The influence of gamma irradiation doses on the morphological and physical properties of wheat

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Abstract. The fluorescence and light absorption and dielectric characteristics of wheat are studied to investigate the influence of gamma exposure on germination, morphological and physical properties of wheat plant. Wheat grains were irradiated at 0, 1.5, 2, 2.5, 3, 5, 7 and 10 krad. The obtained results indicated that, pronounced increase in germination rate, plant height, and root length were obtained at 2.5 krad treatment. Furthermore, those characteristics were evaluated for chlorophyll at different doses given to wheat grains. The analysis of these spectra indicates that the maximum emission and absorption obtained at 2.5 krad gamma irradiation dose. Moreover, the dielectric properties and the electric conductivity of the different irradiated samples were determined in the frequency range 20 Hz- 100 kHz. The obtained data were treated precisely to determine the dielectric constant and the Ac conductivity that easily describe the plant growth. The predictions of the obtained results give further support for the 2.5 krad to be the best dose to stimulate the plant growth features.

1, Introduction
Wheat represents a serious problem for majority of people. In many countries, the needed amount is greater than that locally produced. Therefore, increasing wheat productivity and the cultivated areas are highly recommended. Much work is being done to develop wheat productivity by means of genetic engineering and plant tissue culture [1]. Gamma rays have been found as an excellent tool to improve the production of many crops [2–6]. Irradiating grains with suitable doses of gamma rays produces physiological and/or genetically changes in plant tissues that may affect the yield of plants [7–12].

Previous works indicated that exposure of wheat grains to low gamma ray doses up to 80 Gy increased germination, plant growth and yield parameters [13,14], while higher irradiation doses above 100 Gy mainly causes remarkable bad effects on the plant morphological properties and the dry weight is inversely proportional to the radiation doses [15,16].

Furthermore, wheat grains have very low germination rate at 300 and 400 Gy doses [17]. Not only the irradiation dose but also the storage time for the irradiated grains may cause a notable effect on germination rate. It was found that after long storage time, some rates of germination of wheat grains exposed to radiation were higher than that of non-exposed wheat grains. This mainly attributed to the self-repair process of irradiated organism [18]. In addition to the physical characteristics, lipase inactivation in wheat germ by gamma irradiation was obtained at doses more than 12 kGy where the stability of wheat germ is obtained [19].
Biophysical state of corn plants outlined by using both fluorescence spectra analysis and light absorption technique has indicated that, all growth parameters such as root and shoot lengths as well as dry and fresh weights have the most significant increase at 1.5 Gy irradiation dose [20]. Moreover, making use of the dielectric properties of chlorophyll, they found that the physical properties such as relative permittivity is inversely proportional to the applied frequency in certain range, while the effect of the frequency on the electric conductivity is to great extent relatively small.

Recently, the side effects of gamma irradiation on the wheat flour and the properties of pan breads produced from this flour are investigated [21]. It was concluded that protein and chlorophyll and mean MDA (malondialdehyde) may be utilized in the pre-assessment of effective nuclear radiation doses to cause mutations in the genotypes of wheat [17].

The target of the present work was to study the effects of low doses of gamma irradiation on wheat grains via the chlorophyll properties of the wheat plant. This study is based on the measurements of fluorescence spectra, absorption spectra and dielectric properties and AC conductivity along with the corresponding morphological properties of wheat plant.

2. Materials and Methods.

2.1. Wheat grains and Gamma irradiation
Mature wheat grains (Yecora Roio variety) were irradiated with different gamma doses (1.5, 2, 2.5, 3, 5, 7, 10 krad). Gamma irradiation was performed using 60Co gamma source delivering 170 ± 1.45 rad/s at 95% confidence limits. The chamber’s central dose was determined making use of a Ferrous-Sulphate dosimeter (QC-16-3511) by Noridian International, Ontario, Canada. Twelve wheat grains exposed to the same dose were germinated in each pot of 30 cm diameter. The pots were filled with a mixture of equal weights of beatmoss and sand.

The irrigation process was periodically performed three times weakly with equal quantities of water inside a greenhouse under natural illumination and daylong conditions. After two weeks, thinning was carried out where 6 seedlings were left. Growth parameters were precisely determined and statistically treated with F-test at 5%. The germination time was set to be thirty days.

2.2. The fluorescence and absorption spectrum of chlorophyll.
A spectrofluorometer model fluoromax 2 and the Shimadzu UV-1601 PC (UV/Visible double beam spectrophotometer) have been used to obtain the fluorescence and absorption spectra of chlorophyll of the treated samples at excitation wavelength 420 nm for the former and wavelength range 200-800 nm for the latter.

2.3. Dielectric constant and AC electrical conductivity measurements of chlorophyll.
A loss factor meter type 19250-60 manufactured by Cole Palmer Co. has been used to measure the dielectric properties of the samples in the frequency range of 20 to 100 kHz. The sample cell has two 1x1 cm² platinum black electrodes separated by 1cm distance. The measurements were done at constant temperature of 20 °C. The obtained values of capacitance (C), and resistance (R), were used to calculate the dielectric constant k and the AC conductivity σ of chlorophyll samples as follows:

\[ C = \frac{\varepsilon_0 kA}{d} \]  
\[ \sigma = \frac{d}{RA} \]  

where A and d are the area and separation between the two electrodes respectively; \( \varepsilon_0 \) is the permittivity of the free space.
3. Results and Discussion.

3.1. The effect of gamma irradiation on the growth parameters.

The effect of different gamma doses (0, 1.5, 2, 2.5, 3, 5, 7, 10 krad) on all growth parameters of the wheat grains are shown in table 1 and 2. The data included in those tables represent the mean values of the growth parameters that measured four times during four consequent years. It is clear that a remarkable increase of shoot and root lengths as well as fresh and dry weights was observed at 2.5 krad. The highest doses of gamma rays (>5.0 krad) have an inhibitory effect on both growth and germination rate of wheat plant. These results are going in parallel with those obtained previously [13,14,20].

Table 1. Percentage of wheat grains germination (%) at different gamma doses.

| Treatment dose (krad) | After 1 day | 2 days | 5 days | 7 days |
|-----------------------|-------------|--------|--------|--------|
| 0 (Control)           | 20          | 60     | 90     | 100    |
| 1.5                   | 23          | 70     | 100    | -      |
| 2.0                   | 24          | 72     | 100    | -      |
| 2.5                   | 25          | 75     | 100    | -      |
| 3.0                   | 23          | 65     | 92     | 100    |
| 5.0                   | 20          | 50     | 90     | 100    |
| 7.0                   | 15          | 40     | 80     | 80     |
| 10                    | 10          | 30     | 40     | 40     |

3.2. Fluorescence emission of irradiated chlorophyll

An example of the fluorescence emission spectra for the chlorophyll samples irradiated by different gamma irradiation doses (0, 1.5, 2, 2.5, 3, 5, 7& 10 krad) are shown in figure 1. Maximum emission were obtained at 2.5 krad. These results indicated that 2.5 krad gamma dose is the best excitation dose among all irradiation treatment doses.

Table 2. Effect of different gamma doses on the growth parameter of Wheat plants 30 days after sowing.

| Treatment Dose (krad) | Shoot Length (cm) | Root Length (cm) | Fresh weight (g) | Dry weight (g) |
|-----------------------|-------------------|------------------|------------------|---------------|
| Control               | 17.1              | 21.8             | 1.11             | 0.200         |
| 1.5                   | 18.0              | 24.0             | 1.24             | 0.205         |
| 2.0                   | 18.8              | 25.1             | 1.41             | 0.215         |
| 2.5                   | 20.0              | 26.0             | 1.70             | 0.220         |
| 3.0                   | 17.8              | 23.8             | 1.35             | 0.190         |
| 5.0                   | 15.3              | 21.6             | 1.05             | 0.144         |
| 7.0                   | 12.5              | 18.1             | 0.90             | 0.076         |
| 10.0                  | 15.5              | 15.2             | 0.52             | 0.062         |
| L.S.D. 5%             | 2.12              | 2.321            | 0.62             | 0.053         |
3.3. Absorption spectra of irradiated chlorophyll

An example of the absorption spectra of the aforementioned chlorophyll samples irradiated by different gamma irradiation doses (0, 1.5, 2, 2.5, 3, 5, 7, 10 krad) are shown in Fig. 2. The 2.5 krad irradiation dose gives the highest absorption compared with all other irradiation treatments besides the control. This means that, gamma irradiation stimulates the photo-hormonal activity. This could explain an observed increase in the germination capacity of wheat grains as well as the higher initial growth rate of wheat plant. These results recommend the use of low gamma dose (2.5 krad) in producing pigments maximum values in the wheat plant that achieve the related best stimulating effects.

3.4. Relative permittivity and electric conductivity of irradiated chlorophyll
The changes of the relative permittivity (dielectric constant) and AC electric conductivity of chlorophyll samples as a function of the applied electric field frequency in the range 20Hz-100kHz at four different gamma irradiated doses (0.5, 1.5, 2.5, 5 krad) are shown in Fig. 3 & 4 respectively. The obtained results indicated that, highest values for both the relative permittivity and the electric conductivity of chlorophyll samples were occurred at 2.5 krad grains treatment. These results gives another support in the favor of the 2.5 krad wheat grain treatment to be the most significant dose in stimulating wheat plant growth. The deviation between the obtained four years repeated results do not exceed 3%.

![Dielectric Constant](image1)

**Figure 3.** Dielectric constant for selected gamma irradiated chlorophyll samples as a function the applied frequency.

![AC Conductivity](image2)

**Figure 4.** Ac conductivity ($\sigma$) for selected gamma irradiated chlorophyll samples as a function the applied frequency.

4. **Conclusion.**
Gamma irradiation effects on the stimulating conditions and/or growth parameters such as root and shoot lengths and fresh and dry weights have been studied by means of morphological and physical methods. The predictions of the present results clearly illustrated the preeminence of the 2.5 krad irradiation dose...
compared with the other irradiation treatments (0, 1.5, 2, 2.5, 5, 7, 10 krad) in increasing the plant growth. The present work may emphasize the importance of both fluorescence and absorption spectra besides the dielectric properties in the investigation of the plant growth characteristics. For the sake of reproducibility of these results, other types of wheat should be experienced and different environment and soil should be used.

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