثانية، والأشعة فوق البنفسجية لمدة ساعتين، وأشعة جاما بجرعة 5 جراي علاجات فعالة لتحسين إنتاج مسك الروم مع تعزيز النمو وجودة الأزهار.