Chapter 5

Seed Dormancy

Mustafa Yildiz, Ramazan Beyaz, Mehtap Gursoy,
Murat Aycan, Yusuf Koc and Mustafa Kayan

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70571

Abstract

Dormancy is when there is a lack of germination in seeds or tubers even though the required conditions (temperature, humidity, oxygen, and light) are provided. Dormancy is based on hard seed coat impermeability or the lack of supply and activity of enzymes (internal dormancy) necessary for germination. Dormancy is an important factor limiting production in many field crops. Several physical and chemical pretreatments are applied to the organic material (seeds/tubers) to overcome dormancy. Physical and physiological dormancy can be found together in some plants, and this makes it difficult to provide high-frequency, healthy seedling growth, since the formation of healthy seedlings from the organic material (seeds/tubers) sown is a prerequisite for plant production. This chapter will focus on the description of four different methods we have not seen reported elsewhere for overcoming dormancy.

Keywords: dormancy, magnetic field strength, squirting cucumber fruit juice, sodium hypochlorite, gamma radiation

1. Introduction

Seeds germinate to grow and survive from seedlings at a favorable time and place. The prevention of germination in unfavorable circumstances is described as dormancy. Dormancy is where there is a lack of germination in a seed/tuber even though the required conditions (temperature, humidity, oxygen, and light) are provided [1]. Dormancy is a trait gained during evolution to survive in adverse conditions such as heat, cold, drought, and salinity. Dormancy enables plant species to adapt to different geographical regions, showing variations in precipitation and temperature [2]. Dormancy has a significant role in the development of new species and the successful dispersal of existing species [2].

There are two types of seed dormancy in general: seed coat (physical) dormancy and internal dormancy. In seed coat dormancy, the seed coat prevents oxygen and/or water permeating into the seed. Sometimes, dormancy is caused by inhibiting chemicals inside the seed. Seeds with seed coat dormancy can remain on/in the ground without germinating until the seed coat allows water and oxygen to enter the seed or eliminate the inhibiting chemicals. Seed coat dormancy is common in California lilac (*Ceanothus*), manzanita (*Arctostaphylos*), sumac (Rhus), and members of the legume family. Scarification, hot water, dry heat, fire, acid and other chemicals, mulch, and light are the methods used for breaking seed coat dormancy [3].

Physiological conditions causing internal dormancy arise from the presence of germination inhibitors inside the seed. The adverse effects of these inhibitors should be eliminated in order to start germination by using germination-promoting substances such as gibberellic acid (GA3) and potassium nitrate (KNO_3). The most common inhibitor is abscisic acid (ABA). Sugar maple [4], Norway maple (*Acer platanoides* L.) [5], planetree maple (*Acer pseudoplatanus*) [6], European hazel (*Corylus avellana* L.) [7], white ash (*Fraxinus americana* L.) [8], apple (*Malus pumila* Mill.) [9], northern red (*Quercus rubra* L.), and English oaks [10] are the species that have ABA as an internal inhibitor. Another type of internal dormancy is caused by lack of enzymes, which is required for complete physiological maturation.

Seed coat and internal dormancy can be found together in a species. Seeds with this combined dormancy should be treated by overcoming the problems raised by the impermeable seed coat first, and then overcoming the internal dormancy [3].

In this chapter, the effects of magnetic field strength squirting cucumber (*Ecballium elaterium* (L.) A. Rich.) fruit juice, sodium hypochlorite solutions, and gamma radiation on overcoming dormancy are discussed.

2. New methods for overcoming dormancy

2.1. Magnetic field strength

All living creatures are exposed to magnetic field throughout their lives. Exposing seeds to magnetic field is one of the physical treatments to increase seed germination and plant development [11–13]. It was reported that seed germination was improved by physiological changes in seeds, such as faster water assimilation and higher photosynthesis, under the effect of magnetic field [14]. Many researchers have reported that exposing seeds to a magnetic field increased seed vigor and germination [12, 13, 15–18]. Although there are many reports on the effects of magnetic field on seed germination, plant growth, protein biosynthesis, and root development, to our knowledge the effect of magnetic field on overcoming dormancy has not been reported before.

In the studies conducted with lentil (*Lens culinaris* Medik.), grass pea (*Lathyrus sativus* L.), and potato (*Solanum tuberosum* L.), magnetic field rapidly increased seed/tuber germination and seedling growth by overcoming dormancy. Seeds/tubers from lentil (cv. "Çiftçi"), grass pea

http://dx.doi.org/10.5772/intechopen.70571

(cv. "Gürbüz") and potato (cv. "Marabel") were sown in soil after keeping them in different magnetic field strengths (0-control, 75, 150, and 300 mT) for different period of times (0-control, 24, 48, and 72 h), and then lentil and grass pea were incubated for 14 days at 24 ± 1°C for a photoperiod of 16 h of light/8 h of darkness under white fluorescent light (27 μmol m^{-2} s^{-1}), while potatoes were grown in a greenhouse at 24°C for 2 months. Tubers weighing 40–60 g were used in the study. Five replications were used for the lentil and grass pea, and 10 replications for the potatoes. Pots containing 10 seeds for lentil and grass pea and 1 tuber for potato were considered as an experimental unit. The study used two parallel treatments according to the "Completely Randomized Design" concept. Data were statistically analyzed with Duncan's multiple range test using IBM SPSS Statistics 22 software. Values presented in percentages were subjected to arcsine ($\sqrt{X}$) transformation before statistical analysis [19].

Observations were performed on the characteristics of germination percentage, seedling growth percentage, plant height, and total chlorophyll content in lentil; germination percentage, seedling growth percentage, seedling fresh and dry weights in grass pea; and day of emergence, plant height, and total chlorophyll content in potato. Seed germination percentage was determined at the end of the 5th day in lentil and the 4th day in grass pea, while seedling growth percentage was noted at the end of the 10th day in lentil and the 14th day in grass pea [20]. For all other characteristics, observations were performed at the end of the 14th day in lentil and grass pea, and the 2nd month from the study initiation for the potato.

The total chlorophyll content was determined in leaves of plants according to the protocol of Curtis and Shetty [21]. Fresh tissue from 50 mg of leaves was put in 3 ml of methanol and kept in total darkness at 23°C for 2 h. In this way, chlorophyll in the fresh tissue passed through into the methanol. After 2 h, absorbencies were determined at wavelengths of 665 and 650 nm using UV spectrophotometer. The total chlorophyll content was calculated as μg chlorophyll/g fresh tissue.

In lentil, the lowest values were noted in the control treatment where no magnetic field was used. Lower results in germination and seedling growth percentages were the indicators of dormancy. On the other hand, the highest results in all characteristics were recorded from seeds treated with a magnetic field with a strength of 300 mT for 24 h. At this strength, the highest germination, seedling growth percentages, plant height, and total chlorophyll content were noted as 96.50 %, 100.00%, 7.16 cm, and 586.32 μg chlorophyll/g fresh tissue, respectively (**Table 1**).

There is a close relationship between photosynthesis and chlorophyll content [22–25]. The chlorophyll content of a leaf is accepted as an indicator of the photosynthetic capacity of tissues [26–28]. The total chlorophyll content was determined to be 586.32 μg of chlorophyll/g fresh tissue when treated with a magnetic field strength of 300 mT for 24 h, while it was 125.56 μg of chlorophyll/g fresh tissue in the control sample (**Table 1**).

In grass pea, the lowest results were again recorded for the control treatment, while the highest values were obtained from seeds treated with a magnetic field strength of 300 mT for 72 h. At the end of the study, the germination and seedling growth percentages, plant height, plant fresh, and dry weights were recorded as 0.00%, 75.00%, 21.66 cm, 0.556 g, and 0.131 g, respectively, for the control treatment, whereas they were 100.00%, 100.00%, 28.50 cm, 0.798 g, and 0.160 g, respectively, from seeds treated with a magnetic field strength of 300 mT for 72 h. The

Magnetic field strength (mT)	Treatment period (h)	Germination (%)	Seedling growth (%)	Plant height (cm)	Total chlorophyll content (μg chlorophyll/g fresh tissue)
0—control	0	5.00 g	15.00 f	2.00 e	125.56 g
75	24	25.00 f	37.50 ef	2.54 e	205.48 f
	48	32.25 e	42.25 e	2.88 de	238.56 ef
	72	44.50 d	52.00 d	3.22 d	289.75 e
150	24	55.75 cd	63.75 c	3.76 cd	378.56 d
	48	58.00 c	67.25 c	4.45 c	399.74 d
	72	62.50 c	72.50 b	4.85 bc	445.21 c
300	24	96.50 a	100.00 a	7.16 a	586.32 a
	48	92.25 ab	98.25 a	6.46 ab	541.00 ab
	72	88.75 b	95.75 ab	5.85 b	510.32 b

Each value is the mean of five replications. All experiments were repeated two times.
Values within a column followed by different letters are significantly different at the 0.01 level.

Table 1. The effect of different magnetic field strengths applied to lentil seeds for different periods of time on seed germination and seedling growth in cv. "Çiftçi".

significant effect of magnetic field strength on overcoming dormancy was easily seen when the results of the control sample using a magnetic field strength of 300 mT for 72 h were compared. Germination percentage that was 0.00% in the control sample increased to 100.00% when treated with a magnetic field strength of 300 mT for 72 h (**Table 2**).

In both genotypes (lentil and grass pea), high biomass formation above ground was observed after magnetic field treatments, where the highest values were recorded, compared with the control where no magnetic field was applied (**Figure 1**). Leaf numbers were higher for the magnetic field treatment compared with the control, and it is the main reason for higher photosynthetic activity that achieves a higher yield. Higher biomass accumulation above ground gives a higher food supply for livestock. In our case, the plant fresh weight was 0.798 g when treated with a magnetic field strength of 300 mT for 72 h, while it was only 0.556 g in the control sample at the end of the study (**Table 2**). This means more than a 50% increase in fresh weight and also more than a 50% increase in food supply for livestock.

In potatoes, sprouting emerged above ground 17 days after planting with tubers treated with a magnetic field strength of 300 mT for 72 h. In the control treatment, sprouts emerged on day 39.50. There was 22.50 days difference observed between the treatment with a magnetic field and the control. In the control sample where no magnetic field was used, the lowest results in plant height and total chlorophyll content were found to be 25.56 cm and 1127.46 μg chlorophyll/g fresh tissue, respectively, at the end of the study. On the other hand, the highest values in plant height and total chlorophyll content were recorded as 90.78 cm and

http://dx.doi.org/10.5772/intechopen.70571

Magnetic field strength (mT)	Treatment period (h)	Germination (%)	Seedling growth (%)	Plant height (cm)	Plant fresh weight (g)	Plant dry weight (g)
0—control	0	0.00 g	75.00 d	21.66 c	0.556 c	0.131 c
75	24	27.50 f	80.00 c	23.66 c	0.603 bc	0.130 bc
	48	35.00 f	85.00 bc	24.16 bc	0.613 b	0.133 bc
	72	70.00 c	90.00 b	24.66 bc	0.626 b	0.134 bc
150	24	30.00 f	90.00 b	25.76 b	0.631 b	0.136 bc
	48	45.00 e	95.00 ab	25.96 b	0.636 b	0.138 b
	72	80.00 b	97.50 a	26.25 b	0.638 b	0.142 b
300	24	40.00 e	97.50 a	27.33 ab	0.720 ab	0.145 b
	48	55.00 d	100.00 a	27.66 ab	0.725 ab	0.150 ab
	72	100.00 a	100.00 a	28.50 a	0.798 a	0.160 a

Each value is the mean of five replications. All experiments were repeated two times.
Values within a column followed by different letters are significantly different at the 0.01 level.

Table 2. The effect of different magnetic field strengths applied to grass pea seeds for different periods of time on seed germination and seedling growth in cv. "Gürbüz".

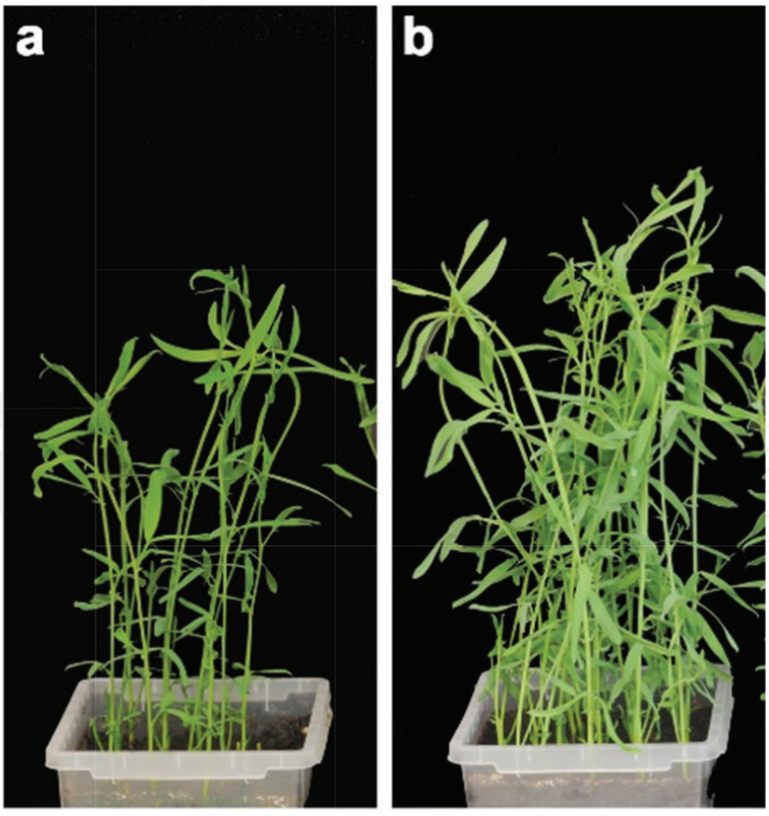

Figure 1. Plant development of grass pea in control (a) and in a magnetic field strength of 300 mT for 72 h (b) at the end of the 14th day.

2105.74 μg of chlorophyll/g fresh tissue, respectively, for the treatment with a magnetic field strength of 150 mT for 72 h (**Table 3** and **Figure 2**).

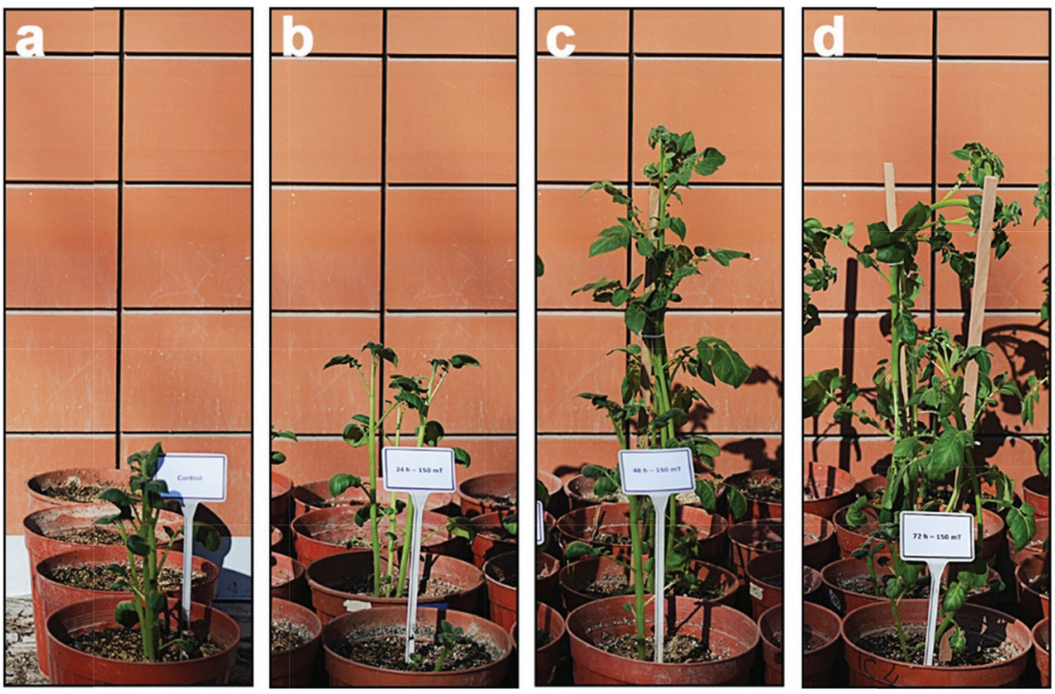

Figure 2. The effect of a magnetic field strength of 150 mT applied to potato tubers for different periods (a. 0 h, b. 24 h, c. 48 h and d. 72 h) on plant development in cv. "Marabel".

Magnetic field strength (mT)	Treatment period (h)	Day of emergence of sprouts	Plant height (cm)	Total chlorophyll content (μg chlorophyll/g fresh tissue)
0—control	0	39.50 e	25.56 e	1127.46 g
75	24	31.25 d	39.00 d	1214.56 f
	48	30.75 d	40.25 d	1327.69 e
	72	29.25 d	42.45 d	1321.12 e
150	24	26.00 c	80.35 b	1927.36 b
	48	21.25 b	88.27 a	2000.27 ab
	72	17.00 a	90.78 a	2105.74 a
300	24	31.00 d	75.76 c	1500.48 d
	48	26.25 c	77.27 b	1558.34 d
	72	20.50 b	78.00 b	1789.46 c

Each value is the mean of five replications. All experiments were repeated two times.
Values within a column followed by different letters are significantly different at the 0.01 level.

Table 3. The effect of different magnetic field strengths applied to potato tubers for different periods of time on the day of emergence of sprouts, plant height, and total chlorophyll content in cv. "Marabel".

2.2. Squirting cucumber (*Ecballium elaterium* (L.) A. Rich.) fruit juice

Squirting cucumber (*Ecballium elaterium* (L.) A. Rich.), which is commonly found in Turkey, is an important medicinal plant [29]. It contains different compounds such as α-elaterin (cucurbitacin E), β-elaterin (cucurbitacin B), elatericine A [30], and elatericine B (cucurbitacin I) in different plant organs [31]. It also contains sterols, phenolic compounds, vitamins, flavonoids, alkaloids, resin, starch, amino acids, and fatty acids [31]. *In vitro* regeneration was affected significantly by squirting cucumber fruit juice [32]. It was also reported that squirting cucumber fruit juice stimulated rapid germination and seedling growth in rapeseed [33].

Mature squirting cucumber fruits were collected from their natural growing areas around Ankara. Fruit juice was extracted and then filtered in order to remove the bigger parts. The fruit juice was subject to sterile filtration and kept in the refrigerator at −20°C.

In a study conducted for overcoming dormancy in cv. "Marabel" potato tubers using squirting cucumber mature fruit juice, tubers at 40–60 g in weight were rinsed for 6 h at 180 rpm in bottles containing water with different concentrations of mature squirting cucumber fruit juice (0-control, 200, 400, 800, and 1600 μl/L). Then, the tubers were planted in pots. Ten pots were used for each concentration, and one tuber was put in each pot. A pot was considered an experimental unit. The study used two parallel treatments according to the Completely Randomized Design concept. Data were statistically analyzed by Duncan's multiple range test using IBM SPSS Statistics 22 software. Values presented in percentages were subjected to arcsine ($\sqrt{X}$) transformation before statistical analysis [19].

Results clearly showed that squirting cucumber fruit juice had a significant role in overcoming dormancy in potato tubers. The best result was recorded at a concentration of 800 μl/L of fruit juice as 16.25 days. That meant that the sprouts of tubers treated with 800 μl/L of fruit juice emerged above the ground 16.25 days after planting. In contrast, in the control treatment where no fruit juice was used, sprouts emerged above ground later than the other treatments. From the results of the study, it could be concluded that squirting cucumber fruit juice stimulated sprout development by overcoming dormancy in potato tubers (**Table 4**).

In **Figure 3**, plant development was recorded for tubers treated with different concentrations of squirting cucumber fruit juice at the end of the 45th day. For a concentration of 800 μl/L of fruit juice, the plants grew better than any of the others. Squirting cucumber fruit juice at a concentration of 800 μl/L encouraged plants to develop faster and with more energy by overcoming dormancy in tubers. At this concentration, plants had more branches and leaves.

2.3. Sodium hypochlorite solutions

Sodium hypochlorite (NaOCl) has been most widely used for surface sterilization. NaOCl is highly effective against all kinds of bacteria, fungi, and viruses [34, 35]. Moreover, NaOCl has strong oxidizing properties that make it highly reactive with amino acids [36, 37], nucleic acids [38], amines, and amides [39, 40].

The most important treatment prior to culture initiation is perhaps surface-sterilization of the explant. Since *in vitro* conditions provide bacteria and fungi with an optimal growth

Concentration of squirting cucumber fruit juice (μl/L)	Day of emergence of sprouts
0—control	31.50 c
200	23.00 bc
400	22.00 bc
800	16.25 a
1600	20.00 b

Each value is the mean of five replications. All experiments were repeated two times.
Values within a column followed by different letters are significantly different at the 0.01 level.

Table 4. The effect of different concentrations of squirting cucumber fruit juice on the day of emergence of sprouts in potato cv. "Marabel".

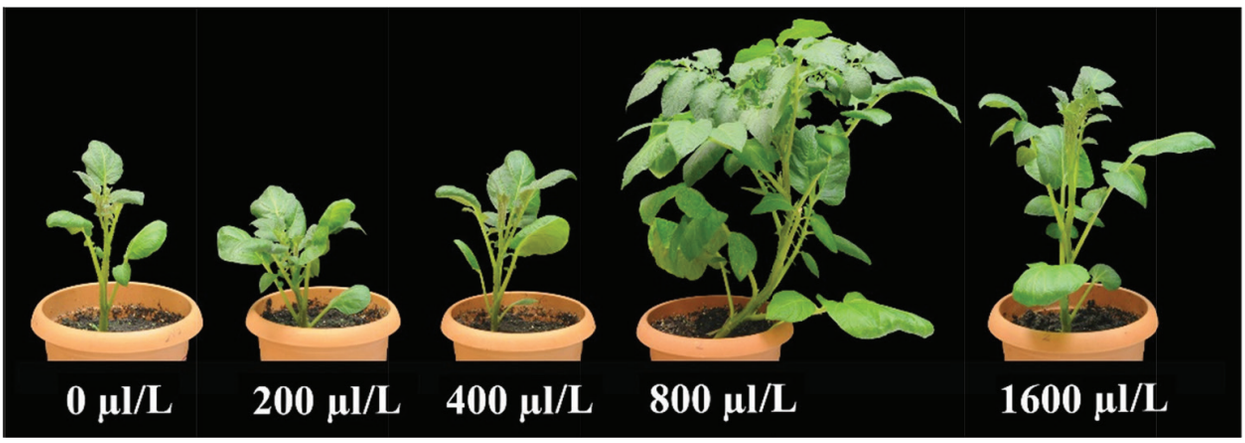

Figure 3. Plant development at the 45th day for potato tubers of the cv. "Marabel" treated with different concentrations of squirting cucumber fruit juice.

environment, unsuccessful sterilization hinders the progress of tissue culture studies. On the one hand, sterilization of the tissue aims to eliminate all microorganisms that can easily grow *in vitro* conditions; on the other hand, it should guarantee the explant's viability and regeneration capacity, which are known to be affected by the concentration, treatment period [41], and temperature of the disinfectant [42].

NaOCl can also be used for overcoming dormancy [43–45] by decomposing germination inhibitors [46], scarifying the seed coat [42, 47], and increasing α-amylase activity [48].

In the study conducted by Telci et al. [49], sodium hypochlorite (NaOCl) solution was successfully used to overcome dormancy in the seeds of *Lathyrus chrysanthus* Boiss., which is used as an ornamental plant with its big, colorful flowers. In the study, *L. chrysanthus* Boiss. seeds of an ecotype (Diyarbakir) from southeast Turkey were treated with a 3.75% NaOCl solution at three different temperatures (25, 35, and 45°C) for 15 min with continuous stirring. This was followed by rinsing three times with sterile water. Seeds were then germinated on a basal medium containing Murashige and Skoog's (MS) mineral salts and vitamins [50], 3%

sucrose, and 0.7% agar in Magenta vessels (15 × 15 cm). The pH of the medium was adjusted to 5.8 prior to autoclaving. For seed germination, cultures were incubated at 15±1°C in the dark for 5 days. Then, all cultures were transferred to a growth chamber for incubation at 25±1°C under cool white fluorescent light (27 μmol m^{-2} s^{-1}) with a 16-h light/8-h dark photoperiod. Seed germination and seedling growth percentages were recorded after 5 and 14 days following culture initiation, whereas seedling height and root length, seedling fresh and dry weights, chlorophyll a, chlorophyll b, and total chlorophyll contents were noted 28 days after culture initiation. The chlorophyll contents were determined in the leaves of seedlings according to the protocol of Curtis and Shetty [21]. All statistical analyses were performed using SPSS for Windows software. Three replicates were tested. Petri dishes (100 × 10 mm) were considered the units of replication, and there were 30 seeds per replication. All experiments were repeated twice. One-way Analysis of Variance (ANOVA) was used to test the effect of the 3.75% NaOCl solution at different temperatures. Duncan's multiple range test was used for comparing the means. Data given in percentages were subjected to arcsine ($\sqrt{X}$) transformation before statistical analysis [19].

The lowest values were recorded in a 3.75% NaOCl solution at a 45°C temperature. Low results at 45°C could be attributed to the fact that the activity of NaOCl increases [51], and it penetrates more easily through the seed coat [52]. The highest results in all characteristics examined were obtained from a 3.75% NaOCl solution at 35°C. Seed germination and seedling growth percentages decreased to 67.76 and 53.53% at 45°C, while they were 88.74 and 77.74% in a 3.75% NaOCl solution at 35°C. Seedling height and root length were 6.77 and 9.26 cm in a 3.75% NaOCl solution at 35°C temperature (**Table 5** and **Figure 4**). These findings were parallel to those of Hsiao and Hans [53], Hsiao and Quick [54], and Yildiz and Er [42] who reported that disinfectants at high concentrations and high temperatures affected seed germination and seedling growth negatively.

The highest seedling fresh and dry weights and tissue water content were recorded when seeds were treated with a 3.75% NaOCl solution at 35°C for 15 min (**Table 5**). The fresh weight

Dis. temp (°C)	Germination (%)	Seedling growth[1] (%)	Seedling height (cm)	Root length (cm)	Seedling		Chlorophyll contents (μg chlorophyll/g fresh tissue)		
					Fresh weight (g)	Dry weight (g)	Chl. a	Chl. b	Total Chl.
25	69.17 b	53.05 b	3.90 b	6.20 b	0.218 c	0.037 b	1297.89 b	561.28 ab	1020.81 ab
35	88.74 a	77.74 a	6.77 a	9.26 a	0.370 a	0.043 a	1546.14 a	760.61 a	1296.42 a
45	67.76 b	53.53 b	4.87 b	7.11 b	0.323 b	0.039 b	1125.98 b	504.52 b	900.81 b

Values in a column followed by different letters are significantly different at the 0.01 level in germination percentage, root length, seedling fresh, and dry weights and chlorophyll a content, while significantly different at the 0.05 level in seedling growth, seedling height, chlorophyll b, and total chlorophyll contents.

[1]Seedling growth means seedlings developed out of the total germinated seeds.

Table 5. The effects of a 3.75% NaOCl solution at different temperatures on *in vitro* seed germination, seedling growth, seedling height, root length, seedling fresh and dry weights, chlorophyll a, chlorophyll b, and total chlorophyll contents in the leaves of *L. chrysanthus* Boiss. seedlings.

Figure 4. *In vitro* seedling growth from *L. chrysanthus* Boiss. seeds treated with a 3.75% NaOCl solution at temperatures of (a) 25°C, (b) 35°C and (c) 45°C for 15 min.

increase could be attributed to cell enlargement [55]. The increase in dry weight was due to cell division and new material synthesis [56]. Higher results in seedlings grown were from seeds treated with 3.75% NaOCl solution at 35°C for 15 min and could be caused by higher tissue water content as reported that *in vitro* explant growth and plantlet establishment have been affected significantly by tissue water content [57].

In the study, the highest chlorophyll a, chlorophyll b, and total chlorophyll contents were seen with a 3.75% NaOCl solution at 35°C temperature (**Table 5**).

2.4. Gamma radiation

Gamma rays have an ionizing radiation effect on plant growth and development by inducing cytological, biochemical, physiological, and morphological changes in cells and tissues by producing free radicals in cells [58–60]. Higher doses of gamma radiation have been reported to be inhibitory [61, 62], whereas lower doses are stimulatory. Low doses of gamma rays have been reported to increase seed germination and plant growth, cell proliferation, germination, cell growth, enzyme activity, stress resistance, and crop yields [63–69]. Stimulation of plant growth at low gamma radiation doses is known as hormesis [70]. The hormesis phenomenon is described as a stimulating effect on any factor in the growth of an organism [71].

In the study conducted by Beyaz et al. [72], the effects of gamma radiation on overcoming dormancy in seeds of *L. chrysanthus* Boiss. under *in vitro* conditions were examined. In the study, *L. chrysanthus* Boiss., seeds of an ecotype "Diyarbakir" were first irradiated with different

doses (0-control, 50, 100, 150, 200, and 250 Gy) of ^{60}Co γ rays at 0.8 kGy h^{-1} at the Sarayköy Nuclear Research and Training Center of the Turkish Atomic Energy Authority at Sarayköy, Ankara. Seeds were surface-sterilized with a 3.75% NaOCl solution at 35°C temperature for 15 min. as reported by Telci et al. [49]. The seeds were then placed between filter papers in Petri dishes each containing 6 ml of distilled water. The Petri dishes were incubated for 7 days at 15±1°C in the dark for seed germination. The pre-germinated seeds were then transferred to Magenta vessels (12 × 12 cm) containing a basal medium of Murashige and Skoog's (MS) mineral salts and vitamins [50], 3% sucrose, and 0.7% agar 14 days after the study initiation. The pH of the medium was adjusted to 5.8 prior to autoclaving. Then, all cultures were transferred to a growth chamber for incubation at 25±1°C under cool white fluorescent light (27 μmol m^{-2} s^{-1}) with a 16-h light/8-h dark photoperiod. The seed germination percentage was determined at the end of the 7th day, while seedling growth percentage, seedling height, and root length were recorded 14 days after culture initiation [20]. All statistical analyses were performed using SPSS for Windows software. Three replicates were tested, and there were 30 seeds per replication. All experiments were repeated twice. One-way Analysis of Variance (ANOVA) was used to test the effect of different doses of gamma radiation on seed germination and seedling growth. Duncan's multiple range test was used for comparison of the means. Data given in percentages were subjected to arcsine ($\sqrt{X}$) transformation before statistical analysis [19].

The stimulatory effect of low gamma doses was observed in the study at a radiation dose of 150 Gy. The best results in seed germination percentage at the end of the 7th day and in seedling growth percentage, seedling height, and root length at the end of the 14th day were observed at a dose of 150 Gy of gamma radiation (**Table 6** and **Figure 5**). In doses over 150 Gy, the inhibitory effect of gamma radiation was seen. Seed germination percentage was 62.4% at a gamma radiation dose of 150 Gy, while it was 14.3% for a gamma radiation dose of 250 Gy (**Table 6**). The highest seedling growth percentage, seedling height, and root length were again recorded for a 150 Gy gamma radiation dose as 75.7%, 1.2 cm, and 2.9 cm, respectively.

Gamma doses (Gy)	Day 7	Day 14		
	Seed germination (%)	Seedling growth (%)[1]	Seedling height (cm)	Root length (cm)
0	35.0 c	40.0 b	0.5 d	1.8 cd
50	26.7 c	45.0 b	0.7 c	2.1 bc
100	48.6 b	74.6 a	0.9 b	2.4 b
150	62.4 a	75.7 a	1.2 a	2.9 a
200	35.4 c	68.8 a	0.6 cd	1.6 d
250	14.3 d	37.5 b	0.5 cd	1.3 e

Values in a column followed by the different letters are significantly different at the 0.01 level.
[1]Seedling growth percentage means seedlings developed out of the total seed number.

Table 6. Effects of different gamma doses on *in vitro* seed germination, seedling growth, seedling height, and root length in *L. chrysanthus* Boiss.

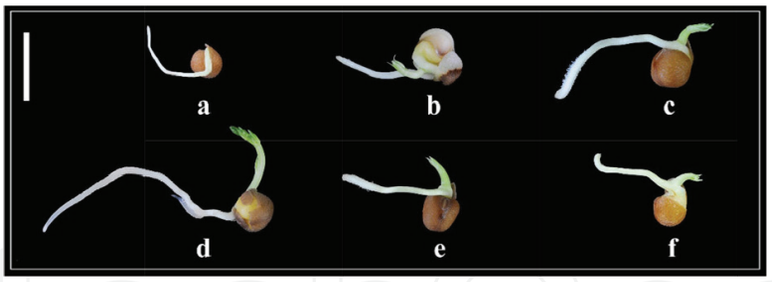

Figure 5. *In vitro* seed germination and seedling growth in *L. chrysanthus* Boiss. seeds irradiated with (a) 0, (b) 50, (c) 100, (d) 150, (e) 200, and (f) 250 Gy gamma doses (white vertical bar = 1 cm).

The root length obtained from seeds irradiated with 150 Gy of gamma radiation was significantly increased by 63.2% from 1.8 cm in the control treatment (0 Gy) to 2.9 cm, which has been confirmed by Melki and Marouani [73].

3. Conclusion

Dormancy is a state of lack of germination in seeds/tubers even though the required conditions (temperature, humidity, oxygen, and light) have been provided and is based on hard seed coat impermeability or a lack of supply and activity of the enzymes necessary for germination. Dormancy is an important factor limiting production in many field crops. Several physical and chemical pretreatments are applied to organic material (seeds/tubers) for overcoming dormancy. Physical and internal dormancy can be found together in some plant species and this makes it difficult to provide high-frequency healthy seedling growth, whereas the sprouting of seeds/tubers sown and the formation of healthy seedlings is a prerequisite for plant production. This chapter focuses on four different methods that have not been reported elsewhere for overcoming dormancy. We think that these newly described methods will help growers and researchers to overcome dormancy problem in plant production.

Author details

Mustafa Yildiz[1]*, Ramazan Beyaz[2], Mehtap Gursoy[3], Murat Aycan[4], Yusuf Koc[4] and Mustafa Kayan[4]

*Address all correspondence to: myildiz@ankara.edu.tr

1 Department of Field Crops, Faculty of Agriculture, Ankara University, Ankara, Turkey

2 Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ahi Evran University, Kırsehir, Turkey

3 Guzelyurt Vocational School, Aksaray University, Aksaray, Turkey

4 Department of Field Crops, Graduate School of Natural and Applied Sciences, Ankara University, Ankara, Turkey

References

[1] Bonner FT. Glossary of Seed Germination Terms for Tree Seed Workers. Gen. Tech. Rep. SO-49. New Orleans: USDA Forest Service, Southern Forest Experiment Station; 1984. p. 4

[2] Baskin CC, Baskin JM. Germination ecology of seeds with nondeep physiological dormancy. In: Baskin CC, Baskin JM, editors. Seeds: Ecology, Biography, and Evolution of Dormancy and Germination. San Diego, California: Academic Press; 1998. pp. 57-64

[3] Emery DE. Seed Propagation of Native California Plants. Santa Barbara, CA: Santa Barbara Botanic Garden; 1987

[4] Enu-Kwesi L, Dumbroff EB. Changes in abscisic acid in the embryo and covering structures of *Acer saccharum* during stratification. Zeitschrift für Pflanzenphysiologie. 1978;**86**:371-377

[5] Tillberg E, Pinfield NJ. Changes in abscisic acid levels during, after-ripening and germination of *Acer platanoides* L. seeds. New Phytologist. 1982;**92**:167-172

[6] Webb DP, Wareing PF. Seed dormancy in Acer: Endogenous germination inhibitors and dormancy in *Acer pseudoplatanus* L. Planta. 1972;**104**:115-125

[7] Williams PM, Ross JD, Bradbeer JW. Studies in seed dormancy: 4. The abscisic acid content of the seeds and fruits of *Corylus avellana* L. Planta. 1973;**110**:303-310

[8] Sondheimer E, Tzou DS, Galson EC. Abscisic acid levels and seed dormancy. Plant Physiology. 1968;**43**:1443-1447

[9] Singh Z, Browning G. The role of ABA in the control of apple seed dormancy re-appraised by combined gas chromatography-mass spectrometry. Journal of Experimental Botany. 1991;**42**:269-275

[10] Szczotka Z. Changes in the activity of indole acetic acid and abscisic acid in the embryo axes and cotyledons of *Quercus borealis* Michx. and *Quercus robur* L. acorns stored under controlled conditions. Arboretum Kornickie. 1977;**22**:257-273

[11] Florez M, Carbonell MV, Martinez E. Exposure of maize seeds to stationary magnetic fields: Effects on germination and early growth. Environmental and Experimental Botany. 2007;**59**:68-75

[12] Soltani F, Kashi A, Arghavani M. Effect of magnetic field on *Asparagus officinalis* L. seed germination and seedling growth. Seed Science and Technology. 2006;**34**:349-353

[13] Carbonell MV, Martinez E, Florez M, Maqueda R, Lopez-Pintor A, Amaya JM. Magnetic field treatments improve germination and seedling growth in *Festuca arundinacea* Schreb. and *Lolium perenne* L. Seed Science and Technology. 2008;**36**:31-37

[14] Podlesny J, Misiak L. Podlesna a concentration of free radicals in pea seeds afterpresowing treatment with magnetic field. International Agrophysics. 2004;**18**:261-267

[15] Martinez E, Carbonell MV, Amaya JM. A static magnetic field of 125 mT stimulates the initial growth stages of barley (*Hordenumvulgare L.*). Electro and Magnetobiology. 2000;**19**(3):271-277

[16] Florez M, Carbonell MV, Martinez E. Early sprouting and first stages of growth of rice seeds exposed to a magnetic field. Electro and Magnetobioloy. 2004;**23**(2):167-176

[17] Mano J, Nakahara T, Torii Y, Hirose H, Miyakoshi J, Takimoto K. Seed deterioration due to high humidity at high temperature is suppressed by extremely low frequency magnetic fields. Seed Science and Technology. 2006;**34**:189-192

[18] De Souza A, Garcia D, Sueiro L, Gilart F, Porras E, Licea L. Pre-sowing magnetic treatments of tomato seeds increase the growth and yield of plants. Bioelectromagnetics. 2006;**27**:247-257

[19] Snedecor GW, Cochran WG. Statistical Methods. Iowa, USA: The Iowa State University Press; 1967

[20] ISTA. International Rules for Seed Testing. Basserdorf: International Seed Testing Association; 2003

[21] Curtis OF, Shetty K. Growth medium effects on vitrification, total phenolics, chlorophyll, and water content of *in vitro* propagated oregano clones. Acta Horticulturae. 1996;**426**:498-503

[22] Emerson R. Chlorophyll content and the rate of photosynthesis. Proceedings of the National Academy of Sciences of the United States of America. 1929;**15**(3):281-284

[23] Rensburg LV, Kruger GHJ. Evaluation of components of oxidative stres metabolism for use in selection of drought tolerant cultivars of *Nicotiana tabacum* L. Journal of Plant Physiology. 1994;**143**:730-737

[24] Kyparissis A, Petropoulou Y, Manetas Y. Summer survival of leaves in a soft-leaved shrub (*Phlomis fruticosa* L., Labiatae) under Mediterranean field conditions: Avoidance of photoinhibitory damage through decreased chlorophyll contents. Journal of Experimental Botany. 1995;**46**:1825-1831

[25] Jagtap V, Bhargava S, Sterb P, Feierabend J. Comparative effect of water, heat and light stresses on photosynthetic reactions in *Sorghum bicolor* (L.). Moench. Journal of Experimental Botany. 1988;**49**:1715-1721

[26] Pal RN, Laloraya MM. Effect of calcium levels on chlorophyll synthesis in peanut and linseed plants. Biochemie and Physiologie der Pflanezen. 1972;**163**:443-449

[27] Wright GC, Nageswara RRC, Farquhar GD. Water use efficiency and carbon isotope discrimination in peanut under water deficit conditions. Crop Science. 1994;**34**:92-97

[28] Nageswara RRC, Talwar HS, Wright GC. Rapid assessment of specific leaf area and leaf nitrogen in peanut (*Arachis hypogaea* L.) using chlorophyll meter. Journal of Agronomy and Crop Science. 2001;**189**:175-182

[29] Sezik E. Research on the Turkish medicinal plant *Ecballium elaterium*. Chemistry of Natural Compounds. 1997;**33**:541-542

[30] Özcan SF, Yıldız M, Ahmed HAA, Aasim M. Effects of squirting cucumber (*Ecballium elaterium*) fruit juice on *Agrobacterium tumefaciens*-mediated transformation of plants. Turkish Journal of Biology. 2015;**39**:790-799

[31] Memişoğlu M, Toker G. Biological activities and traditional usage of *Ecballium elaterium* (L.) A. Rich. FABAD Journal of Pharmaceutical Science. 2002;**27**:157-164

[32] Yildiz M, Kayan M, Aycan M. The effect of squirting cucumber (*Ecballium elaterium* (L.) A. Rich.) fruit juice on *in vitro* shoot regeneration in durum wheat (*Triticum durum* Desf.). 18. National Biotechnology Congress, 19-18 December, Konya, Turkey; 2015

[33] Darcin S, Aycan M, Kayan M, Köm D, Taher M, Yildiz M. The effect of squirting cucumber (*Ecballium elaterium* (L.) A. Rich.) fruit juice on seed germination and seedling growth in rapeseed (*Brassica napus* L.). National Botanic Plant Science Congress, 25-28 October, Antalya, Turkey; 2014

[34] Smith CR. Mycobactericidal agents. In: Lawrence CA, Block SS, editors. Disinfection, Sterilization, and Preservation. Philadelphia: Lea and Febiger; 1968. pp. 504-514

[35] Spaulding EH. Chemical disinfection of medical and surgical materials. In: Lawrence CA, Block SS, editors. Disinfection, Sterilization, and Preservation. Philadelphia: Lea and Febiger; 1968. pp. 517-531

[36] Bietz JA, Sandford PA. Reaction of sodium hypochlorite with amines and amides: Automation of the method. Analytical Biochemistry. 1971;**44**:122-133

[37] Kantouch A, Ardel-Fattah SH. Action of sodium hypochlorite on a-amino acids. Chemicke Zvesti. 1971;**25**:222-230

[38] Hayatsu H, Pan S, Ukita T. Reaction of sodium hypochlorite with nucleic acids and their constituents. Chemical & Pharmaceutical Bulletin. 1971;**19**:2189-2192

[39] Sandford PA, Nafziger AJ, Jeanes A. Reaction of sodium hypochlorite with amines and amides: A new method for quantitating amino sugars in manomeric form. Analytical Biochemistry. 1971;**42**:422-436

[40] Sandford PA, Nafziger AJ, Jeanes A. Reactions of sodium hypochlorite with amines and amides: A new method for quantitating polysaccharides containing hexosamines. Analytical Biochemistry. 1971;**44**:111-121

[41] Allan A. Plant cell culture. In: Stafford A, Warren G, editors. Plant Cell and Tissue Culture. Milton Keynes: Open University Press; 1991. pp. 1-24

[42] Yildiz M, Er C. The effect of sodium hypochlorite solutions on *in vitro* seedling growth and shoot regeneration of flax (*Linum usitatissimum*). Naturwissenschaften. 2002;**89**:259-261

[43] Igbinnosa I, Okonkowo SNC. Stimulation of germination of seeds of cowpea witchweed (*Striga gesneriodes*) by sodium hypochlorite and some growth regulators. Weed Science. 1992;**40**:25-28

[44] Bewley JD, Seeds BM. Physiology of Development and Germination. New York: Plenum Press; 1994. p. 445

[45] Kayan N, Yildiz M, Ozgen M. Breaking dormancy and seedling growth in lentil (*Lens Culinaris* Medik.) under in vitro conditions. XIV. National Biotechnology Congress, Eskişehir, Turkey; 2005. pp. 348-351

[46] Ogawa K, Iwabuchi M. A mechanism for promoting the germination of *Zinnia elegans* by hydrogen peroxide. Plant & Cell Physiology. 2001;**42**:286-291

[47] Böhm J. Terrestrial orchid seed handling: Growing orchids of temperate climates from seed. In: Seed Pretreatment Protocol. Homnurg-Saar, Germany: Institute of Physiology, Medical Faculty, University of Saarland; 2003

[48] Kanecko Y, Morohashi Y. The effect of sodium hypochlorite treatment on the development of α-amylase activity in mung bean cotyledons. Plant Science. 2003;**164**:287-292

[49] Telci C, Yıldız M, Pelit S, Önol B, Erkılıç EG, Kendir H. The effect of surface-disinfection process on dormancy-breaking, seed germination, and seedling growth of *Lathyrus chrysanthus* Boiss. under *in vitro* conditions. Propagation of Ornamental Plants. 2011;**11**:10-16

[50] Murashige T, Skoog F. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiologia Plantarum. 1962;**15**:431-497

[51] Racoppi F. Domestic bleaches containing sodium hypochlorite. Procter and Gamble. Rome: Italia SPA Product Development Department; 1990

[52] Schull W. Temperature and rate of moisture intake in seeds. Botanical Gazette. 1920;**69**:361

[53] Hsiao AI, Hans JA. Application of sodium hypochlorite seed viability test to wild oat populations with different dormancy characteristics. Canadian Journal of Plant Science. 1981;**61**:115-122

[54] Hsiao AI, Quick AW. Action of sodium hypochlorite and hydrogene peroxide on seed dormancy and germination of wild oats, *Avena fatua* L. Weed Research. 1984;**24**:411-419

[55] Dale JE. The control of leaf expansion. Annual Review of Plant Physiology and Plant Molecular Biology. 1988;**39**:267-295

[56] Sunderland N. Cell division and expansion in the growth of the leaf. Journal of Experimental Botany. 1960;**11**:68-80

[57] Yildiz M, Özgen M. The effect of a submersion pretreatment on in vitro explant growth and shoot regeneration from hypocotyls of flax (*Linum usitatissimum*). Plant Cell, Tissue and Organ Culture. 2004;**77**:111-115

[58] Gunckel JE, Sparrow AH. In: Ruhland W, editor. Encycl. Plant Physiology, in Ionizing Radiation: Biochemical, Physiological and Morphological Aspects of their Effects on Plants. Berlin: Springer-Verlag; 1961. p. 555-611

[59] Kim JH, Chung BY, Kim JS, Wi SG. Effects of in Planta gamma-irradiation on growth, photosynthesis, and antioxidative capacity of red pepper (*Capsicum annuum* L.) plants. Journal of Plant Biology. 2005;**48**:47-56

[60] Wi SG, Chung BY, Kim JH, Baek MH, Yang DH, Lee JW, Kim JS. Ultrastructural changes of cell organelles in Arabidopsis stem after gamma irradiation. Journal of Plant Biology. 2005;**48**:195-200

[61] Radhadevi DS, Nayar NK. Gamma rays induced fruit character variations in Nendran, a varieties of banana (*Musa paradasiaca* L.). Geobios. 1996;**23**:88-93

[62] Kumari R, Singh Y. Effect of gamma rays and EMS on seed germination and plant survival of *Pisum sativum* L. and *Lens culinaris* medic. Neo Botanica. 1996;**4**:25-29

[63] Chaomei Z, Yanlin M. Irradiation induced changes in enzymes of wheat during seed germination and seedling growth. Acta Agriculturae Nucleatae Sinica. 1993;**7**:93-97

[64] Maherchandani N. Effects of gamma radiation the dormant seeds of *Avena fatua*. Radiation Botany. 1975;**15**:439-443

[65] Kuzin AM, Vagabova ME, Vilenchik MM, Gogvadze VG. Stimulation of plant growth by exposure to low-level gamma radiation and magnetic field, and their possible mechanism of action. Environmental and Experimental Botany. 1986;**26**:163-167

[66] Charbaji T, Nabulsi I. Effect of low doses of gamma irradiation on in vitro growth of grapevine. Plant Cell, Tissue and Organ Culture. 1999;**57**:129-132

[67] Baek MH, Kim JH, Chung BY, Kim JS, Lee IS. Alleviation of salt stress by low dose g-irradiation in rice. Biologia Plantarum. 2005;**49**(2):273-276

[68] Chakravarty B, Sen S. Enhancement of regeneration potential and variability by g-irradiation in cultured cells of *Scilla indica*. Biologia Plantarum. 2001;**44**:189-193

[69] Kim JS, Lee YK, Park HS, Back MH, Kim DH. Influence of low dose gamma radiation on the growth of maize (*Zea mays* L.) varieties. Korean Journal of Environmental Agriculture. 2000;**19**:328-331

[70] Sheppard SC, Evenden WG. Factors controlling the response of field crops to very low doses of gamma irradiation of the seed. Canadian Journal of Plant Science. 1986;**66**:431-441

[71] Szarek S. Use of concept of hormesis phenomenon to explain the law of disminishing returns part II. Electronic Journal of Polish Agricultural Universities. 2005;**8**(4):61

[72] Beyaz R, Telci Kahramanogullari C, Yildiz C, Darcin ES, Yildiz M. The effect of gamma radiation on seed germination and seedling growth of *Lathyrus chrysanthus* Boiss. under *in vitro* conditions. Journal of Environmental Radioactivity. 2016;**162-163**:1-5

[73] Melki M, Marouani A. Effects of gamma rays irradiation on seed germination and growth of hard wheat. Environmental Chemistry Letters. 2010;**8**:307-310

IntechOpen