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Effect of gamma irradiation on some characteristics of seed germination, seedling parameters and biochemical compounds of *Satureja hortensis*

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Introduction

In recent decades, the use of radiation process has led to a great breakthrough in plant research (Laanen *et al.*, 2023). The use of gamma rays is more effective and economical than the other types of ionizing rays due to easier access and higher penetration power (Moussa, 2006). The results of some researchers have shown that low doses of gamma rays can have favorable physiological effects on some activities of plants such as seed germination (Nepal *et al.*, 2014). Irradiation of seeds by gamma rays with relatively low doses causes the decomposition of some macromolecules into smaller components that can be used by the embryo. Also, these rays increase the rate of cell proliferation and the intensity of metabolic activities due to the raise the activity of some enzymes and improvement the rate of germination (Borzouei *et al.*, 2010). Production of protein and chlorophyll, oxidation of lipids, change of enzyme activities and accumulation of phenolic compounds have been among the results obtained by some researchers in relation to the effects of gamma rays on the seeds of some plants (Alikamanoglu *et al.*, 2011; Kafi, 2013). The effects of radiation on plants are different depending on the type of plant, intensity and time of radiation. For example, the amount of phenols in *Cymbopogon schoenanthus* has revealed increase with enhancement the intensity of gamma radiation (Hala Ahmed Abdolla *et al.*, 2010).

Summer savory (*Satureja hortensis*) is a medicinal and aromatic plant from the mint family (Lamiaceae), has economic importance and is used in various industries (Timperio *et al.*, 2008). This plant has biologically active compounds such as carvacrol and thymol, which has enabled its use in medicine and pharmacy (Hadian *et al.*, 2011). The aim of this research was the evaluation of the effect of different intensities of gamma rays on the seeds of the savory plant and study its effect on the germination stage, characteristics of the seed sprouts and the biochemical compositions of the plants grown from them.

Methods and Materials

After purchasing from Pakan Bazr Company, Isfahan, the seeds of *Satureja hortensis* medicinal plant were sent to Nuclear Agriculture Research School, Karaj, Iran. Seeds were irradiated with doses of 15, 30, 60, and 90 Gy from the Cobalt 60 source with a radiation speed of 10 Gy in 2 minutes and 48 seconds, and a sample of them was considered as a control (zero Gy). In order to investigate germination, the seeds were placed in petri dish and 8 ml of sterile distilled water was added to each of them. Petri dishes were placed in an incubator for 48 hours wiht photoperiod regime 14/10 h of light/dark and an average temperature of 27±3 °C. The germinated seeds were counted daily. After 12 days, the morphological characteristics of seedlings were measured and analyzed by related formulas. In order to investigate the biochemical composition of plants, in July 2019, the seeds treated with different doses of gamma rays were grown in 20×20 cm pots filled with Klasmann-Deilman potgrond and placed in greenhouse conditions. The leaf samples collected at the end of the vegetative phase and were extracted after drying. Total phenolic content, total flavonoid content and antioxidant potential of the extracts were evaluated using Folin-Sicaltio colorimetric method (Gheshlaghpour *et al.*, 2021), aluminum chloride method (Gheshlaghpour *et al.*, 2021) and measuring the ability to inhibit DPPH free radicals (Asghari *et al.*, 2020), respectively.

For statistical analysis, analysis of variance ANOVA statistical analysis method, and for comparison of averages, Duncan's Test and SPSS 16 software were used. The required graphs were drawn by Excel software. All the tests have been carried out in four replications.

Results & Discussion

The results showed that the highest percentage of seed germination was in the dose of 90 Gy ($p \leq 0.05$) and the highest seed germination index in the treatment of 15 Gy ($p \leq 0.01$). The external factors can affect the number of cells and the appropriate degree of their differentiation

for the development of different parts of the seedlings and also impact on characteristics of seed germination (Bedell, 1998). The highest dose of gamma radiation (90 Gy) had a negative effect on the length of the stemlets of the savory plant, which showed a significant difference with the control and other treatments ($p \leq 0.01$). These results can be related to the decrease in the amount of hormones, especially cytokinin, which is the result of its decomposition or decrease in synthesis with increase in the intensity of gamma radiation (Kiong *et al.,* 2008). Gibberellin, which is one of the most important growth regulators and plays a major role in cell growth and thus increasing plant length, can be deactivated by reacting with hydroxyl free radicals created by gamma radiation and reduce the length of rootlets and stemlets (Bagheri *et al.*, 2017). The highest dry weight of seedlings was observed in the treatment of 90 gray, which revealed a significant difference ($p \leq 0.05$) with the treatments of 15 and 30 gray, as well as the control. Among the factors affecting this process can be mentioned to the accumulation of more dry matter, amount of leaf surface and photosynthesis, distribution of different organs from photosynthetic materials, physical characteristics of seed, rate of germination, more and faster decomposition of endosperm. The biochemical results showed that the samples affected with 30 Gy radiation dose had a significantly higher phenolic and flavonoid compounds as well as DPPH free radical scavenging capacity than the other samples. Phenols are compounds that protect plant cells against the oxidative effects of reactive oxygen species (ROS) (Dangles, 2012; Gill & Tuteja, 2010). Accumulation of phenolic compounds in cells can be due to increased activity of PAL enzyme (Bhat *et al.*, 2007). Flavonoids are among the most important inhibitors of free radicals (Havsteen, 2002). Increase in the amount of leaf flavonoids in this study was in accordance consistent with the results of some previous researchers (Lois, 1994). Irradiation of savory seeds with 30 Gy of gamma radiation can increase antioxidant compounds and also antioxidant properties in the extracts of the plants grown from them. In this way, the danger of possible stress caused by free radicals for different compounds such as lipids, proteins and DNA inside the cells is reduced (Moghaddam *et al.*, 2011).

Conclusion

The results of present study revealed that 90 Gy treatment has the most positive effects on the germination percentage and dry weight of the savory seedlings. Also, 15 Gy dose treatment causes the highest vigour index of the plant seeds. On the other hand, 30 Gy radiation dose increases the amount of total phenol and flavonoid compounds (antioxidant molecules) as well as inhibitory property of DPPH free radicals in the savory extract. According to the obtained

results, irradiation with a dose of 30 Gy on savory seeds can be suggested, due to obtain a useful crop for health, with maximum valuable metabolites, like phenols and flavonoids.

Key words: *Antioxidant molecules, Free radicals, Ionizing Radiations, Savory, Seedling.*

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