PSM Biological Research
2017 │Volume 2│Issue 1│30-35
ISSN: 2517-9586 (Online)

www.psmpublishers.org

Review Article **Open Access**

Effect of Gamma Irradiation on Growth and Post-harvest Storage of Vegetables

Abdul Majeed[1,2*], Zahir Muhammad[3], Rehman Ullah[3], Zabeeh Ullah[2], Rafi Ullah[2], Zubeda Chaudhry[2], Saira Siyar[4]

[1]Department of Botany, Govt: Degree College Naguman Peshawar, Peshawar, Khyber Pakhtunkhwa, Pakistan.
[2]Department of Botany, Hazara University, Mansehra, Khyber Pakhtunkhwa, Pakistan.
[3]Department of Botany, University of Peshawar, Peshawar, Khyber Pakhtunkhwa, Pakistan.
[4]Department of Botany, Qurtuba University of Science and Technology, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Received: 13.Nov.2016; Accepted: 05.Dec.2016; Published Online: 10.Jan.2017
***Corresponding author: Abdul Majeed; Email: majeedpsh@gmail.com**

Abstract
Gamma irradiation is the process of exposing subject materials to gamma rays – a type of highly energetic electromagnetic rays – which have extraordinary potentials of penetrating deep into subject materials. Owing to its high penetrability, gamma irradiation is generally used in agriculture for possible healthy mutations in plants and for control of microbial spoilage of agricultural products. Growth, production and post-harvest storage of vegetables- which serve important source of human diet- need to be improved for provision of healthier diets to the increasing population of humankind. Pre-sowing treatment of vegetable seeds (or other propagating organs) with mutating agents such as gamma irradiation may cause a reshuffling of genes associated with quality and quantity controlling traits in both positive and negative directions. These genetic changes give rise to mutant progenies which may exhibit superiority or inferiority in characters over their parent plants. Similarly, post-harvest rot of vegetables during storage due to microbial attack results in losses which may be effectively controlled by the use of gamma irradiation. The aim of this review is to evaluate vegetative growth response of different cultivated plants particularly vegetables to gamma irradiation. Radiation treatment as post-harvest controlling technique of fresh produce is also discussed.
Keywords: Ionizing radiation, Mutation, Molecular techniques, Hormesis, Lethal dose, QTLs.

Cite this article: Majeed, A., Muhammad, Z., Ullah, R., Ullah, Z., Ullah, R., Chaudhry, Z., Siyar, S., 2017. Effect of Gamma Irradiation on Growth and Post-harvest Storage of Vegetables. PSM Biol. Res., 02(1): 30-35.

INTRODUCTION

Cultivated plants owe significant importance in human life for their uses as food, medicine, fodder, ornamentation and shelter. To get maximum and sustainable use of domestic plants, agronomist, plant breeders and horticulturists have often dreamed to improve the growth of cultivated crops. For this purpose popularly plant breeding is employed, which results in the emergence of new progenies possessing superior characters. Employing plant breeding, new varieties may be developed with desired traits. However, this process takes too much longer time and extensive labor is required (Majeed *et al*., 2010) because firstly selection from the parent population is made on the basis of desired characters. Selected parental plants are then propagated for obtaining F1, F2, F3… progenies. At every progenic generation again selection procedures are carried out until a successful development of the good variety. Since all qualitative and quantitative characters of living organisms including plants are controlled by genes located in chromosomes, any alteration in the genome may result in structural or chemical modifications with potential healthy or adverse effects on daughter plants.

Gamma irradiation application for modifying the genetic core of plants seems to be a promising technique as compared to plant breeding (Majeed *et al*., 2010). It has been successfully utilized for mutation breeding purposes in domestic plants and agricultural crops. Subhan *et al*. (2004) attain maximum plant height, grain and straw yield of barley at radiation exposure to 10 Krad. Thapa (2004) reveal lethal effect of radiation doses exceeding 20 Krh/min on germination and general growth of *Pinus* species. Zaka *et al*. (2004) demonstrated that vegetative growth and yield characters of pea (*Pisum sativum* L.) are negatively affected by radiation dose above 10 Gy. Dubey *et al*. (2007) document that vegetative growth, floral and fruit traits of Okra show increase at 2000 rad of gamma irradiation. Mollah *et al*. (2009) validate stimulatory effects at low but inhibitory responses of *Amaranthus cruentus* L. to higher doses of gamma irradiation. Hegazi and Hamideldin (2010) also report promised growth, seeds and yield in two varieties of okra (*Abelmoschus esculentus* L.) at gamma irradiation dose 400 Gy. Singh *et al*. (2010) suggests low doses (0.01-0.1 kGy) for improving plant vigor and nutritional quality of wheat. Marcu *et al*. (2013) observe enhanced growth such as germination, radicle and plumule growth of lettuce (*Lactuca sativa*) at dose range 2-30 Gy.

Similarly, post-harvest decay and spoilage of vegetables pose noxious challenges to both farmers and consumers. One of the main reasons for rapid decay of fresh products is their delicate tissues and their vulnerability to microbial flora (Abdullah *et al.,* 2016). Devising environmentally sound procedures for ensuring long shelf life and controlled spoilage seem a thoroughly investigated area of horticultural research. Treatment of vegetables and agricultural products with ionizing radiation has been utilized successfully with good results in different environmental conditions. Keeping in view both positive and negative effects of gamma irradiation on plants, dose range at which healthy responses of plants for potential yield increases occur and fresh produce for longevity in shelf life and quality maintenance need to be thoroughly investigated. The objective of this review is to survey published reports on gamma irradiation effects on morphology and post-harvest storage quality parameters of vegetables.

GAMMA IRRADIATION EFFECTS ON PLANTS

Mode of action

Gamma irradiation is a type of nuclear electromagnetic rays which are highly energetic and can penetrate deep into exposed materials (http://steritech.com.au). The penetration capacity of gamma irradiation depends on subjected materials wither living or dead, soft or hard. There are several sources of gamma irradiation, but most commonly used commercial sources are Co-60 and Cs-137. When plant parts such as seeds, buds or seedlings are irradiated, they undergo chemical changes by ionization phenomena. The physical environment in which the radiation is performed such as moisture, temperature, dose magnitude and duration of exposure play important role in causing chemical changes (Silva, 2012). Chemical changes include the production of reactive oxygen species (ROS), hydroxyl ions (OH) and formation of H_2O_2 which in turn alter the genome of subjected organs of plants resulting in mutations (Zaka *et al*., 2004; Silva, 2012; Majeed *et al*., 2014) (Figure 1).

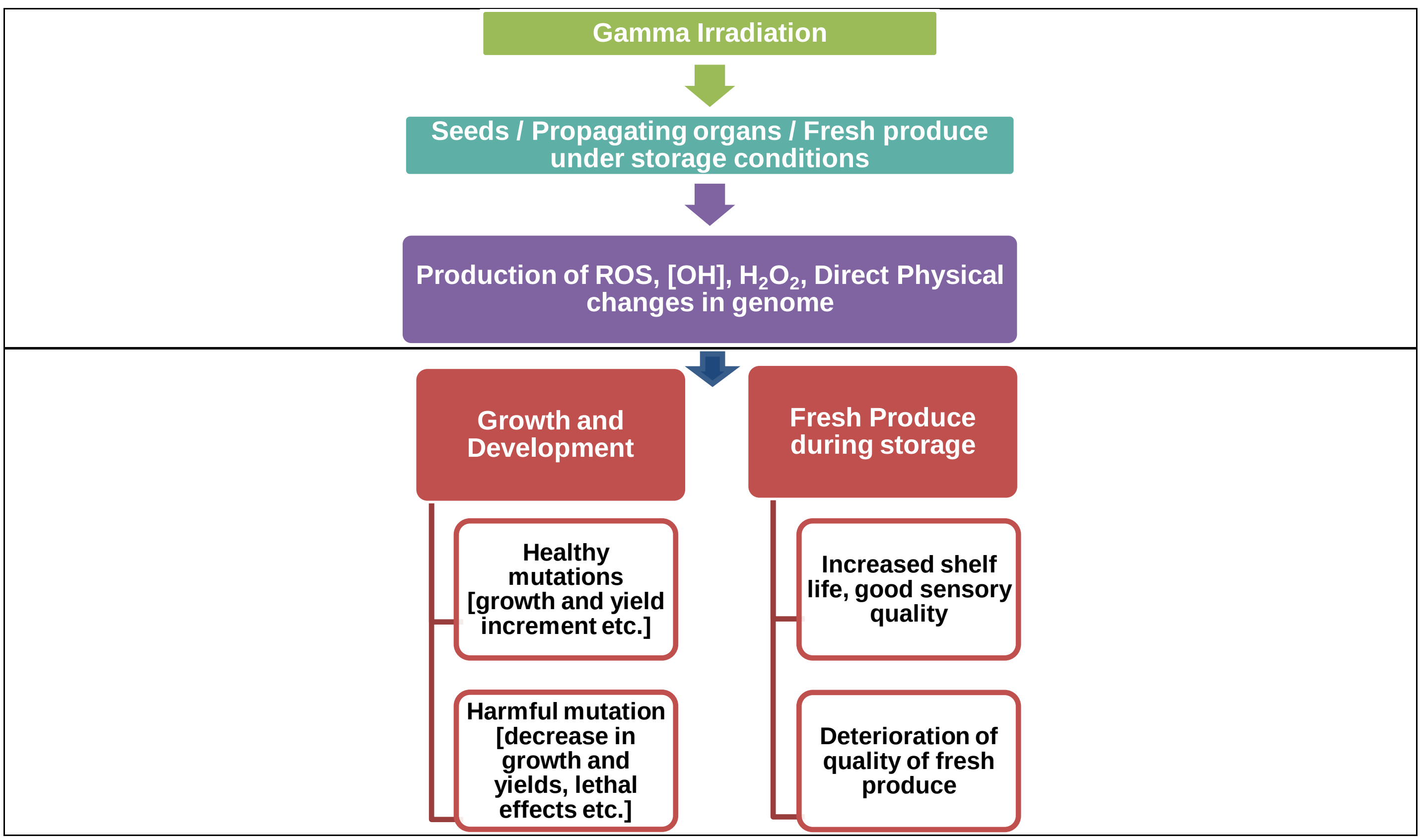

Fig. 1. Schematic presentation of the effect of gamma irradiation on target plants and fresh produce which induces either direct genetic changes or produces chemical changes resulting in healthy or harmful effects.

Effect of gamma irradiation on plant morphology, growth and developmental process is thought to be associated with induction of changes in cytology, biochemistry, genetics and physiology (El-Beltagi *et al*., 2011). Plants being living organisms, reserve genetic information in their chromosomes which control qualitative and quantitative characteristics such as those concerned with growth phenomena in field conditions while resistance to decay in storage conditions. When struck by energizing radiation, the chromosomes in the propagating organs (usually seeds) of plants undergo structural changes which modify the genetic structures (genes) in both positive and negative manner. Magnitude and duration of exposure to gamma irradiation are the key factors which either stimulate or suppress the genes concerned with the desired characters of plants. In general, higher doses have negative while low doses have stimulatory effects on plant growth. Changes in genome, biochemistry, physiological aspects and cytology incurred by radiation exposure are known to be correlated with intensity of radiation dose and duration of exposure, plant species and radiation environment. Different plant species show different responses to gamma irradiation. Similarly different doses of gamma irradiation exert different effects on plants. Generally, low doses do not impart harmful effects in contrast to higher doses which have drastic effects in most of the studied cases (Zaka *et al*., 2004; Dubey *et al*., 2007; El-Beltagi *et al*., 2011). Gamma rays when applied to plants are known to induce in them hormonal changes, enzymatic alteration, and cell cycle modification in both directions which in turn have effect on morphological, physiological and developmental phenomena of plants (Zaka *et al*., 2004; Melki and Marouani, 2010). These changes in response to applied doses of gamma irradiation are expressed in progenies either in improved or suppressed growth and vigor.

Responses of different cultivated vegetables to gamma irradiation

Impact of gamma irradiation on growth and morphological characters has been rigorously studied. Previously Al-Safadi and Simon (1996) has revealed that low doses (0.5-1 Krad) accelerated germination, plant height and root weight of carrots (*Dacus carrota*) in M1 generation but high doses had inhibitory effects on the studied characters (parameters). On the other hand, M2 generation revealed that higher doses were positively correlated with plant size and dry weight of root. Kim *et al*. (1998) studied the effect of different doses of gamma irradiation on Chinese cabbage. They observed that radiation doses (4-8 Gy) increased growth of cabbage. Germination, shoot length and diameter were positively influenced by low doses. Zaka *et al*. (2004) investigated radiation effect of 0-60 Gy on pea (*Pisum sativum* L.) through two generations. They found that plant growth and productivity were retarded by doses exceeding 6 Gy. Kim *et al*. (2005) stated that growth of red pepper (*Capsicum annum* L.) got stimulated at 2 and 4 Gy doses of gamma irradiation while inhibited by 8 and 16 Gy. Norfadzrin *et al*. (2007) recorded significantly decreased germination in tomato (*Solanum lycopersicon* L.) after its seeds were treated with different doses of gamma irradiation. A dose of 800 Gy decreased germination up to 48 % when compared to control. Kurtar (2009) observed stimulatory effects of low doses of gamma rays on germination and general growth behavior of pumpkin (*Cucurbita pepo*). Study revealed that 50 Gy caused 75% increase in germination of pumpkin. Majeed et al. (2010) elucidated that 8 Krad doses enhanced germination of *Lepidium sativum* L up to 97%. Cheng *et al*. (2010) stated that mini-tubers of potato (*Solanum tuberosum L.*) cultivar Shepody irradiated with different doses were both positively and negatively influenced. Doses 10-30 significantly improved vegetative growth and sprouting while doses above 30 Gy retarded growth characters of potato. Hegazi and Hamideldin (2010) reported that seeds of two varieties Sabahia and Baladi of okra (*Abelmoschus esculentus* L.) irradiated with different doses of gamma rays showed differential responses in terms of germination and growth and under different treatments. 300 Gy enhanced growth and germination of okra when dry seeds were irradiated in Balady variety.

El-Sherif *et al*. (2011) found both stimulatory and inhibitory effects of different doses of radiation ranged between 100-800 Gy on growth criteria of *Hibiscus sabdariffa* L. Generally, all the investigated growth parameters got enhanced at 600 Gy but decreased at intensive doses. Rahimi and Bahrani (2011) documented that growth, yield and fatty contents of canola (*Brassica napus* L.) showed decreasing tendency with increasing doses. Minimum growth was observed at 500 Gy. Marcu *et al*. (2013) have observed enhanced vegetative growth of lettuce (*Lactuca sativa*) at low doses. Germination %, germination index, plumule and radicle lengths and chlorophylls pigments were significantly increased by doses 2-30 Gy but decreased by 70 Gy. Khan *et al*. (2015) showed that germination and plant height of *Brassica napus* significantly increased at doses 5-15 Krad while a decrease in growth and germination was revealed at higher doses. Elangovan and Pavadai (2015) studied the effect of doses 10-60 Krad on the growth of Bhindi (*Abelmuscus esculentus* L.) which revealed that applied doses stimulated days to flowering, plant height and general vegetative growth of test plant.

Influence on storage quality of vegetables and fresh produce

Fresh produce such as vegetables and fruits are useful agricultural commodities used either in raw form or processed materials for different purposes. Fresh vegetables are generally perishable and require great care during storage to maintain their quality. Post-harvest transportation, marketing and storage of fresh produce is influenced by several factors which include storage conditions such as temperature, moisture, saprobes attacks and non-availability of storage facilities (Olaimat and Holley, 2012; Wani *et al*., 2014). Several strains of bacteria, fungi and other microorganism seek opportunities to contaminate vegetables and fruits making them unacceptable for consumption. Coating and fumigation to some extent decrease the rate of decay and spoilage of vegetables and fruits; however, they may not be valued by consumers due to concerns over health related issues. Since plucking from parent plants will initiate changes in metabolic activities of vegetables, triggering these activities in a suitable direction by appropriate mechanism are likely to help in maintenance of quality and durability. Gamma irradiation is one of such techniques which has been recommended by the International Atomic Energy Agency (IAEA) for processing and storage of fresh vegetables, fruits, juices and other food materials and doses ≥10 kGy have been identified as safe preservation tools (Alothman *et al*., 2009). In earlier studies ascorbic acid contents increased in celery, cabbage and lettuce while maintenance of carotenoids and vitamin C in carrots and cucumber were achieved in a dose range between 1 and 2 kGy (Bandekar *et al*., 2006).

Prakash *et al*. (2002) observed significantly reduced microbial count of spoilage fungi of tomatoes at dose 0.5 kGy without any unacceptable changes in chemical, sensory and quality parameters of stored tomatoes. Irradiated mushrooms (*Lentinula edodes*) stored for 20 days revealed firmness and high level of antioxidant activity at 1.0 kGy (Jiang *et al*., 2010). Improved chlorophyll contents, sensory and visual quality while reduced microbial load on fresh mint irradiated with 0.25-1 kGy was reported by Hsu *et al*. (2010). Sprouting, specific gravity and weight loss was significantly reduced while shelf life of potato increased as a result of pre-storage treatment with different doses of gamma irradiation in the range between 50 and 150 Gy (Rezaee *et al*., 2011). Mahto and Das (2014) also reported decreased sprouting and improved textural properties of potatoes under post-harvest treatment with gamma irradiation doses 0.04-1 kGy. Iqbal *et al*. (2013) demonstrated that 6 kGy radiation treatment was effective in reducing fungal load and aflatoxins in red chilies to significant level. Browning in cabbage has been successfully minimized by irradiation treatment with 2 kGy (Banerjee *et al*., 2015). Guerreiro *et al*. (2016) revealed effectiveness of 3 kGy irradiation for extension of shelf life and improvement of quality of cherry tomatoes stored at 4°C for 14 days.

Since fresh vegetable and fruits remain living even after detachment from plant, they tend to undergo biochemical and physiological variation in storage conditions resulting in production of secondary metabolites, structural and textural changes (Reyes and Cisneros-Zevallos, 2007; Ahmad and Siddiqui, 2015). These changes are important determinants in specifying shelf life and sensory attributes of fresh products. Consumers generally evaluate vegetables and fruits by firmness, odor, and aroma and skin color. These characters are influenced by several factors such as temperature, humidity in atmosphere, wounds development on fresh products, population of spoilage organisms, production of secondary metabolites etc. Treatment of fresh produce with ionizing radiation results in production of reactive oxygen species which may have healthy effects on ripening and shelf life of fresh produce by inhibiting oxidative stress and other biochemical atrocities (Kumar *et al*., 2014). Moreover, spoilage organisms can be effectively controlled by radiation doses. Inhibition of fungal, bacterial and other spoilage microbes in response to gamma irradiation may be associated with intensity and exposure duration of irradiation. Gamma irradiated induced cell wall disruption and hindering of spore formation in bacteria while germ tube initiation and mycelia growth retardation in spoilage fungi may be one of the possible causes of improved storage life and quality of vegetables and fruits (Kumar *et al*., 2014; Shahbaz *et al*., 2014).

CONCLUSION

Gamma irradiation is a suitable alternative to plant breeding for the creation of desired characters in cultivated plants. It can penetrate very deep into host tissues and is capable of genetic reshuffling with possible healthy mutations. It is generally apparent from different studies on ionizing radiation effect on cultivated plants that low doses have positive and healthy effects on plant growth parameters while higher doses cause injury and lethality. Moreover, gamma irradiation either alone or in combination with other techniques may significantly reduce decay and spoilage of fresh produce during storage conditions. Thus, for obtaining good results, low doses should be used in irradiation experiments. Since most of the vegetables are herbaceous in nature, they show different responses to radiation exposure as compared to other plants. Literature review reveals little work is done on radio sensitivity of vegetables therefore it is required that gamma irradiation effects on common vegetable be investigated in field conditions for healthy mutation in respect to growth and yield while in storage for maintaining quality and shelf life.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to Department of Botany, Hazara University, Mansehra, Khyber Pakhtunkhwa, Pakistan for supporting this research.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

Abdullah, Q., Mahmoud, A., Al-harethi, A., 2016. Isolation and Identification of Fungal Post-harvest Rot of Some Fruits in Yemen. PSM Microbiol., 01(1): 36-44.

Ahmad, M.S., Siddiqui, M.W., 2015. Factors affecting postharvest quality of fresh fruits. In: Postharvest Quality Assurance of Fruits (pp. 7-32). Springer International Publishing.

Alothman, M., Bhat, R., Karim, A.A., 2009. Effects of radiation processing on phytochemicals and antioxidants in plant produce. Trends Food Sci., 20(5): 201-212.

Al-Safadi, B., Simon, P.W., 1996. Gamma irradiation-induced variation in carrots (*Daucus carota* L.). J. American Soc. Hortic. Sci., 121(4): 599-603.

Banerjee, A., Suprasanna, P., Variyar, P.S., Sharma, A., 2015. Gamma irradiation inhibits wound induced browning in shredded cabbage. Food Chem., 173: 38-44.

Cheng, L., Yang, H., Lin, B., Wang, Y., Li, W., Wang, D., Zhang, F., 2010. Effect of gamma-ray radiation on physiological, morphological characters and chromosome aberrations of minitubers in *Solanum tuberosum* L. Int. J. Rad. Biol., 86(9): 791-799.

Dubey, A.K., Yadav, J.R., Singh, B., 2007. Studies on induced mutations by gamma irradiation in okra (*Abelmoschus esculentus* (L.) Monch.). Prog. Agric., 7(1and2): 46-48.

Elangovan, R., Pavadai, P., 2015. Effect of gamma rays on germination, morphological and yield characters of bhendi (*Abelmoschus esculentus* [L.] Moench). Hort. Biotechnol. Res., 1: 35-38.

El-Beltagi, H.S., Ahmed, O.K., El-Desouky, W., 2011. Effect of low doses γ-irradiation on oxidative stress and secondary metabolites production of rosemary (*Rosmarinus officinalis* L.) callus culture. Rad. Phys. Chem., 80(9): 968-976.

El-Sherif, F., Khattab, S., Goniam, E., Salem, N., Radwan, K., 2011. Effect of gamma irradiation on enhancement of some economic traits and molecular changes in *Hibiscus Sabdariffa*. Life Sci. J., 8(3): 220-229.

Guerreiro, D., Madureira, J., Silva, T., Melo, R., Santos, P.M., Ferreira, A., Verde, S.C., 2016. Post-harvest treatment of cherry tomatoes by gamma radiation: Microbial and physicochemical parameters evaluation. Innovative Food Sci. Emerg. Technol., 36: 1-9.

Hegazi, A.Z., Hamideldin, N., 2010. The effect of gamma irradiation on enhancement of growth and seed yield of okra [*Abelmoschus esculentus* (L.) Monech] and associated molecular changes. J. Hort. Forestry, 2(3): 38-51.

Hsu, W.Y., Simonne, A., Jitareerat, P., Marshall Jr, M.R., 2010. Low-dose irradiation improves microbial quality and shelf life of fresh mint (*Mentha piperita* L.) without compromising visual quality. J. Food Sci., 75(4): 222-230.

Iqbal, S.Z., Bhatti, I.A., Asi, M.R., Zuber, M., Shahid, M., Parveen, I., 2013. Effect of γ irradiation on fungal load and aflatoxins reduction in red chilies. Rad. Phys. Chem., 82: 80-84.

Jiang, T., Luo, S., Chen, Q., Shen, L., Ying, T., 2010. Effect of integrated application of gamma irradiation and modified atmosphere packaging on physicochemical and microbiological properties of shiitake mushroom (*Lentinus edodes*). Food Chem., 122(3): 761-767.

Kim, J.H., Chung, B.Y., Kim, J.S., Wi, S.G., 2005. Effects of in Planta gamma-irradiation on growth, photosynthesis, and antioxidative capacity of red pepper (*Capsicum annuum* L.) plants. J. Plant Biol., 48(1): 47-56.

Kim, J.S., Kim, J.K., Lee, Y.K., Back, M.W., Gim, J.K., 1998. Effects of low dose gamma radiation on the germination and yield components of Chinese cabbage. Korean J. Env. Agric., 17(3): 274-278.

Kumar, M., Ahuja, S., Dahuja, A., Kumar, R., Singh, B., 2014. Gamma radiation protects fruit quality in tomato by inhibiting the production of reactive oxygen species (ROS) and ethylene. J. Radioanalytical Nuclear Chem., 301(3): 871-880.

Kurtar, E.S., 2009. Influence of gamma irradiation on pollen viability, germinability and fruit and seed-set of pumpkin and winter squash. Afr. J. Biotechnol., 8(24): 6918–6926.

Mahto, R., Das, M., 2014. Effect of gamma irradiation on the physico-mechanical and chemical properties of potato (*Solanum tuberosum* L.), cv.'Kufri Sindhuri', in non-refrigerated storage conditions. Postharv. Biol. Technol., 92: 37-45.

Majeed, A., Khan, AR., Ahmad, H., Muhammad, Z., 2010. Gamma irradiation effects on some growth parameters of *Lepidium sativum* L. ARPN J. Agric. Biol. Sci., 5: 39–42.

Majeed, A., Muhammad, Z., Majid, A., Shah, A.H., Hussain, M., 2014. Impact of low doses of gamma irradiation on shelf life and chemical quality of strawberry (*Fragaria* x *ananassa*) cv.'Corona'. J. Anim. Plant Sci., 24(5): 1531-1536.

Marcu, D., Cristea, V., Daraban, L., 2013. Dose-dependent effects of gamma radiation on lettuce (*Lactuca sativa* var. capitata) seedlings. Int. J. Rad. Biol., 89(3): 219-223.

Melki, M., Marouani, A., 2010. Effects of gamma rays irradiation on seed germination and growth of hard wheat. Env. Chem. Letters, 8(4): 307-310.

Mollah, M.Z.I., Khan, M.A., Khan, R.A., 2009. Effect of gamma irradiated sodium alginate on red amaranth (*Amaranthus cruentus* L.) as growth promoter. Rad. Phys. Chem., 78(1): 61-64.

Norfadzrin, F., Ahmed, O.H., Shaharudin, S., Rahman, D.A., 2007. A preliminary study on gamma radio sensitivity of tomato (*Lycopersicon esculentum*) and okra (*Abelmoschus esculentus*). Int. J. Agric. Res. 2(7): 620–625. doi:10.3923/ijar.2007.620.625.

Olaimat, A.N., Holley, R.A. 2012. Factors influencing the microbial safety of fresh produce: a review. Food Microbiol., 32(1): 1-19.

Prakash, A., Manley, J., DeCosta, S., Caporaso, F., Foley, D., 2002. The effects of gamma irradiation on the microbiological, physical and sensory qualities of diced tomatoes. Rad. Phys. Chem., 63(3): 387-390.

Rahimi, M.M., Bahrani, A., 2011. Effect of gamma irradiation on qualitative and quantitative characteristics of canola (*Brassica napus* L.). Middle-East J. Sci. Res., 8(2): 519-525.

Reyes, L.F., Cisneros-Zevallos, L., 2007. Electron-beam ionizing radiation stress effects on mango fruit (*Mangifera indica* L.) antioxidant constituents before and during postharvest storage. J. Agric. Food Chem., 55(15): 6132-6139.

Rezaee, M., Almasi, M., Majdabadi Farahani, A., Minaei, S., Khodadadi, M., 2011. Potato sprout inhibition and tuber quality after post-harvest treatment with gamma irradiation on different dates. J. Agric. Sci. Technol., 13: 829-842.

Shahbaz, H.M., Ahn, J.J., Akram, K., Kim, H.Y., Park, E.J., Kwon, J.H., 2014. Chemical and sensory quality of fresh pomegranate fruits exposed to gamma radiation as quarantine treatment. Food Chem., 145: 312-318.

Silva, A.K.A., 2012. Sterilization by gamma irradiation. INTECH Open Access Publisher.

Singh, B., Datta, P.S., 2010. Effect of low dose gamma irradiation on plant and grain nutrition of wheat. Rad. Phys. Chem., 79(8): 819-825.

Subhan, F., Anwar, M., Ahmad, N., Gulzar, A., Siddiq, A.M., Rahman, S., Rauf, A., 2004. Effect of gamma radiation on growth and yield of barley under different nitrogen levels. Pak. J. Biol. Sci., 7: 981-983.

Thapa, C.B., 2004. Effect of acute exposure of gamma rays on seed germination and seedling growth of *Pinus kesiya* Gord and *P. wallichiana* AB Jacks. Our Nature, 2(1): 13-17.

Wani, A.A., Singh, P., Gul, K., Wani, M.H., Langowski, H.C., 2014. Sweet cherry (*Prunus avium*): Critical factors affecting the composition and shelf life. Food Pack. Shelf Life, 1(1): 86-99.

Zaka, R., Chenal, C., Misset, M.T., 2004. Effects of low doses of short-term gamma irradiation on growth and development through two generations of *Pisum sativum*. Sci. Total Env., 320(2), 121-129.