The Contribution of Muslim Scientists in Botanical Science: Studies on the Using of Gamma Rays for Ginger Plants (*Zingiber Officinale*)

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Abstract: The effect of different exposure durations of gamma ray was used to determine the growth of ginger (*Zingiber officinale*). The exposure durations were 30, 60, 90, 120 and 150 seconds with dose rate of 0.1613 Gy per second. The research was carried out in a Greenhouse at Institute of Biological Sciences, University Malaya and the parameters used were germination rate, survival rate and other morphological traits such as seedlings height, number of leaves, leaves length, leaves width and number of roots. It was observed that the average germination rate was decreased with each increase in gamma ray exposure duration. The survival rate also showed decrement with increment of exposure duration. In addition, the growth of ginger was reduced with the increment of exposure duration. However, there were some abnormalities in ginger caused by gamma ray. The abnormalities were the formation of dwarf ginger plant, the ginger plant with crooked stems and corrugated leaves. In conclusion, all the parameters were decreased with the increment in exposure duration of gamma ray.

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1. Introduction

Ginger in scientific terms is known as *Zingiber Officinale.* It is the vegetative plant that comes from the family of Zingiberaceae (Artemas, 1911). Zingiberaceae is the largest family in the Zingiberales that include approximately 50 genera and more than 1000 species. Plants in this family are commonly used as ornamental plants, spices, and also for medicinal purposes. Throughout the world, ginger root is commonly used as spice or flavor enhancer in food. In India, ginger is usually fried and eaten as it is or it is included as a spice in curries. In Indonesia, ginger roasted to cozy up or add flavor to fish and meats and made tea. In Chinese society, ginger is usually boiled or fried, for consumption. Similarly, in Japan, ginger is used for dishes such as in sushi. Ibn Qayyim (2010) mentioned that ginger will work as a laxative toxic when add some sugar in some hot water and will remove the toxic in human body. Ginger gives some good effects on humans in terms of oxidation, inflammation, cancer development, hyperlipedma, remedy. Approximately 40 antioxidant compounds have been found in ginger that some of them are heat-proof (Linda et al., 2012). Anti-inflammatory properties of some ginger compounds are recognized since a long time ago and are well-proved in vitro (Linda et al., 2012). Based on the Islamic view, agriculture is an important activity because food can be produced through it. There are many verses in the Quran that states about agriculture and crops. For example in Surah Al-An'am, Allah SWT says:

"It is He Who sends down water (rain) from the sky, and with it We bring forth vegetation of all kinds, and out of it We bring forth green stalks, from which We bring forth thick clustered grain. And out of the date palm and its spathe come forth clusters of dates hanging low and near, and gardens of grapes, olives and pomegranates, each similar (in kind) yet different (in variety and taste). Look at their fruits when they begin to bear, and the ripeness thereof. Verily! In these things there are signs for people who believe."(Al-An'am, 6: 99)

In addition, Quran also states that the nature of crops is economical including ginger. This means that plants is cash crops cultivated by man mentioned more in the Quran than other plants. This was stated by Allah SWT in Surah Yunus verse 24 which said:

"Verily the likeness of (this) worldly life is as the wáter (rain) which We send down from the sky, so by it arises the intermingled produce of the earth of which men and cattle eat until when the earth is clad with its adornments and is beautified, and its people

think that they have all the powers of disposal over it, Our Command reaches it by night or by day and We make it like a clean-harvest, as if it had not flourished yesterday! Thus do We explain the Ayat (proofs, evidences, verses, lessons, signs, revelations, laws, etc.) in detail for the people who reflect."(Yunus, 10:24)

Allah Almighty has created an exotic herb ginger a variety of powers. Ginger is also mentioned by Allah SWT as one drink for the heaven. This is explained by Allah SWT who has spoken through the verse of Surat al-Insan 17 which means:

"And they will be given to drink there a cup (of wine) mixed with Zanjabil (ginger)." (Al-Insan, 76:17)

In addition, there is a Hadith of Prophet Muhammad narrated by Abu Sa'eed Al-Khudri RA where it is stated that:

"Byzantine king gave a vat containing ginger to the Prophet Muhammad as a gift and he gives everyone a part of it. I also got ones of piece" (Ibn Qayyim, 2010).

Based on the verses of Allah SWT in Quran and Prophet's Hadith clearly proved that ginger is a plant that has numerous benefits for human either as a source of food, drinks and also medicine.

Gamma rays are often used on plants in developing varieties that are agriculturally and economically important and have high productivity potential (Jain et al., 1998). Gamma rays are also very important in mutation breeding and in *in vitro* mutagenesis in order to develop required features of plants and increase the genetic variability. Gamma irradiation can be useful for the alteration of one or a few physiological characters (Lapins, 1983). Mutagenesis by means of gamma rays has played an important role in the producing new mutants with improved properties which can produce higher amounts of commercially important metabolites (Sanada, 1986). Gamma rays with different irradiation levels can damage or modify important components of plant cells and even have been reported to affect differentially the morphology, anatomy, biochemistry and physiology of plants (Wi et al., 2007; Kovacs and Keresztes, 2002). Irradiation-induced mutation breeding is effective in improving sweet potato characters such as yield, starch and soluble sugar content, carotenoids content of storage roots and disease resistance (Kukimura, 1986; Wang et al., 2007). Irradiation has also been successfully used for mutation breeding in various crops and ornamental plants (Song and Kang, 2003) and has proven encouraging the expression of recessive genes and producing new genetic variations (Song and Kang, 2003; Schum, 2003). Shin et al. (2011) reported sweet potato mutants by irradiation produced high yield and high starch content. Biochemical studies on *O. stamineus* revealed that the total soluble protein and total chlorophyll content decreased notably as the gamma dosage increases (Kiong et al., 2008). They also observed severe increase in specific activity of peroxidase especially in plantlets irradiated at high gamma ray dosages. The present study was conducted to investigate the effect of gamma irradiation with different exposure times. The objective of this research was to study the effect of different exposure of gamma rays on the growth of ginger plant.

2. Materials and Methods

The rhizomes of ginger which looked yellowish brown and quite dark were used. All surveyed ginger plants were grown in the greenhouse at Centre for Fundation Studies in Science, University of Malaya and greenhouses at Institute of Biological Sciences, University of Malaya. Gamma irradiation was conducted by Gammacell 220, Department of Physics, University of Malaya. Old ginger rhizomes were treated with radiation rays based on different exposure periods of 30, 60, 90, 120, and 150 seconds while the dose rate was fixed at the rate of 0.1613 Gy per second. Gamma ray radiation was obtained from Gammacell 220 (Figure 1). Varieties were grown in a greenhouse using polybags measuring about 15 × 30 cm. Ginger rhizome irradiated and kept in a black plastic bag for 2 days to ensure that all gamma cell particles are absorbed by the cells of the ginger. Soil used was a mix of compost soil patch. Each polybag was planted with ginger rhizomes ranged from 5.5cm to 11.5cm long. The parameters used were bud growth rate, the number of days for the first shoots, the first leaf and the second leaf to grow, leaf size (length and width), number of leaves per plant, plant height, number of roots, the germination rate and survival rate. Observations for each parameter were monitored every week and morphological abnormalities were also observed (if any).

3. Results

In control plants, it was found that all the buds produced first shoots on the 4th day after cultivation while the first root production was after 6 days. On Day 9, it was found that 3 shoot buds already produced the first leaves, followed by the second leaf on the 12th and forth leaves on the day 15. For the ginger-treated with 30-second exposure period, it was found that all rhizomes produced shoots on the 6th day after planting. On the 8th day, the rhizomes that were exposed to 60 seconds and 90 seconds had issued the first buds. After 10 days of planting, it was observed that all the gingers treated with gamma rays already produced the first buds. After 2 weeks of planting, it was perceived that a ginger rhizome treated with 60-second exposure time produced roots. Roots were only produced after 3 weeks of planting in all exposure periods (30, 60, 90, 120, 150 seconds). On the 20th day of cultivation, two shoots from the ginger treated with 30-second exposure period produced the first leaf, while one shoot from among the ginger treated with 60-second exposure period gave the first leaf. After 4 weeks of planting, the budding shoots of ginger (the exposure to gamma rays 30, 60, 90, 120 and 150 seconds) produced a leaf. From the data taken, the average germination rate was decreased with increasing exposure time to gamma rays (Figure 2). In Control group, the average germination rate was 43.68% (Table 1), and for the exposure time of 30 seconds, the average rate was 40.35%, for 60 seconds was 32.75%, and for 90 seconds was 25.70% (Table 2). But, for 120 seconds exposure, the average germination rate was increased slightly by 25.92% and for 150 seconds was 24.48% (Table 2).

Table 1. Germination rate for plants under normal condition

Rhizom Height (cm)	Expected Number of Buds	Reality Number of Grow Buds	Germination Rate (%)
11.5	8	4	50.0
12.7	9	4	44.4
10.3	7	3	42.9
9.8	7	3	42.9
11.2	9	4	44.4
10.4	8	3	37.5

Average Germination Rate = 43.68 %

Table 2. Average germination rate ginger treated with different exposure period

Exposure Duration (seconds)	Average Germination Rate (%)
30	40.35
60	32.75
90	25.70
120	25.92
150	24.48
Control	43.68

The survival data was recorded after 3 weeks of planting. While the survival rate for ginger treated with 90 and 120 seconds is 92.3%. Ginger treated with 150 seconds exposure showed the lowest value of survival rate at 91.7%. Similarly after 4 weeks of planting, it was found that survival rate for all ginger plant was decreased. Survival rate for the control was 95.24% while the 30 second exposure period was 94.74%, 92.30% for 60 seconds, while 90 seconds and 120 seconds showed the same value survival rate of 84.62%. Finally, ginger trees treated with gamma rays at 150 seconds exposure period showed the lowest value of survival rate at 83.33%. The number of dead trees was one for control ginger plant and also one for ginger plant treated with 30-second and 60 seconds exposure period. While for ginger treated with 90, 120 and 150 seconds of exposure period, the number of dead trees per dose were 2 sticks. After 5 weeks of planting, it was found that survival rate for all treated ginger plant was decreased. Ginger control showed that the survival rate was 95.24%, while the 30 seconds was 94.74%, 60 seconds was 92.30%, 90 seconds was 84.62% and 120 seconds was 76.92% but the value of survival rate in 150 was 83.33%. The number of dead trees was one for ginger plant control and also one for ginger plant treated with 30-second and 60 seconds exposure period. While for ginger treated with 90 seconds exposure period the number of dead trees per dose was 2 stick. For 120 and 150 seconds, the number of dead plant per dose was 3 sticks. While ginger plant treated with the 120 and 150 seconds exposure showed the highest number of plant deaths.

Table 3. The survival rate of Ginger 3 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Number of Shoots Sprouting Buds	Number of Seedling Life	Survival Rate (%)
0	21	21	100.0
30	19	19	100.0
60	13	13	100.0
90	13	12	92.3
120	13	12	92.3
150	12	11	91.7

Table 4. The survival rate of Ginger 4 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Number of Shoots Sprouting Buds	Number of Seedling Life	Survival Rate (%)
0	21	20	95.24
30	19	18	94.74
60	13	12	92.30
90	13	11	84.62
120	13	11	84.62
150	12	10	83.33

Table 5. The survival rate of Ginger 5 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Number of Shoots Sprouting Buds	Number of Seedling Life	Survival Rate (%)
0	21	20	95.24
30	19	18	94.74
60	13	12	92.30
90	13	11	84.62
120	13	10	76.92
150	12	9	75.00

After 2 weeks of planting, it was found that the average height for ginger plant was decreased for each increasing in the exposure of gamma rays except between 120 seconds and 150 seconds of exposure the ginger. Ginger control showed the highest average height (2.10 cm), followed by ginger treated with 30 seconds that (1.04 cm). At the duration of exposure of 60 seconds, height of ginger plant was decreased from 0.82cm to 0.27cm for ginger tree treated with 90 seconds. While ginger treated with 120 seconds and 150 seconds, it was found that the average height of ginger were same at 0.16cm (Table 6). In other situation after 3 weeks of planting, the ginger plant showed that average height value was decreased for each additional exposure period of gamma rays. It was showed that ginger growth was decreased with the increasing of exposure duration where ginger control indicated the average height was 11.20 cm while ginger treated with exposure period 30, 60, 90, 120 and 150 seconds was decreased tremendously. In addition, after 3 weeks of cultivation, there were still seedling yet to grow roots and leaves. For exposure periof of 150 seconds, all shoots did not produce any roots and leaf, as the growth rate was very low with an average shoot height of 0.27 cm (Table 7). After 4 weeks of planting, all ginger trees had produced each leaves and roots with at least two veins of a leaf and root, except 2 of ginger treated with 150 seconds exposure period that did not produce any leaves yet. In terms of growth, ginger treated with 120 and 150 seconds exposure period showed very slow growth compared to ginger control and ginger treated with 30, 60 and 90 seconds exposure duration. Based on the plotted graph, the average ginger height was decreased with the increase in gamma rays exposure period. Control ginger showed the highest average height of 24.10 cm followed by 30 second exposure period which was 21.21cm (Table 8). Ginger treated with exposure period of 60, 90 and 120 second, respectively showed the average height of 13.62 cm, 11cm and 7.65cm. Ginger treated with 150 seconds exposure period showed the lowest average height of 5.25 cm. After 4 weeks of planting, it was found that no ginger plant showed abnormalities in terms of morphology from every exposure period (Table 8). After 5 weeks of planting, all ginger had leaves and roots with at least one leaf and three roots. In terms of growth, ginger treated with 120 and 150 seconds exposure showing very slow growth compared with ginger control and treated with 30, 60 and 90 seconds exposure. Control ginger showed the heighest rate of 45.13cm followed by 42.34cm for exposure period of 30 seconds. Ginger treated with the exposure duration of 60, 90 and 120 seconds, showed the average height of 22.65cm, 13.75cm and 11.14cm respectively. Ginger treated with 150 seconds exposure period showed the lowest average height of 10.08cm (Table 9). At this stage, it appeared that some ginger already showed abnormalities in morphology especially for the ginger treated with 30 seconds and 60 seconds exposure periods. For example, rhizomes skin was flaking and some leaves were wrinkled. While ginger treated with the 120 and 150 seconds of exposure period, the rhizomes skin was flaked, leaves was wrinkled, crumpled and also the bent was shaft. Furthermore, that ginger also looked dwarf (Table 10).

Table 6. Morphological traits of Ginger 2 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Plant Height (cm)	Number of Leaves	Leaf Length (cm)	Leaf width (cm)	Number of Roots
Control	2.10	-	-	-	-
30	1.04	-	-	-	-
60	0.82	-	-	-	-
90	0.27	-	-	-	-
120	0.16	-	-	-	-
150	0.16	-	-	-	-

Table 7. Morphological traits of Ginger 3 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Plant Height (cm)	Number of Leaves	Leaf Length (cm)	Leaf width (cm)	Number of Roots
Control	11.2	3	4.5	0.9	3
30	8.31	3	2.8	0.3	3
60	6.87	2	3.4	0.8	3
90	2.55	2	2.5	1.0	3
120	0.37	-	-	-	-
150	0.27	-	-	-	-

Table 8. Morphological traits of Ginger 4 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Plant Height (cm)	Number of Leaves	Leaf Length (cm)	Leaf width (cm)	Number of Roots
Control	24.10	3	9.98	1.84	4
30	21.21	3	11.62	1.98	5
60	13.62	2	6.84	0.98	3
90	11.00	2	3.9	0.68	3
120	7.65	2	1.86	0.54	2
150	5.25	1	0.7	0.46	2

Table 9. Morphological traits of Ginger 4 weeks after cultivation

Gamma Ray Exposure Period (Seconds)	Plant Height (cm)	Number of Leaves	Leaf Length (cm)	Leaf width (cm)	Number of Roots
Control	45.13	5	18.5	2.83	5
30	42.34	5	17.3	2.9	5
60	22.65	4	13.6	2.0	4
90	13.75	3	7.5	1.0	3
120	11.14	3	5.5	0.8	3
150	10.08	2	3.4	0.4	3

Figure 1. Gammacell 220 used for gamma irradiation

Figure 2. Ginger growth and development

Figure 3. The morphology of Ginger plant at different exposure rates

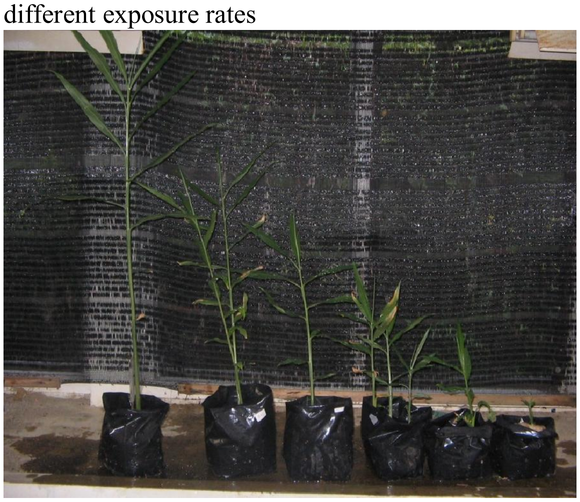

Figure 4. Abnormalities observed in Ginger

Table 10. Observation of abnormalities in Ginger

Gamma Ray Exposure Period (Seconds)	Abnormalities
0	None
30	Rhizomes Skin looked Flake
60	Rhizomes Skin looked Flake
90	Rhizomes Skin Looks Flake, Some Plant Have Wrinkling Leaves.
120	Rhizomes Skin looked Flake, Crumpled and Wrinkling Leaf, The Crooked Stem, looked Dwarf
150	Rhizomes Skin looked Flake, Crumpled and Wrinkling Leaf, The Crooked Stem, looked Dwarf

4. Discussions

According to the results obtained, the germination rate was decreased with increase in gamma rays exposure period. The difference of germination rate may be due to the source of ginger which was derived from different varieties. Also, the difference of germination rate may also be caused by age and level of maturity for different ginger obtained. Mutation can also cause a change in the germination rate. This is because the exposed ginger cells from gamma rays can be retarded. It was found that survival rate value was decreased with the increasing of exposure period of gamma rays. Each dose exposure showed decreases in survival rate value every week until 5 week of planting. In other words, the death of ginger was occured for each doses of gamma ray used. For example, the exposure of 120 and 150 seconds showed the highest mortality rates compared to other exposure dose that showed a low mortality rate. The mortality rate increased with the increasing exposure to gamma rays was probably due to damage of the cells that caused ginger to be dead. Based on theory, in every organism, there is a DNA repair mechanism called "DNA Repair Mechanism". This mechanism acts to repair the DNA when cells are exposed to any radiation source such as ultraviolet rays, X-rays, gamma rays and so on. But, when cells are exposed too long to the radiation sources or radiation source intensity is too high, then the mechanism is no longer able to repair all the severe cell damaged caused by the radiation source. As a result, the exposed cells will die. If they survive, they will form a mutated cell that will produce a mutant. When too many cells die, the ginger is no longer able to live properly and die after several days of planting. According to Konzak (1986), the most useful dose for most breeding objective is the dose that gives survival rate of 50 to 60% for the seedlings that are planted in the field or crop plots. Therefore, it can be said that the doses used in this study was less useful because these studies often influenced by environmental factors, weather, climate, soil, disease and so on. Furthermore, this research was only done in the last 5 weeks of cultivation in the greenhouses. Based on the data, the average ginger height was decreased with the increasing of exposure period of gamma rays. It may be because of mutations that occur in DNA and chromosomes of cells treated ginger. Mutations that occur may result in DNA synthesis at the level of interphase cells which disrupt buds and causes the process of cell division to be interrupted. Thus, the growth of the plant will become less with the increasing doses of mutagen. Konzak (1986) mentioned that the most useful dose for most of the breeding objective are the dose that gives 25% reduction in height of seedlings planted in the greenhouse. But from this research, it was quite difficult to get a timely value proposition because it could be influenced by a variety of errors and factors such as varieties, species, weather, climate and so on. It should be noted that the selection of appropriate doses are necessary because breeders should apply doses that will provide the optimal mutation frequency instead of giving the maximum mutation frequency to achieve a high frequency of beneficial mutations and minimize the occurrence of mutation (Konzak, 1986). The ginger plant treated with the 120 and 150 seconds exposure, just showed the growth of roots and leaves after 4 weeks of planting, compared to control ginger plant after 3 weeks of planting. This may also be caused by mutations that occur in ginger cell. That is after 5 weeks of planting, ginger plant treated with a certain exposure period of growth became stunted and dwarf. For example, ginger plant treated with 30 and 60 seconds exposure period, showed abnormalities such as peeled skins, ginger treated with 90-second exposure period, peeling skin was visible, and some trees hadwrinkled leaves. While the ginger treated with 120 and 150 seconds exposure, the rhizomes skin looked peeling, wrinkled, crumpled leaves and stems were bent. In addition, the ginger plant also looked dwarf. This occurred may be due to mutagen that caused severe damage to stem cells.

5. Conclusions

Gamma rays are a type of mutation that can affect ginger growth, the germination rate of trees, tree keterushidupan rate, and produce mutant plants with certain abnormalities. Different periods of exposure highly influenced germination rate and the rate of tree keterushidupan ginger. When the duration of exposure increased, it decreased the germination and survival rate of tree. When ginger was treated with exposure period of more than 90 seconds, ginger had stunted growth. Exposure to gamma rays can also produce mutants with abnormalities such as dwarf trees, wrinkled leaves, crumpled and bent trunk. For future studies, it is recommended that the duration of exposure can be between 60 to 150 seconds and for doses less than this range will not have any significant changes compared to the control. Doses above this range may cause the tree to be very slow growth and cause many deaths in these plants. Mutation breeding studies using *in vitro* techniques are also very encouraged in which in *in vitro* methods it is posible to increase the specimen to rise the accuracy of the data.

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References

1. Artemas W. *The Grocer's Encyclopedia*. 1911. Retrieved from Wikipedia The Free Encyclopedia: http://en.wikipedia.org/wiki/Ginger
2. Ibn Qayyim AJ. *Healing with the Medicine of the Prophet.* Riyadh: Maktaba Dar-us-Salam, 2010.
3. Jain SM, Ahloowalia BS, Veilleux RE. Somaclonal Variation and Induced Mutation in Crop Improvement. Kluwer Academic Publishers 1998;12(3): 203-218.
4. Kiong A, Ling Pick A, Grace Lai SH, Harun AR. Physiological responses of *orthosiphon stamineus* plantlets to gamma irradiation. Am-Eurasian J. Sustain Agric 2008;2(2): 135-149.
5. Konzak C. Role of Induced Mutations. In: Vose P, Blixt S, Crop Breeding, A Contemporary Bases. Pergamon Press. Oxford. 1984:216-292.
6. Kovacs E, Keresztes A. Effect of gamma and UV-B/C radiation on plant cell. Micron 2002;33: 199-210.
7. Kukimura H. Mutation breeding in sweet potato and tuber crops. Gamma Field Symp 1986;25: 109-130.
8. Lapins T. Mutation breeding: methods in fruit breeding. Gamma Field Symposia 1983;1(3): 74-99.
9. Linda TN, Louajri A, Benajiba M. Therapeutic effects of ginger. ISESCO Journal of Science and Technology 2012; 8(14): 64-69.
10. Sanada T. Induced mutation breeding in fruit trees resistant mutant to black spot disease of Japanese pear. Gamma Field Symposia 1986;25(4): 87-108.
11. Schum A. Mutation breeding in ornamentals and efficient breeding method. Acta Hortica 2003;612: 47-60.
12. Shin JM, Kim BK, Seo SG, Jeon SB, Kim JS, Jun BK. Mutation breeding of sweet potato by gamma-ray radiation. African Journal of Agricultural Research 2011;6(6): 1447-1454.
13. Song H, Kang S. Application of natural variation and induced mutation in breeding and functional genomics: Papers for International Symposium; Current Status and Future of Plant Mutation Breeding. Korean Journal of Breed Science 2003;35(1): 24-34.
14. Wang Y, Wang F, Zhai H, Liu Q. Production of a useful mutant by chronic irradiation in sweet potato. Science Hortica 2007;111(2): 173-178.
15. Wi SG, Chung BY, Kim JS, Kim JH, Baek MH, Lee JW, Kim YS. Effects of gamma irradiation on morphological changes and biological responses in plants. Micron 2007;38(1): 553-564.

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