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Quality Evaluation of Sunflower Seeds Resulted in Irradiated Seeds Cultivation by Gamma Radiation of Cesium (Cs137)

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Abstract

This study was done to evaluate the occurrence of quality parameters in harvested sunflower (*Helianthus annuus* L.) seeds which were irradiated with 0, 5, 10, 15, 20, 25, and 30 Gy of gamma radiation in a cesium (Cs137) before cultivation in two seasons. The quality characteristics of sunflower seeds including production quality such as disc weight, disk seeds weight and hundred seeds weight, and parameters of seed quality such as content of oil, protein, total phenol, and carbohydrate were analyzed. Obtained results were as follows: For production quality parameters: It shows that increasing the dose from 5 to 25 Gy increases from (233.7 to 299.9 g.), (180.9 to 249.7 g), and (7.25 to 8.1 g) for the disc weight, the disc seeds weight, and the hundred seeds weight, respectively in the first season. While, in the second season they were increased from (149.1 to 266.6 g), (138.3 to 209.7 g,), and (7.1 to 7.8 g) for same production quality, untreated sample (control) which were (129 and 120.7 g), (163.6 and 124.4 g), and (6.9 and 6.85 g) for (first and second season), respectively. So, the optimal gamma radiation dose cesium (Cs137) ranges between 20 and 25 Gy., for production quality parameters.

For seeds quality parameters: It shows that increasing the dose from 5 to 25 Gy increases from (39.5 to 44.0%), (16.8 to 18.2%), (13.8 to 16.9 mg/g.) and (42.1 to 44.1%.) for the oil content, protein content, total phenol content and Carbohydrate content, respectively in the first season. While, in the second season they were increased from (36.6 to 42.5%), (15.9 to 17.9%), (12.2 to 15.8 mg/g) and (42.0 to 43.8%) for same seeds quality, untreated sample (control) which were (36.5 and 36%), (15.8 and 15.6%), 12.0 and 11.9 mg/g), and (41.0 and 40.6%) for (first and second season), respectively. So, the optimal gamma radiation dose cesium (Cs137) ranges between 20 and 25 Gy., for seed quality parameters

Keywords: Chemical Properties; Gamma Irradiation of (Cesius-37); Seed Quality; Production Quality; Sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is an oleaginous crop belonging to family Asteraceae. It contains 2n = 34 numbers of chromosome. It is the world's fourth largest oil-seed crop. Sunflower seeds are used as food and its dried stalk as fuel. It is also used as an ornamental plant and was used in prehistoric celebrations in ancient time [22]. Sunflower (*Helianthus annuus* L.) is recognized as one of the most extensively cultivated oilseeds crops worldwide and ranks among the leading contributors to global vegetable oil production [2, 24]. The crop provides multiple value-added products: its edible oil is characterized by a high concentration of unsaturated fatty acids, its protein-rich seeds are suitable for direct human consumption, and its diverse by-products serve as raw materials for the livestock feed, pharmaceutical, cosmetic, and biofuel industries. Furthermore, sunflower exhibits broad adaptability to a wide range of climatic and soil conditions, which underpins its role as a key component of sustainable agricultural systems across diverse global regions [3]. Sunflower contributes to food security by providing a reliable source of oil and essential nutrients in global diets. Consequently, ensuring high seed quality is essential for sustaining both the productivity and profitability of sunflower cultivation [14]. In processing and commercial markets—particularly where quality standards are stringent—even minor deviations in seed integrity can lead to significant economic consequences. One of the primary threats to seed quality is infestation by insect pests, notably the red sunflower seed weevil (*Smicronyx fulvus*). The larvae of this insect feed internally on the seed, often consuming a substantial portion of the seed's mass. This internal feeding reduces oil content and nutritional quality while also diminishing germination potential and overall yield. Furthermore, such physical injury predisposes seeds to fungal infection and subsequent mycotoxin contamination, thereby introducing both economic losses and food safety risks [8]. For growers and processors, even slight insect damage can result in the rejection of entire seed batches, translating into considerable financial losses [14]. The need to safeguard seed quality has driven the adoption of several detection techniques, including manual inspection, RGB imaging, thermal sensing, and X-ray methods. However, each of these techniques is limited in its ability to detect internal insect damage [19, 27].

Gamma irradiation is a non-thermal method used to extend the shelf life of food products and represents a potential alternative technology for oilseed processing. Following harvest, several factors compromise oilseed quality, including pest proliferation, microbial growth, and enzyme-mediated reactions. Gamma radiation has been shown to inhibit undesirable microorganisms; however, it may also alter the physicochemical and nutritional properties of oils [28]. Studied compares the effects of different doses gamma radiation on crude oil yield and moisture of different six variety sunflower (*Helianthus annuus* L.) seeds. Seeds were irradiated with doses of 100, 200, 300, 400 and 500 Gy gamma radiation. Control groups were not subjected to gamma radiation. Irradiation was performed in a cesium (Cs137). It was found that the highest moisture rate in 100 Gy for all seeds variety. According to our results, the moisture content of the seed negatively affected by gamma radiation [18]. Studied biochemical of oil extracted from gamma irradiated sunflower (*Helianthus annuus* l.) seeds. Irradiation doses and storage time significantly increased the AV and PV, and only the storage time significantly increased the TBA value and RI, while both irradiation doses and storage time had no significant effect on IV and SV. Storage time had more pronounced effect on AV, PV, TBA and RI than irradiation. Gamma irradiation had a significant effect on all color parameters of sunflower seeds oil including lightness (L*-value), redness (a*-value), yellowness (b*-value), and color difference (ΔE). The studied qualitative characteristics were influence by the used doses of gamma irradiation.

Yalcin and Ulakoglu (2019) studied of different gamma radiation doses were applied to two sunflower varieties seeds to determine their effects on some plant characteristics in plants and to determine GR50 doses for effective mutation dose values in mutation breeding studies. The effect of gamma irradiation on the germination percentage and seedling height (cm) of two sunflower varieties was investigated at different doses (0, 50, 100, 150, 200, 250, 300, 400 and 500 Gy). Gamma radiation was applied to seeds from Cesium-137 (137Cs) source. As a result, germination percentages of sunflower varieties were not affected with increasing radiation doses. But, as parallel to increasing doses applied of gamma radiation dose seedling height (cm) were affected negatively. On the other hand, the doses that decrease growth by 50 percent (GR50) for AS508 and Nantio were found to be 148 Gy and 165 Gy, respectively.

Despite this, gamma irradiation is considered a safe and environmentally friendly method that can improve the quality, stability, and safety characteristics of oilseeds and derived oils. Specifically, gamma irradiation generally enhances product stability and safety—for example, through effective pest control—while exerting only limited negative effects on oil nutritional parameters. Nevertheless, the extent of compositional change depends on both the applied radiation dose and the oilseed species [23].

Gamma irradiation was effective in generating phenotypic variations across several traits in sunflower (*Helianthus annuus* L.). Specifically, desirable traits—including reduced days to 50% flowering and maturity, increased fertility percentage, and enhanced antioxidant activity of oil—were observed in M3 (mutant generation 3) lines. These M3 lines possess the potential to be utilized as inbred lines in sunflower hybrid development or as a source of desirable traits for future sunflower breeding programs [25]. Hussein *et al.* (1995) studied the effect of γ- radiation 0, 1, 5, 10 and 15K r and manganese application on growth and chemical constituents of *Datura metal* L. found that irradiation treatments, especially lower doses, had stimulatory effect on plant height and number of leaves. Kiong *et al.* (2008) studied the effect of different doses of gamma rays (0, 10, 20, 30, 40, 50, 60, and70 Gy) on shoot tip explants of *Orthosiphon stamineus*. Biochemical study revealed that total Chl content decreased notably as gamma dosage increased. Farid *et al.* (1999) found that exposing the sweet marjoram to low doses of gamma rays (10, 20 and 40 Gray) increased total carbohydrates content. The highest dose (40 Gray) gave the highest total carbohydrate concentration.

Gaber *et al.* (2002) found that treatment of faba beans with gamma radiation increased their carbohydrate content significantly. Low (250r) and high (2500 and 5000 r) dosages of gamma irradiation. Also, they found that treatment of faba bean with gamma radiation increase protein content significantly. Low (250r) and high (2500 and 5000r) doses of gamma irradiation caused significant reduction in the protein content of the seeds; whereas doses of 500 and 1000 r led to an increase in the protein content of faba bean seeds. Khodary (2004) found that the significant decrease in the content's protein of lupine (*Lupinus termis* L) was observed in seeds irradiated with gamma rays (10, 25, 50 and 100 GY) This effect was more pronounced particularly with 25 Gy dose. Also, he investigated the effect of NaCl in presence or absence of gamma irradiation on seeds of *Lupinus termis*. He determined, potassium and phosphorus uptake. Were determined significant decreases in the contents were observed in seeds irradiated with gamma rays (10, 25, 50 and 100 Gy), these nitrogenous fractions were increased after NaCl treatments, particularly with 25Gy dose. Hussein (2010) studied the effect of gamma radiation doses (50- 100 Gy) on mungebean . It was found that all gamma irradiation used were increase total protein contents. Moussa and Abdul Jaleel (2011) studied the effect of gamma radiation doses (0,25,50,100 and 150 Gy) on (*Trigonella foenumgraecum* L.). It was found that gamma irradiation increased dry weight values from plants treated with 150 Gy. Moussa (2006) examined the changes in growth parameters and certain metabolic activities in response to different doses of γ-irradiation (0.0, 20, 50, 100 and 200 Gy) in rocket seedlings. Total protein increased significantly at 20 Gy dose.

Gamma irradiation could influence the levels of phenol compounds, in this respect. Arevalo *et al.* (2002) studied the effect of gamma radiation (100, 150, 250, and 350 Gray) followed by storage at room temperature on avocado fruit. They found that gamma rays at doses of 100 and 150 Gy increased the concentration of phenolic compounds. Moussa (2006) examined the changes in growth

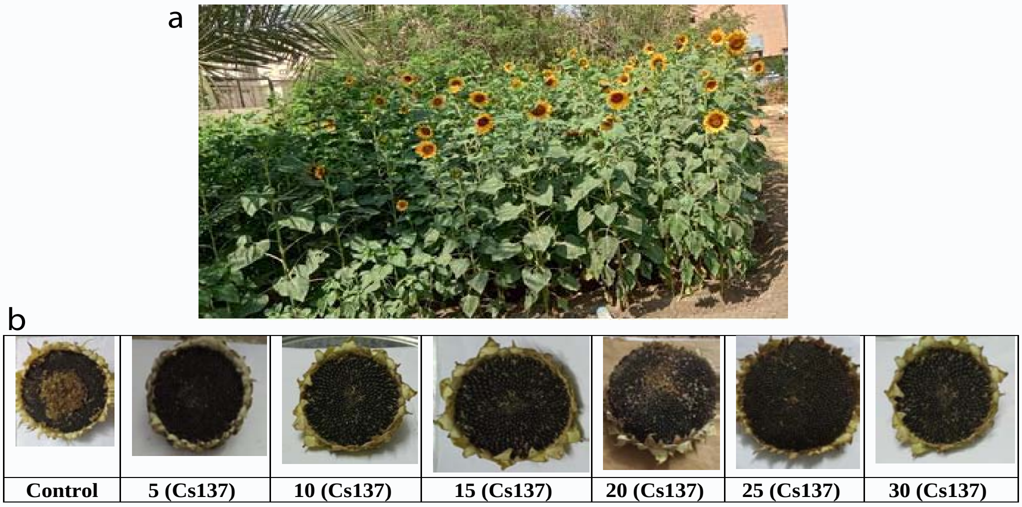

Figure 1: a) Irradiated sunflower plant. **b)** Disc with seeds sunflower after harvest

parameters and certain metabolic activities in response to different doses of γ-irradiation (0.0, 20, 50, 100 and 200 Gy) in rocket seedlings. It was concluded that total soluble phenols, increased significantly at the 20 Gy dose. Harrison and Were (2007) found that Gamma irradiation (0-16 k Gy) showed significant increase in the total phenolics and antioxidant activity in Almond skin. Erkan Khattak *et al.* (2008) found that UV-C treatment for different durations (1, 5, and 10 min) increased the antioxidant capacity and concentration of anthocyanins and phenolic compound in strawberries. Also, they found that in Nigger seed (*Nigella sativa* L.) irradiated with gamma dose (2-16K Gy) enhanced the DPPH free radical-scavenging activity and total phenolic content. The objective of this study to evaluate the occurrence of quality parameters in harvested sunflower (*Helianthus annuus* L.) seeds which were irradiated with 0, 5, 10, 15, 20, 25, and 30 Gy of gamma radiation in a cesium (Cs137) before cultivation in two seasons. The quality characteristics of sunflower seeds including production quality such as disc weight, disk seeds weight and hundred seeds weight, and parameters of seed quality such as content of oil, protein, total phenol, and carbohydrate were studied.

Materials and Methods

This experiment was carried out during the two successive seasons of 2024/2025.

Plant Material: Sunflower seeds, were obtained from the Agriculture Research Center, Ministry of Agriculture, Dokky, Giza, Egypt. Seeds were used for the radiation treatments, then cultivated and after harvesting, the seed transfer to laboratory in order to carry out lab analysis fpr quality evaluation of sunflower seeds (Figure 1).

Radiation treatments Seeds were irradiated with different doses of gamma rays (0, 5, 10, 15, 20, 25 and 30 Gy). The irradiation facility was carried out at the National Center for Radiation Research and Technology (NCRRT) using Cesium 137 as source of gamma rays. The dose rate was 0.89 rad /sec and 0.87 rad/ sec respectively. Gamma treatments shown in Table 1.

Physical and Chemical characteristics: Three seed samples from each treatment were collected to determined Seed weight and percentage of Moisture content of seed, Protein, Carbohydrate, and lipid content were done using the (A.O.A.C. 2000).

Production quality: A Hundred Seeds were tested the average mass was calculated from 4 replicates, using a digital balance before irritated, the weight of 100 seeds is measured for the six irradiated treatments and the control one. Also, d Disc weight (g), seeds weight per disc (g), and hundred seeds weight (g)were measured

Seeds quality: Four samples were taken from each treatment to determine oil, protein, total phenol, and carbohydrate contents using the **(A.O.A.C. 2000)** to analysis and observing changes in the quality of the cowpea seeds during storage.

Total phenols were determined by colorimetric method using Folin-Denis reagent according to Swain and Hillis (1959).

Statistical analysis

The experiment layout was designed in randomized complete block design with factor was seven gamma ray doses (0, 5, 10, 15, 20, 25 and 830) Gy. Data of growth characters were statistically analyzed. Means were compared using the least significant difference test (LSD) at 5% level (Snedecor and Cochran, 1980).

Results and Discussions

Production quality

Disc weight of sunflower plant: Figure 2 illustrates the relationship between gamma radiation doses of cesium (Cs137) and sunflower seed disc weight. It shows that increasing the dose from 5 to 25 Gy increases the disc weight from 233.7 to 299.9 g. The disc weight then decreases to 256.8 g at a dose of 30 Gy in the first season. In the second season, the disc weight increases from 149.1 to 266.6 g, then decreases to 214.4 g at a dose of 30 Gy., compared to untreated sample (control) which was 129 and 120.7 g for first and second season, respectively. These results indicate that the weight of the sunflower seed disc in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. Concerning, fresh and dry weights of non-irradiated stressed damsisa plants grown under different salinity levels in soil Ta It was found that fresh and dry weights decreased, during the three stages of growth as compared to non-irradiated (control) which grown in control soil through both seasons. Similar effects were obtained on Chamomila rectutita with Nassar *et al.* (2004) and Abdul Qados (2009) (Figure 2).

Table 1: Effects of different doses of gamma radiation on number of leaves per plant.

No.	Treatments	Gamma doses of cesium (Cs137)
1	T1	0 Gy (Control)
2	T2	5 Gy
3	T3	10 Gy
4	T4	15 Gy
5	T5	20 Gy
6	T6	25 Gy
7	T7	30 Gy

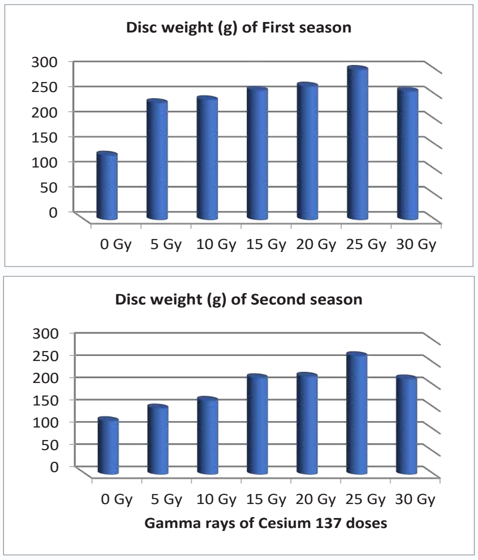

Figure 2: Effect of gamma ray of cesium 37 on disk weight of sunflower plant.

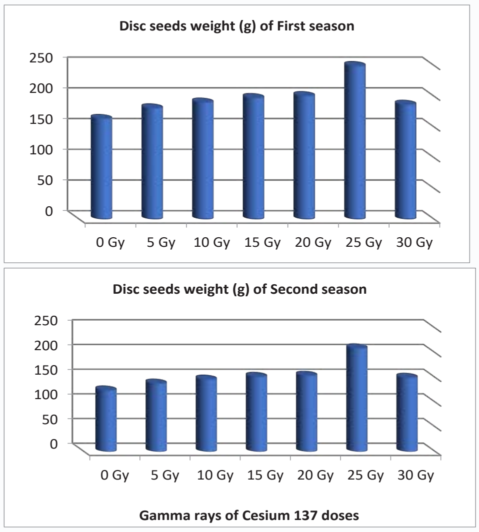

Figure 3: Effect of gamma ray of cesium 37 on disk seeds weight of sunflower plant.

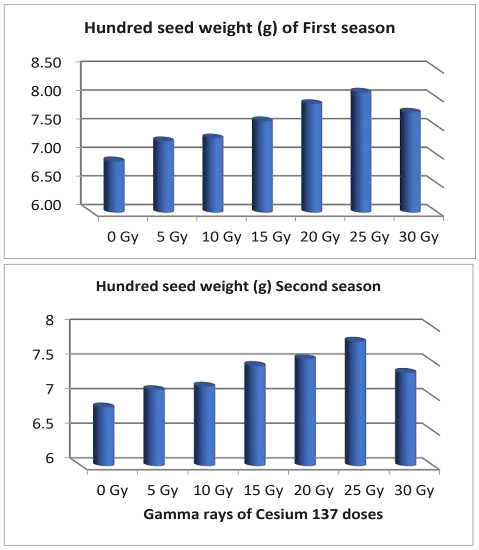

Figure 4: Effect of gamma ray of cesium 37 on hundred seeds weight of sunflower plant.

Disc seeds weight of sunflower plant

Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and disc seeds weight. It shows that increasing the dose from 5 to 25 Gy led to increases the disc seeds weight from 180.9 to 249.7 g. The disc seeds weight then decreases to 186.7 g at a dose of 30 Gy in the first season. In the second season, the disc seeds weight increases from 138.3 to 209.7 g, then decreases to 150.1 g at a dose of 30 Gy., compared to untreated sample (control) which was 163.6 and 124.4 g for first and second season, respectively.

These results indicate that the weight of the sunflower disc seeds in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. Increasing salt concentration caused a significant reduction in the fresh and dry masses of both shoots and roots as well as seed yield of *Ammolei mayus* was mentioned by Ashraf and Harris (2004) and Abdul Qados (2009) (Figure 3).

Hundred seeds weight of sunflower plant

Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and hundred seeds weight. It shows that increasing the dose from 5 to 25 Gy led to increases the hundred seeds weight from 7.25 to 8.1 g. The hundred seeds weight then decreases to 7.75 g at a dose of 30 Gy in the first season. In the second season, the disc seeds weight increases from 7.1 to 7.8 g, then decreases to 7.35 g at a dose of 30 Gy., compared to untreated sample (control) which was 6.9 and 6.85 g for first and second season, respectively.

These results indicate that the weight of the sunflower disc seeds in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. Baek (2005) mentioned for gamma irradiation, the results indicated that the low doses (20, 30 and 40 Gy dose) stimulated the plant growth parameters, i.e. height, number of leaves, fresh and dry weight of plants, also, seeds weight (Figure 4).

Seeds quality

Oil content: Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and oil content of seeds. It shows that increasing the dose from 5 to 25 Gy led to increases the oil of seeds from 39.5 to 44.0%., then the oil of seeds decreases to 41% at a dose of 30 Gy in the first season. In the second season, the oil of seeds increases from 36.6 to 42.5%, then decreases to 37.2% at a dose of 30 Gy., compared to untreated sample (control) which was 36.5 and

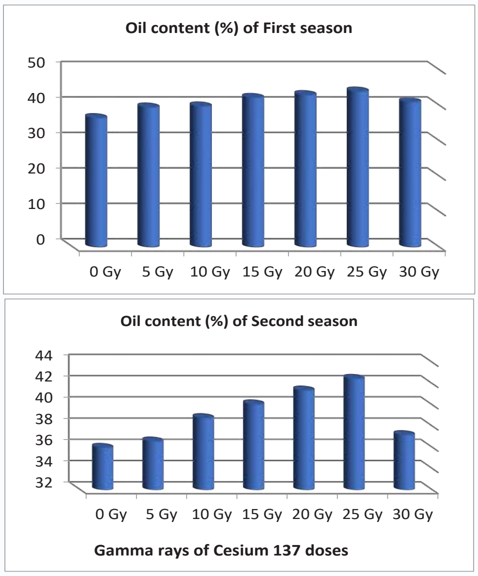

Figure 5: Effect of gamma ray of cesium 37 on oil content of sunflower seeds.

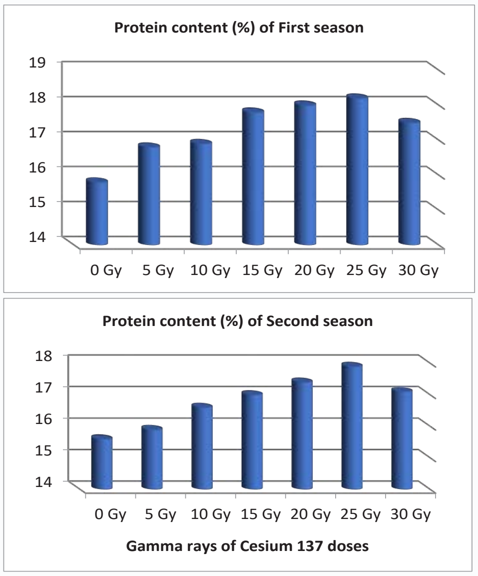

Figure 6: Effect of gamma ray of cesium 37 on protein content of sunflower seeds.

36% for first and second season, respectively. These results indicate that the seed oil content of the sunflower in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. Within this context, seed quality represents a critical variable, as it directly determines germination rates, seedling vigor, crop establishment, oil yield, and consumer acceptance [26]. The significant reduction in seed moisture content (9.68%) began at 100 Gy of gamma rays and continued to decline to up to 4.04% at 500 Gy. The crude oil yield showed not a important increase in 100 and 200 Gy doses. The result showed that the highest crude oil yield was also obtained from 400 Gy and 33.49% in Ege-2001 seeds [28] (Figure 5).

Protein content

Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and protein content of seeds. It shows that increasing the dose from 5 to 25 Gy led to increases the protein content of seeds from 16.8 to 18.2%., then the protein content of seeds decreases to 17.5% at a dose of 30 Gy in the first season. In the second season, the protein content of seeds increases from 15.9 to 17.9%, then decreases to 17.1% at a dose of 30 Gy. compared to untreated sample (control) which was 15.8 and 15.6% for first and second season, respectively. These results indicate that the protein content of seeds in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. El Mogy (1999) showed that the moderate and higher treatments of soil salinity (0.2% and 0.4%) tended to decrease the nitrogen percentage and protein content of Ambrosia maritima leaves compared to control. Also, Hussein (2010) observed that treating seeds before sowing by gamma rays (50-250 Gy) increased total protein contents in the produced seedlings of mungbean seeds. Radiation caused oxidative injury by accelerating free radical generation in living systems. The primary damage induced by ionizing radiation is modified in enzymatic repair processes (Alikamanoglu et al. 2007) (Figure 6).

Total phenol content

Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and total Phenol content of seeds. It shows that increasing the dose from 5 to 25 Gy led to increases the total

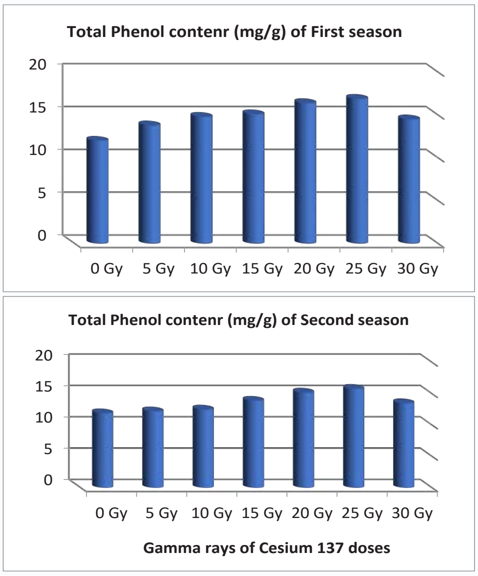

Figure 7: Effect of gamma ray of cesium 37 on total phenol content of sunflower seeds.

Phenol content of seeds from 13.8 to 16.9 mg/g., then total Phenol content of seeds decreases to 14.5 mg/g at a dose of 30 Gy in the first season. In the second season, the total Phenol content of seeds increases from 12.2 to 15.8 mg/g, then decreases to 13.5 mg/g at a dose of 30 Gy., compared to untreated sample (control) which was 12.0 and 11.9 mg/g for first and second season, respectively. These results indicate that the total Phenol content of seeds in both seasons is similar. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. The obtained results are in accordance with these results, Abu-Daya. (1990) found that radiation treatment significantly decreased the phenol compounds in the olive cake. Irradiation with 100 kGy destroyed about 75% of total phenol compounds.

Yonies (1997) also found that gamma radiation of soybean seeds and sesame seeds by 2.5,5 and 8 kGy increased the phenol contents as

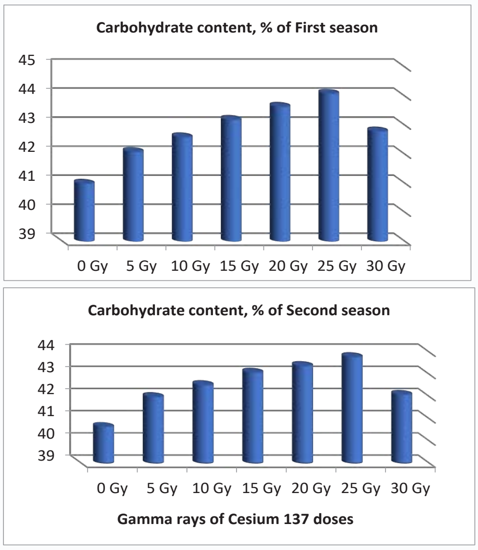

Figure 8: Effect of gamma ray of cesium 37 on Carbohydrate content of sunflower seeds.

compared with the control seeds (Figure 7).

Carbohydrate content

Figure 3 shows the relationship between gamma radiation doses of cesium (Cs137) and Carbohydrate content of seeds. It shows that increasing the dose from 5 to 25 Gy led to increases the disc seeds weight from 42.1 to 44.1%., then the Carbohydrate content of seeds decreases to 42.8% at a dose of 30 Gy in the first season. In the second season, the Carbohydrate content of seeds increases from 42.0 to 43.8%, then decreases to 24.1% at a dose of 30 Gy., compared to untreated sample (control) which was 41.0 and 40.6% for first and second season, respectively. These results indicate that the Carbohydrate content of seeds in both seasons is closed with each other. Furthermore, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy. Nassar *et al.* (2004) found that in *Chamomilla recutita* the pre-sowing irradiation caused gradual increase in total carbohydrates and total soluble sugars, with increasing the dose of gamma radiation from 0.0 to 10 Kr. Same finding was obtained by Parida *et al.* (2003) on *Aegiceras corniculatum*. Al-Sobhi *et al.* (2006) reported that the total soluble and insoluble carbohydrates content in the shoot and root tended to increase with increasing salinity stress in the culture solution and also with plant age which considered playing an important role in the osmotic adjustment of *Calotropis procera* seedlings (Figure 8).

Conclusions

For production quality parameters: It shows that increasing the dose from 5 to 25 Gy increases from (233.7 to 299.9 g.), (180.9 to 249.7 g), and (7.25 to 8.1 g) for the disc weight, the disc seeds weight, and the hundred seeds weight, respectively in the first season. While, in the second season they were increased from (149.1 to 266.6 g), (138.3 to 209.7 g,), and (7.1 to 7.8 g) for same production quality, untreated sample (control) which were (129 and 120.7 g), (163.6 and 124.4 g), and (6.9 and 6.85 g) for (first and second season), respectively. So, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy., for production quality parameters

For seeds quality parameters: It shows that increasing the dose from 5 to 25 Gy increases from (39.5 to 44.0%), (16.8 to 18.2%), (13.8 to 16.9 mg/g.) and (42.1 to 44.1%.) for the oil content, protein content, total phenol content and Carbohydrate content, respectively in the first season. While, in the second season they were increased from (36.6 to 42.5%), (15.9 to 17.9%), (12.2 to 15.8 mg/g) and (42.0 to 43.8%) for same seeds quality, untreated sample (control) which were (36.5 and 36%), (15.8 and 15.6%), 12.0 and 11.9 mg/g), and (41.0 and 40.6%) for (first and second season), respectively. So, the optimal gamma radiation dose of cesium (Cs137) ranges between 20 and 25 Gy., for seed quality parameters

Generally, treating seeds before sowing by gamma radiation generally increase oil percentage, total phenol content, protein content and carbohydrate content concentration in seeds of plant after harvesting as compared by untreated sample (control), which was observed with some exceptions mainly at 25 Gy dose and rarely at 20 Gy dose. So, from the aforementioned results, it could be concluded that sunflower plants with aid of gamma rays in doses of 20-25 Gy which improve quality parameters and active ingredients in two seasons of experiment.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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