Original Article: Gamma and Beta Radiation Effect on Number of Germinations Effective and Growth Rate of Triticale Plant

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ABSTRACT

The triticale plant was produced by humans in the late 19th century from the combination of wheat and rye. This plant is much richer than wheat in terms of nutritional value and combined percentage of elements. In the last few years, there have been reports of diseases and damages of the triticale plant. Irradiation of mixture gamma and beta rays with a suitable dose increases resistance, improves various traits, and increases the percentage of number of germinations effective, growth, seedling length, etc. in triticale plants. The simulation results with MCNPX code in the period of 1 to 6 days, with iodine 131 source (mixture of gamma-beta rays) and with 200mCi activity, doses of 23, 43, 50, 63, 80, 95, and 110 Gy has been obtained and in the stage of planting samples different and normal, the 63Gy sample performed better than other samples in terms of number of germinations effective and growth index.

Introduction

With years of research and breeding, triticale has become an important small grain in the agricultural industry, which has met the needs of many regions of the world in the field of feed, fodder, and sustainable cultivation systems. This seed has played a very important role in improving wheat traits and the genes of the added value of rye are inherited. Triticale is much more resistant to cold, heat, and harsh conditions than wheat. For example, resistance to fungal diseases and stress tolerance. Crossing wheat and rye provided triticale tolerance to adapt to different environments, weather conditions, and a wide range of soils, including dry and marginal lands [1].

Due to the lack of natural evolution of triticale, breeders should always face challenges related to creating the genetic diversity needed for continuous crop improvement [2].

Due to the creation and construction of triticale by humans, in recent years, fungal diseases such as various types of rust, powdery mildew, Fusarium blight have occurred on an epidemic scale in a number of triticale cultivars [1].

In these years, efforts have been made to find ways to grow and increase the resistance of triticale against various stresses and diseases. Among these methods, it can be mentioned that the irradiation of various types of ionizing and non-ionizing rays. Gamma, beta, and UV-B rays have been used for modification. During the last decade, it has been recognized that UV-B radiation is an important regulator of plant secondary metabolism. [3] concluded that sunflower growers could improve crop yield by priming the seeds with magnetic field and laser irradiation before sowing [4]. Ultraviolet radiation (high energy radiation) causes changes in the genome of plants that cause hereditary mutations and affect plant growth and characteristics of the photosystem and soil, and also cause exacerbation of diseases in the crop. The dose of radiation on plants should be controlled. If the radiation dose is higher than a certain amount, it causes changes in the DNA structure of the plant. Changes in plants can be observed at the morphological, biochemical, physiological, and/or biophysical levels, where the extent of change is highly dependent on exposure dose, soil, field management, and other environmental variables [5]. According to the gamma ray energy and how it hits the atom, different phenomena are created. Ionization causes changes and disruptions in the natural process of plant cells, and thus affects the performance of plants. Low dose has fewer side effects compared to high dose. Above leaves effects on the phenotype, plant organs, and plant traits. There are a number of chemical parameters to identify radiation damage, however, plant defense mechanisms are activated under low doses of gamma rays to counter the damage [6]. Recently it was reported the use of low dose gamma irradiation to improve plant vigor, grain development, and yield attributes of wheat [7].

Gamma radiation with low doses had positive effects on plant traits. Gamma irradiation improved plant nutrition, but improved grain nutritional quality, especially in terms of micronutrients [7]. In agriculture, gamma radiation has been used to reduce post-harvest losses by suppressing germination and contamination, eradicating or controlling insect pests, reducing food-borne diseases and increasing shelf life, and to breed high-yielding seeds [8]. Singh and Datta [7] have recently shown that low dose of gamma radiation (0.03-0.07 kGy) can potentially be used to improve plant and seed productivity. Since radiation sensitivity shows the cellular and metabolic activity of the plant, it is expected that there is a relationship between radiation sensitivity and product traits. High intensity gamma was shown to affect the quality of reducing sugar and starch content [9]. Gamma irradiation also changed rooting characteristics, and thus the uptake of mineral nutrients [10]. The effects of gamma radiation are investigated by studying plant germination, growth and development, and biochemical characteristics of maize. Maize dry seeds are exposed to a gamma source at doses ranging from 0.1 to 1 kGy. Results show that the germination potential, expressed through the final germination percentage and the germination index, as well as the physiological parameters of maize seedlings (root and shoot lengths) decreased by increasing the irradiation dose [11].

The effects of low dose radiation are completely different from the effects of high dose radiation. In a study, 200 Gy gamma radiation on chickpea seeds caused the seedling length to increase significantly, while 400 Gy radiation had the opposite effect on seedling length growth [4].

Using gamma rays can be used to increase some properties Physiological and growth rates of wheat seedlings were used to control and tolerate stress [12]. With 20 Gy radiation, the length of wheat roots increased by 32% compared to other samples [13]. Gamma rays are used as nuclear techniques in agriculture.

Gamma radiation can be used for plant modifications with a sufficient and appropriate dose and can be used as a mutagenic agent to induce genetic diversity in plant species [14]. Iodine 131 is a source of Beta and Gamma radiation [15]. Many researches have been done on different samples of wheat, corn, barley, etc. with different treatments, but so far there is no research on the use of gamma and beta mixed field radiation on the growth rate, germination index of triticale plant in different doses, simulation, and also it has not been practically investigated.

Materials and Methods

In the first phase, simulation was done with MCNPX code to do dosimetry calculations based on the obtained information. Since the source used is iodine 131 in the code, it was simulated with the amount of gamma rays and once again with radiation. Triticale seeds with a mass of 10 g were placed in previously designed plastic containers so that the source of Iodine-131 was in the middle so that the amount of radiation to all seeds was the same, and then radiation protection is done with lead bricks in all directions (Figure 1).

Figure 1. Placement of seeds for radiation with lead shield

It is necessary to place triticale seeds in MCNPX code and extract the percentage of elements in triticale seeds, and after using chemical formulas [16], the composition percentages of Triticale was calculated as Table 1 that used in MCNPX code input file as material card.

Table 1. Elements in the triticale plan

Element	Total	Element	Total
Ca	0.468511	Ni	2.75E-05
K	1.258239	Cr	0.000436
P	0.357776	Pb	1.18E-05
S	0.04986	As	1.18E-05
Mn	0.004457	H	6.473433
Fe	0.031486	O	45.4708
Cu	0.000302	C	44.39941
Zn	0.0006	N	1.484635

The amount of gamma and beta energy iodine-131 source is extracted [15] and is presented in Table 2 and is entered as a source in the MCNPX code.

Table 2. Gamma and beta radiation of iodine source 131

Gamma rays		Beta rays	
Energy (Mev)	**Abundance %**	**Energy (Mev)**	**Abundance %**
0.284	5	0.25	2.8
0.364	78.4	0.34	9.3
0.637	9	0.61	87.2
0.722	3	0.81	0.7

The activity of used iodine sourse is 200 mCi and dosimetry calculations are done by obtaining the decay constant. The 10 g seeds were packed after cleaning and weighing and were exposed to iodine 131 radiation for one, two, three, four, five, and six days. In the second phase of the work, the seeds were soaked in Hoagland's solution for 36 hours in containers according the related times (Figure 2).

Figure 2 . Soak the seeds for 36 hours

After the desired time passed, the seeds were planted in sterilized plastic pots with two repetitions together with two normal samples (not exposed to radiation).

To preserve the samples and create natural and identical conditions for all the samples in the germinator, the stages of growth and germination were observed. The temperature in the machine was 26 ℃ and the humidity was %70 (Figure 3).

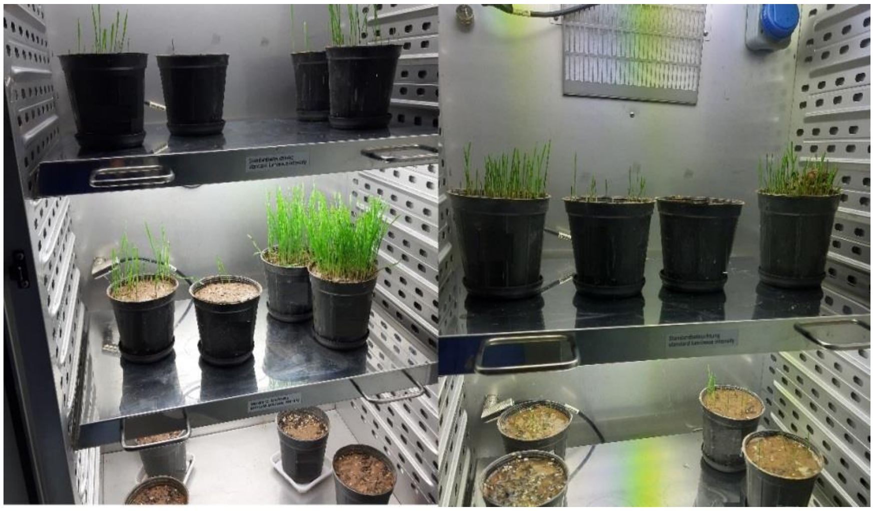

Figure 3. Samples in different doses in the germinator

In the planting stage, 7 pots were needed to plant irradiated samples and 1 pot without irradiation. The experiment was carried out in two stages in controlled conditions and a completely random design with 2 or 3 repetitions.

Results

The results are divided into two parts. The first part is the simulation results with the MCNPX code, and the second part is the results related to seed planting in the stages of the practical part according to the percentage of number of germinations effective and growth. In the first part, the results obtained after simulation with MCNPX code and dosimetry results as presented in Table 3, according to the amount of radiation with the source of Iodine-131 in different time intervals of 1 to 6 days and with dosimetry calculations, doses of 23, 43, 50, 63, 80, 95, and 110 Gy were obtained.

Table 3. Results of dose calculation with MCNPX code

Total dose due to Gamma and Beta rays (Gy)	Time of radiation (Day)
23	1
43	2
50	2.35
63	3
80	4
95	5
110	6

The second part of the results includes the results of the planting stages and practical stages:
The measured indicators included number of germinations effective (NGE) and growth of the samples. The normal sample is T-00 and the other treatments are named as T-01, T-02, T-03, T-04, T-05, T-06, T-07 according to the radiation dose intensity. Table 4 indicates the effective germination percentage of the treatments during 12 days of planting in the same conditions with 100 seeds of Triticale.

Table 4. Number of germinations effective (NGE)

TREATMENT	DOSE (Gy)	NGE
T-01	23	14
T-02	43	22
T-03	50	54
T-04	63	88
T-05	80	45
T-06	95	52
T-07	110	23
T-00	0	76

Figure 4 is the number of germinations effective (NGE) diagram based on the information obtained from Table 4. There is a relationship between dose intensity and germination time, so that in low doses, triticale seeds start to germinate after 3 to 4 days, while at higher doses, the seed started to germinate within 5 to 7 days. The control sample started to germinate after 3 days on average. A variable called Degree of Germination (DG) states that not all seeds germinate at the same time. Figure 5 depicts the growth of the samples and percentage of germination in different dosages. The samples with high dosages wilted and turned yellow after 15 days in the Germinator.

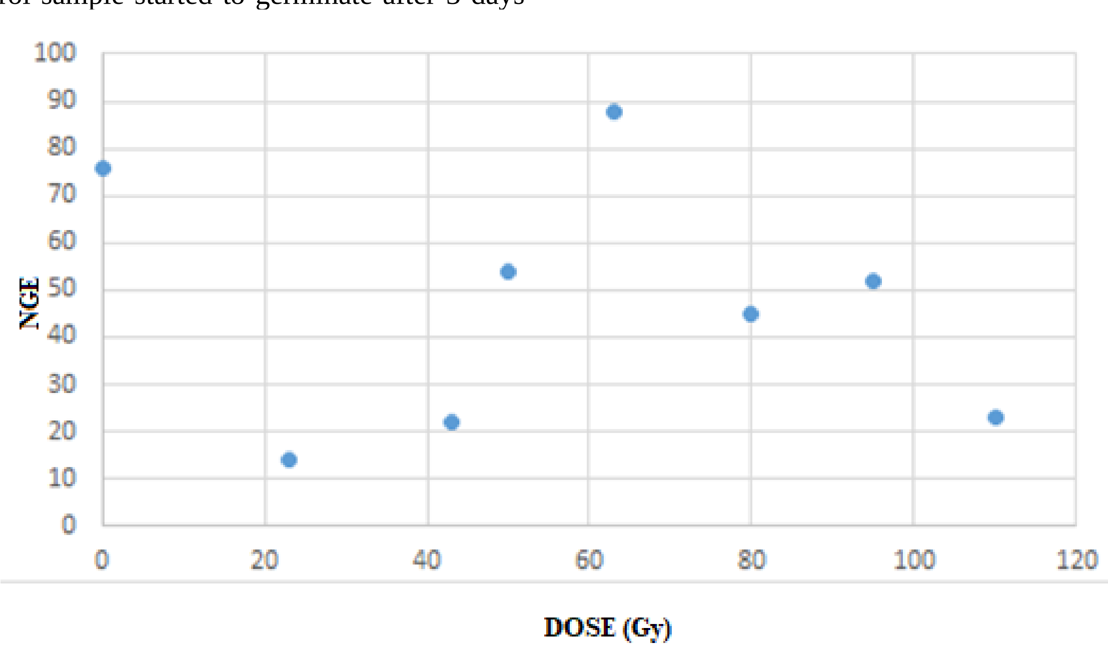

Figure 4 . NGE in different doses in germinator.

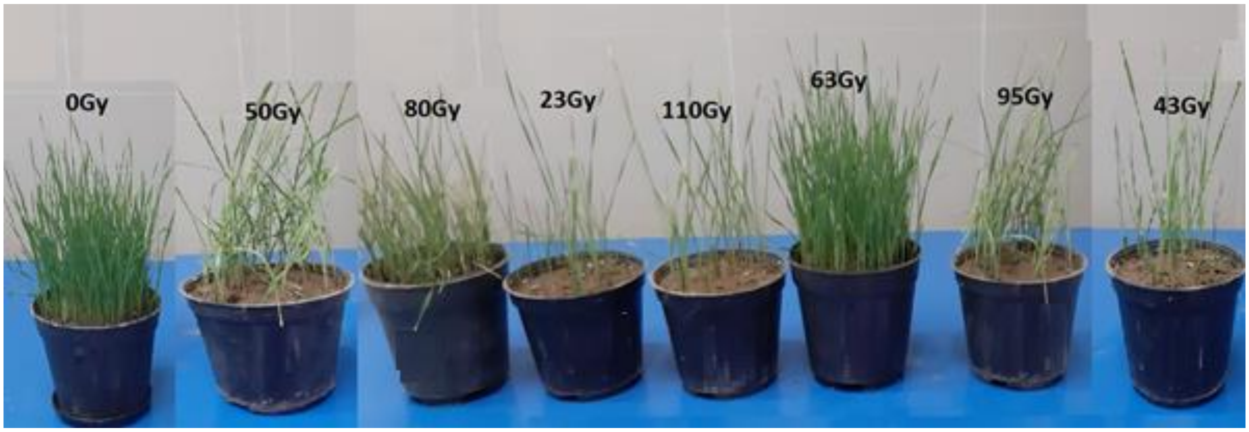

Figure 5 . Growth and germination rate in the 63Gy sample

Discussion

On the other hand, insecticides are predominantly used in Nigeria to control insects like mosquitoes, which vectors malaria parasites and other avalanches of insect pests on legumes, citrus, cereals, and other horticultural crops.

Nigeria spent about 63.4 billion Naira annually on pesticides, an equivalent of about 244 million US Dollars (Tables 5 and 6.), out of which 74%, 16.6%, 4.7%, 5.0%, and 0.06% went to herbicides, insecticides, fungicides, soil fumigants, and mosquito repellant coils, respectively (Table 7). In the USA, pesticide expenditure accounts for approximately 16–18% of the entire world (Atwood and Paisley-Jones, 2017). In the agriculture sector, herbicides (59%) accounted for significant pesticide In the seeds of Pea Pisum sativum L the number of germinations effective was given to 100% for 20 and 40 Gy, and then decreases to a higher dose reaching 20% to 200 Gy, being the average of the proof near to 90% [17]. The low gamma radiation absorbed doses were found to be more effective versus higher doses for enhancing the germination and growth characteristics of sunflower [18]. In the orchid plant, it was found that the induction of gamma radiation led to changes in the morphological characteristics of the orchid, such as increasing plant height, increasing leaf width, decreasing the number of roots, decreasing root length, changing leaf shape, and changing leaf color [19]. The applications of gamma rays were effected on survival plant rate considerably than the percentage of germination [20]. Number of germinations effective (NGE) was 88% for 63 Gy which was the highest germination percentage among all treatments. In addition, the percentage of germination in low doses below 43 Gy and above 80 Gy was below 50% of the total germination percentage. The germination percentage of the dose in the control sample was 76%, which was 12% less than the 63Gy sample. According to Figure 5, growth and resistance of the samples, it was found that the triticale plant with radiation dose of 63 Gy after 15 days in the germinator, the cell structure of the plant was less damaged and the growth length of seedling increased more and it has less wilting and yellowing than to other examples. Samples with a dose of 80 Gy and above have wilted and bent length of stems after the elapsed time, and these damages are also seen in doses lower than 50 Gy. Choosing the right dose is very important to improve plant traits, increase growth, and increase germination percentage, low doses and high doses cause damage to plant cell structure, change in DNA structure and production of free radicals in plant. Free radicals change the characteristics of plant by creating excess oxygen. The germination time of the treatments varied from 3 to 7 days, and the germination time of the control sample was less than the other treatments. Samples with high dose started to germinate in longer times. The results show, the dose of 63Gy in triticale plant caused growth and increased germination percentage compared to other treatments and control sample. So far, many studies have been conducted on the effects of radiation on morphological traits, the number of effective germination, seedling growth, length, etc., but the innovation and novelty in this research is the research on the triticale plant, which has so far been conducted on the effect of mixed radiation gamma and beta (Iodine-131) on triticale seeds and no study has been done to investigate the number of effective germination and its growth.

Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Marjan Atghaei, Mohammad Reza Rezaie, Amin Baghizadeh, and Hossein Mirshekarpour. The first draft of the manuscript was written by Amin Baghizadeh and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflicting interests.

Availability of data and material

All data generated or analyzed during this study are included in this published article and its supplementary information files.

Ethical approval

This article does not contain any studies with human subjects or animals performed by any of the above authors.

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