World Applied Sciences Journal 15 (5): 654-659, 2011
ISSN 1818-4952

Influence of Gamma Irradiation on Some Physiological Characteristics and Grain Protein in Wheat (*Triticum aestivum* L.)

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Abstract: Seed irradiation during pre-sowing processes is one of the most effective methods to improve the plant production, yield components and chemical composition. Therefore, an experiment was conducted using split-plot on the basis of randomized complete block design with four replications in Agricultural Research Station of Islamic Azad University of Yasouj during 2009-2010. Main plots were consisted of two wheat cultivars (Alamut and Zagros) and sub-plots were six levels of gamma irradiation including 0 (control), 25, 50, 75, 100 and 125 Gy. The results of this study showed that 1000-grain weight, grain yield, grain protein content, LAI, CGR and NAR and harvest index were affected with different levels of irradiation. The highest value of kernel weight was obtained in Zagros cultivar and 25 Gy gamma irradiation. Among the two varieties, Zagros cultivar produced more grain yield than Alamot cultivar. Grain yield increased in response to application of gamma irradiation, with the grain yield of the crop that no received gamma irradiation being 5% more than control. 25 and 50 Gy gamma irradiation produced the highest grain protein content. Increasing in gamma irradiation being more than 50 Gy decreased grain protein about 28% to 67%. The LAI and CGR varied from 4.81 to 2 and 25.6 to 12.6 (gr m^2 day^{-1}). The highest LAI and CGR scores with average 4.81 and 25.6 were obtained from 25-Gy gamma irradiation. LAI, CGR and NAR decreased with increasing in gamma irradiation. In order to obtain the best combination with the highest LAI and CGR, the 50 Gy gamma irradiation and Zagros cultivar should be implicated.

Key words: Gamma irradiation · Wheat · Grain yield · Grain protein · Growth physiological indices

INTRODUCTION

Wheat (*Triticum aestivum* L.) improved by acclimatization, selection and hybridization has a very old historical background; today these methods were considered, however, to be unsatisfactory because of the limited genetic variation among the existing wheat population. The previous studies of Muller [1] and Stadler [2], however, opened a new era in the field of plant improvement. Therefore, the plant breeders and geneticists of the 20th century have used the radiation as a new tool for plant improvement. There are several usages of nuclear techniques in agriculture. In plant improvement, the irradiation of seeds may cause genetic variability that enable plant breeders to select new genotypes by improving characteristics such as precocity, tolerance to salinity, grain yield and quality [3]. A number of radiobiological parameters were commonly used in early assessment of effectiveness of radiation to induce mutations. Chaudhuri [4] reported that the irradiation of wheat seeds during germination reduced its shoot and root lengths. Gamma rays belong to ionizing radiation and are the most energetic form of such electromagnetic radiation having the energy level from around 10 kilo electron volts (keV) to several hundred keV. Therefore, they are more penetrating than other types of radiation such as alpha and beta rays [5]. Gamma radiation can be useful for the alteration of physiological characters [6]. The biological effect of gamma-rays is based on the interaction with atoms or molecules in the cell, particularly water, to produce free radicals [5]. Seed irradiation during the pre-sowing is one of the most effective methods to improve plant production, yield components and chemical composition

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[7, 8]. Induced mutations have been used for the improvement of major crops such as wheat (*Triticum spp.*), rice (*Oryza sativa*), barley (*Hordeum vulgare*), cotton (*Gossypium hirsutum*), chickpea (*Cicer arietinum*) which are seed propagated [9].

Gamma ray with ionization molecules cause to make free radicals that these free radicals attacked to DNA molecule which make breaking one or two chains of DNA [10, 11]. Rao *et al.* [12] discussed the findings related to the different researches with gamma irradiation in wheat and they reported that the doses above 5 kGy created a bad influence on bread quality, as well. Ghafoor and Siddiqui [13] studied the effects of gamma rays on tillers number and plant height in six cultivars of wheat. The results showed that these cultivars differed significantly for both the characters. Choudhry [14] exposed dry grains of six wheat cultivars to 10-14 kr gamma rays and evaluated for germination and survival. The results suggested that the lower dose may increase germination particularly in lines with poor germination. Hassan [15] observed that 40 Krad dose caused maximum reduction in various genetic parameters of wheat and triticale. Studies on the effects of gamma-rays from Co60 on wheat have been reported by Melki and Marouani [16].

The objective of the research was to investigate the effects of gamma irradiation on some agronomic characteristics, growth physiological indices and grain protein content of two Wheat (*Triticum aestivum* L.) cultivars.

MATERIALS AND METHODS

The experiment was conducted in Agricultural Research Station of Islamic Azad University of Yasouj, Iran (51°, 41' E, 30°50' N, 1831.5 m height from sea level) during 2009-2010. The experiment was a split plot based on a complete randomized block design with four replications. Main plots, wheat cultivars, were C1=Alamot and C2=Zagros, obtained from the Seed and Plant Improvement Institute in Iran. Sub plot, cobalt 60 gamma irradiation, were irradiation at rates of G1=zero (control), G2=25, G3=50, G4=75 G5=100 and G6=125 Gray (Gy). Seeds of wheat (*Triticum aestivum* L.) were surface sterilized with 1 % Calcium Hypochloride, dried under laminar flow hood. The seeds were then exposed to radiations with 60 Cobalt emitting gamma rays with time periods of 2.46, 4.92, 7.38, 9.85 and 12.31 minutes for 25, 50, 75, 100 and 125 Gy, respectively. The seeds were irradiated at the Atomic Energy Organization of Tehran, Iran. One hundred and fifty kg ha^{-1} Superphosphates and 50 kg ha^{-1} potassium sulphate were applied according to recommendations of the soil testing laboratory. Plots were sown on Nov.11, 2009 with a cone seeder at the rate of 400 seed m^2 and were 8 m in length and 1.6 m wide, with 8 rows of 0.2 m apart. Plots were ploughed and disked after the winter wheat harvest in July. The plots were disked again before sowing in October. To control both broad- and narrow-leaved weeds, Apirus was applied in early April. Apirus is a sulphonylurea (Su) herbicide and therefore controls weeds through inhibition of the acetolactase synthase enzyme. The three most common active ingredients of Su herbicides are chlorsulfuron, metsulfuron-methyl and triasulfuron. Irrigation of each main plot was measured volumetrically by field calibrated gypsum block. The soil at 30-cm depth was kept -0.025 MPa to maturity. The irrigation system was operated so that runoff did not occur. At maturity, 10 plants were taken randomly from each subplot for recording the following morphological, yield components and grain yield.

1000-Kernel Weight: Average kernel weight was determined by weighing 250 kernels randomly drawn from the bulk grain sample from each plot.

Grain Yield: Centre six rows (of 8 rows) of each plot were harvested for grain yield and converted to grain yield per hectares.

Harvest index: [wt. of grain/ (wt. of grain +straw)]

Grain Protein: Calculated by multiplying grain N concentration by 5.7 [17]. -Leaf Area Index (LAI) = $\frac{LA}{GA}$

Where, LA and GA are Leaf Area and Ground Area.

Crop Growth Rate (CGR): The following equation was used for the CGR.

$$\text{CGR } \frac{W2 - W1}{T2 - T1} \times \frac{1}{GA}$$

Where, W, T and GA refer dry matter weight, time and ground area, respectively. Net assimilation rate (NAR) = LAI × CGR

Samples were dried in a forced-air oven at 72°C for 48 h.

Data were analysed by analyses of variance using the general linear model (GLM) procedure provided by SAS [20]. When significant differences were found ($P = 0.05$), the Duncan's multiple range test (DMRT) was carried out.

RESULTS AND DISCUSSION

1000-Kernel Weight: Cultivar and gamma irradiation had significant effect on kernel weight at 1 % probability level (Table 1). The highest value of kernel weight was obtained in Zagros cultivar and 25 Gy gamma irradiation (Table 2). Significant cultivar × gamma irradiation interactions were detected at $P \geq 0.01$ in this trait (Table 1). Zagros cultivar at 25 and Alomot cultivar at 125 Gy produced the highest and the lowest kernel weight, respectively (Table 3). The stimulation effect of gamma rays irradiation on growth, especially at low doses was reported in several investigations. When Khan [7] exposed seeds of *Cicer arietinum* to gamma rays at doses ranging from 5 to 15 Krad, a stimulation of branching capacity, fresh weight and dry weight was reported. Millado *et al.* [19] studied the effect of various doses of gamma radiation on plant height, number of tiller plant-1, grain weight plant in wheat and concluded that in general 10 KR and 15 KR increased the mean value of each trait studied. On the other hand higher doses tended to reduce them. Similar results were observed by Kaul and Bradu [20] in *Atropa belladonna*, Suhas *et al*. [21] in *Cassia angustifalia*, Selenina and Stepanenko [8] in *Matricaria recutita* and Youssef and Moussa [22] in geranium.

Grain Yield: Cultivar, gamma irradiation and interaction between them were significant in grain yield (Table 1). Among the two varieties, Zagros cultivar produced more grain yield than Alamot cultivar (Table 2). Grain yield more than 25 Gy gamma irradiation was reduced by 3 to 57 % (Table 2). Grain yield increased in response to application of gamma irradiation, with the grain yield of the crop that no received gamma irradiation being 5% more than control (Table 2). Among the five gamma irradiations and two wheat cultivars, 25 Gy gamma irradiation and Zagros cultivar produced the highest grain yield (Table 3). The presowing treatment with a magnetic field showed a positive impact on seeds of soybean, maize, peas, okra and beans leading to an increase of yield for soybean by 48%, for peas by 15%, for okra by 19% and for bean by 21%. High doses of gamma irradiation (over 15 k-rad) were reported to be harmful in several studies. Ramachandran and Goud [23] reported that higher doses of gamma irradiation (40-120 k-rad) reduced plant height, number of leaves and branching capacity of safflower. Physical mutagens and about 60% of them were created by applying gamma ray mutants at barley caused to product high yield, resistant to mildew, strong stem, high protein and skinless seeds [24]. Gamma irradiation was reported to induce oxidative stress with overproduction of reactive oxygen species (ROS) such as superoxide radicals (O_2^-), hydroxyl radicals (OH^-) and hydrogen peroxides (H_2O_2) [25], which react rapidly with almost all structural and functional organic molecules, including proteins, lipids and nucleic acids causing disturbance of cellular metabolism [26].

Harvest Index: There was significant difference between cultivar and gamma irradiation in this trait (Table 1). 25 Gy gamma irradiation was more efficient than other treatments to increase harvest index (Table 2). Significant cultivar × gamma irradiation was detected at $P \geq 0.01$ on harvest index (Table 1). Zagros cultivar and the lowest Gy gamma irradiation level produced the highest value. Gunckel and Sparrow [27] supported our observations that gamma rays are known to influence plant growth and development by inducing cytological, genetical, biochemical, physiological and morphogenetic changes in cells and tissues. Several workers have studied effect of gamma rays on seed germination of Gymnosperms. Mucci [28] observed variations in height, ear length, tillering, harvest index, number of spikelet per ear and time of maturity of plants due to gamma rays in wheat. The higher exposures were usually inhibitory [29-31]. The higher exposures are usually inhibitor on seed germination of Gymnosperm and Angiosperm [32] whereas lower exposures are sometimes stimulatory [33, 34].

Grain Protein Percent: Gamma irradiation and interaction between cultivar and gamma irradiation were significant in grain protein percent (Table 1). 25 and 50 Gy gamma irradiation produced the highest grain protein content. Increasing in gamma irradiation more than 50 Gy decreased grain protein about 28% to 67% (Table 2). Among the five gamma irradiations and two wheat cultivars, 50 Gy gamma irradiation and Zagros cultivar produced the highest grain protein content (Table 3). However it was in the same statistical group with Alamot cultivar and 50 Gy gamma irradiation. Nayeem *et al*. [35] found nine irradiationally induced mutants in wheat with improved pattern of water soluble protein (glutenin) that could be used successfully as breeding material for the improvement of protein quality in bread wheat. Reddy and Viswanathan [36] induced rust resistance in hexaploid wheat variety "WH 147" by using gamma rays and EMS. Crops with improved characteristics have successfully been developed by mutagenic inductions [37-39] developed a high yielding barley variety with early maturity, high protein contents and stiff straw by

Table 1: The results of the variance analysis in wheat cultivars and gamma irradiation

Sources	df	1000-Kernel weight (gr)	Grain Yield Kg ha^{-1}	Harvest Index (%)	Grain protein	LAI	CGR (gr m^2 day^{-1})	NAR (gr m^2 day^{-1})
Replication	3	0.492 ns	91083.22 ns	854.12 ns	52.17 ns	4.4 ns	0.605 ns	0.27 ns
Cultivar (C)	1	49.21**	4409935.2**	354.1**	45.21ns	40.1ns	17.917**	165.1**
Error A	3	0.545	184019	17.42	52.45	.07	0.876	1.605
Gamma Irradiation (GI)	5	0.0491**	3300134.3**	745.21**	317.11**	1.3**	54.715**	11.11**
C × GI	5	0.072**	326046.4**	87.42**	9.21**	.6**	0.537**	0.195**
Error B	30	0.391	115536.22	17.42	6.28	.003	0.351	0.095
CV (%)		15.13	18.19	20.21	18.17	14.17	21.22	18.71

*,** Significant at 0.05 and 0.01 probability levels, respectively. NS = nonsignificant at P> 0.05

Table 2: Mean values of traits of wheat cultivar at six gamma irradiations

Treatments	1000-Kernel weight (gr)	Grain Yield Kg ha	Harvest Index (%)	Grain protein	LAI	CGR (gr m^2 day^{-1})	NAR (gr m^2 day^{-1})
Cultivars							
Zagros	38.2a	4850.6a	43.2a	12.9a	4.92a	23.7a	5.43a
Alamut	35.6b	4621.7b	40.1b	12.8a	3.87b	18.9b	5.76a
Gamma Irradiation							
0	41.7a	4844.2a	43.6a	13.1b	4.61a	25.1a	5.8a
25	42.7a	4929.8a	44.8a	14.2a	4.81a	25.6a	5.6
50	41.6a	4912.6a	44.6a	14.8a	4.22a	25a	5.9a
75	32.7b	3621.6b	33.8b	11.6c	3.4b	21.2b	4.1b
100	29.6c	3498.1c	32.9b	10.9d	3c	16.7c	3.1c
125	22.6	2945.6d	28.7c	8.9e	2.1d	12.6d	2.4d

The same letters in columns are not significantly different at P ≤ 0.05

Table 3: Mean values of interaction between cultivar and gamma radiation

Treatments	1000-Kernel weight (g)	Grain Yield Kg ha^{-1}	Harvest Index (%)	Grain protein	LAI	CGR (gr m^2 day^{-1})	NAR (gr m^2 day^{-1})
C1GI1	43.6 A	4965.7A	45.6 A	15.6 A	4.8 A	25.1 A	6.3 A
C1GI2	43.8 A	4996.7 A	46.7 A	15.1 A	4.9 A	26.7 A	6.3 A
C1GI3	43.7 A	4981.6 A	45.9 A	16.9 A	5.1 A	26.9 A	5.9 A
C1GI4	38.3 B	3949.1 B	41.3 C	11.3 C	2.9 C	22.2 B	3.7 B
C1GI5	30.9 C	3899 BC	35.3 D	11.2 C	3.1 C	19.6 C	3.9 B
C1GI6	23.1 D	2833.7 D	22.7 D	11.2 C	2. E	11.3 E	2.2 C
C2GI1	42.8 AB	4892 AB	44.1 AB	13.9 B	3.8 B	22.5 B	6.2 A
C2GI2	42.9 AB	4883 AB	44.2 AB	13.8 B	3.9 B	22.1 B	6.4 A
C2GI3	42.5 AB	4839AB	43.1 AB	16.7 A	3.7 B	22.1 B	6.4 A
C2GI4	38.2 B	3958.3 B	40.8 CD	11.3 C	3. C	19.1 C	3.8 B
C2GI5	30.6 C	3743.3 C	35.2 D	10.1 D	2.5 D	14.2 D	2.3 C
C2GI6	19.9 E	2432.8 E	19.6 F	8.9 E	1.99 E	8.9 F	1.5 D

Same letters in columns are not significantly different at P ≤ 0.05

mutation breeding techniques. Frank and Lendvi [40] and Mahmoud [41] reported an increase in carbohydrates and soluble sugars in response to seed irradiation. However, a decrease in carbohydrate content was reported in other studies [42,43].

Growth Physiological Indices: Table 2 and Table 3 show summary of the Growth physiological indices. The LAI and CGR varied from 4.81 to 2 and 25.6 to 12.6 (gr m^2 day^{-1}). The highest LAI and CGR obtained in 25 Gy gamma irradiation with average 4.81 and 25.6, respectively (Table 2). LAI, CGR and NAR decreased with increasing in gamma irradiation (Table 2). The best combination in order to obtain the highest LAI and CGR was 50 Gy gamma irradiation and Zagros cultivar (Table 3). The highest NAR was obtained in Alamot cultivar and 50 Gy gamma irradiation (Table 3). Gamma rays belong to ionizing radiation and interact on atoms or molecules to produce free radicals in cells. These radicals can damage or modify important components of plant cells and have been reported to affect differentially the morphology, anatomy, biochemistry and physiology of plants depending on the irradiation level. These effects include changes in the plant cellular structure and metabolism e.g., dilation of thylakoid membranes, alteration in photosynthesis, modulation of the antioxidative system and accumulation of phenolic compounds [44, 45].

CONCLUSION

The results of this study showed that 25 and 50 Gy irradiation were the best rate for increasing all traits. Higher doses of gamma irradiation decreased all traits in this study. Also, Zagros cultivar produced the highest values in all traits in this experiment. It recommends carry out the experiment under irrigation levels, soil types and other conditions.

ACKNOWLEDGMENT

Funding support for this research was provided by the Islamic Azad University of Yasouj.

REFERENCES

1. Muller, H.J., 1927. Artificial transmutation of the gene. Sci., 66: 84-7.
2. Stadler, L.J., 1928. Mutations in barley induced by X-rays and radiations. Sci., 68: 186-7.
3. Ashraf, M., A.A. Cheema, M. Rashid and Z. Qamar, 2003. Effect of gamma rays on M1 generation in Basmati rice. Pak. J. Bot., 35(5): 791-795.
4. Chaudhuri, K.S., 2002. A simple and reliable method to detect gamma irradiated lentil (*Lens culinaris* Medik.) seeds by germination efficiency and seedling growth test. Radiat. Phys. Chem., 64: 131-136.
5. Kovacs, E. and A. Keresztes, 2002. Effect of gamma and UV-B/C Radiation on Plant Cell. Micron., 33: 199-210.
6. Kiong, A., A. Ling Pick, S.H. Grace Lai and A.R. Harun, 2008. Physiological responses of *Orthosiphon stamineus* plantlets to gamma irradiation. Am. Eurasian J. Sustain. Agric., 2(2): 135-149.
7. Khan, B.M., 1970. Effect of gamma rays irradiation on yield and the incidence of blight disease of gram. Agric. J. Pakistan., 21: 43-6.
8. Selenia, L.V. and O.G. Stepanenko, 1979. Effect of presowing gamma irradiation on the productivity and active principle content of*Matricaria recutita*. Rastitel'nye Ressusy, 15: 143-54.
9. Ahloowalia, B.S. and M. Maluszynski, 2001. Induced mutations- a new paradigm in plant breeding. Euphytica., 119: 167-173.
10. Hagberg, A. and G. Persson, 1968. Induced mutations in barley breeding, Heredit., 59: 396-412.
11. Jyoti, P.M., C.S.K. Sukalyan, P. Subrata, J. Jiin-Shuh, C. Alok, C. Anindita and C.S. Subhas, 2009. Effects of gamma irradiation on edible seed protein, amino acids and genomic DNA during sterilization. Food Chem., 114: 1237-1244.
12. Rao, S.R., R.C. Hoseney, K.F. Finney and M.D. Dhogren, 1975. Effect of gamma-irradiation of wheat on breadmaking properties. Cereal Chem., 52: 506-512.
13. Ghafoor, A. and K.A. Siddiqui, 1976. Effect of gamma rays and fast neutrons treatments on tillers number and plant height in wheat. Pakistan J. Bot., 8: 1-7.
14. Choudhry, R.K., 1983. A note effect of gamma irradiation in wheat. Wheat Information Sci., 57: 21-3.
15. Hassan, S., 1986. Gamma irradiation induced variations in genetic parameters of wheat and triticale. Sarhad J. Agric., 2: 173-9.
16. Melki, M. and A. Marouani, 2009. Effects of gamma rays irradiation on seed germination and growth of hard wheat. Environ Chem Lett., Doi: 10.1007/s10311-009-0222-1.
17. A.A.C.C., 1971. Cereal laboratory methods, 8th ed. Amer. Assoc. of Cereal Chem. St. Paul, Minn.
18. SAS Institute, Inc., 2004. SAS/STAT 9.1 User's guide. SAS Institute Inc., Cary, NC.
19. Millado, Z., M.A. Trajilo and F.R. Mendozoz, 1972. Effect of different doses of gamma rays Co60 on four quantitative characters in wheat (*T. aestivum* L.). Agro. Sci., 8B: 41-65.
20. Kaul, B.L. and B.L. Bradu, 1972. Studies on the induced mutation in medicinal plant. I.Spectrum of adult plant mutations in *Atropa bellaldonna.* Planta Medica., 20: 205-10.
21. Suhas, K., V.K. Deshumukh and A.N. Saoji, 1976. Stimulating effect of gamma radiation on growth of senna (*Cassia angustifolia)* vahl. Referativenys Zhumal., 8: 882-7.
22. Youssef, A.A. and A.Z. Moussa, 1998. Effect of gamma rays on growth and essential oil composition of chamomile (*Chamomilla recutita* L.). Arab. Univ. J. Agric. Sci., 6: 301-1110.
23. Ramachandran, M. and J.V. Goud, 1983. Mutagenesis in safflower (*Carthamus tinctorius*). I Differential radio sensitivity. Genetic Agraria., 37: 309-18.
24. Ananthaswamy, H.N., U.K. Vakil and A. Sreenivasan, 1971. Biochemical and physiological changes in gamma-irradiated wheat during germination. Radiat. Bot., 11: 1-12.

25. Xienia, U., G.C. Foote, S. Van, P.N. Devreotes, S. Alexander and H. Alexander, 2000. Differential developmental expression and cell type specificity of dictystelium catalases and their response to oxidative stress and UV light. Biochem. Biophys. Acta., 149: 295-310.
26. Salter, L. and C.N. Hewitt, 1992. Ozonehydrocarbon interactions in plants. Phytochem., 31: 4045-4050.
27. Gunckel, J.E. and A.H. Sparrow, 1961. Ionizing radiation: Biochemical, Physiological and Morphological aspects of their effects on plants. In: Encycl. Plant Physiol. (Ed.) Ruhland, W.XVI: pp: 555-611, Springer-verlag, Berlin.
28. Mucci, F., 1962. Notes on seven years of observations of wheat types from induced mutation in c.v. Tavere. Ann. Pac. Sci. Agri. Protic., 28: 314-89.
29. Bora, K.C., 1961. Relative biological efficiencies of ionizing radiation on the induction of cytogenetic effect in plants. In: Proceeding of the Symposium on the effect of ionizing radiation on seed and their Significance for Crop Improvement, pp: 345-357.
30. Radhadevi, D.S. and N.K. Nayar, 1996. Gamma rays induced fruit character variations in Nendran, a variety of banana (*Musa paradasiaca* L.). Geobios., 23(2-3): 88-93.
31. Kumari, R. and Y. Singh, 1996. Effect of gamma rays and EMS on seed germination and plant survival of *Pisum sativum* L. and *Lens culinaris*. Medic. Neo Botanica., 4(1): 25-29.
32. Thapa, C.B., 1999. Effect of acute exposure of gamma rays on seed germination of *Pinus kesiya* Gord and *P. wallichiana* A.B. Jacks. Botanica Orientalis J. Plant Sci., pp: 120-121.
33. Chauhan, Y.S. and R.P. Singh, 1980. Effect of chronic gamma rays on *Chenopodium album* L. J. Indian Bot. Soc., 59: 170-172.
34. Taylor, F.G., 1968. Some effect of acute gamma radiation in giant sequoia seedlings. Radiat. Bot., 8: 67-70.
35. Nayeem, K.A., S.N. Devokule and S.G. Bhagwat, 1999. Seed protein variations in radiation induced mutants of wheat. Indian J. Genetics and Plant Breeding, 59: 371-373.
36. Reddy, V.R.K. and P. Viswanathan, 1999. Induced rust resistant mutants in hexaploid wheat "WH 147" Crop Research (Hisar), 18: 443-445.
37. Rehman, A., M.L. Das, M.A.R. Howlidar and M.A. Mansur, 1987. Promising mutants in Brassica campestris. Mut. Breed. Newsletter, 29: 14-15.
38. Javed, M.A., A. Khatri, I.A. Khan, M. Ahmad, M.A. Siddiqui and A.G. Arain, 2000. Utilization of gamma irradiation for the genetics improvement of oriental mustard (*Brassica juncea* Coss.). Pak. J. Bot., 32: 77-83.
39. Gustafsson, A., A. Hagberg, G. Persson and K. Wikland, 1971. Induced mutation and barley improvement. Theo. Appl. Gene., 41: 239-48.
40. Frank, J. and Z. Lendvi, 1971. Effect of gamma irradiation on quantitative changes in the carbohydrate content of germinating peas. Acta Agron., 2: 123-7.
41. Mahmoud, F.A.N., 2002. Effect of gamma radiation and some agrochemicals on germination, growth and flowering of *Delphinium ajacis* and *Mathiola incana* plants. M.Sc. Thesis. Fac. Agric. Moshtohor, Zagazig Univ. Egypt.
42. Tselishev, S.P., G.F. Ivanova and N.I. Shmelkora, 1970. The effect of gamma rays on some metabolic processes in pea plants. Izv.Timiryazev Sel. Khoz. Acad., 4: 87-95.
43. Jiracek, V., R. Kryzenek and J. Kostir, 1970. Research on the radiation biochemistry of plants. The effect of chronic gamma rays irradiation on the metabolism of amino acids and sugars in pea and wheat. Rostl. Vyroba., 16: 657-70.
44. Kim, J.H., M.H. Baek, B.Y. Chung, S.G. Wi and J.S. Kim, 2004. Alterations in the photosynthetic pigments and antioxidant machineries of red pepper (*Capsicum annuum* L.) seedlings from gamma-irradiated seeds. J. Plant Biol., 47: 314-321.
45. Wi, S.G., B.Y. Chung, J.H. Kim, M.H. Baek, D.H. Yang, J.W. Lee and J.S. Kim, 2005. Ultra structural changes of cell organelles in *Arabidopsis* stem after gamma irradiation. J. Plant Biol., 48(2): 195-200.