# Developments of Gamma Ray Application on Mutation Breeding Studies in Recent Years

Kamile Ulukapi and Ayse Gul Nasircilar

***Abstract*—**The aim of the plant breeding is to change and improve the genetic structure of plants to meet people requirements. For many years, traditional breeding methods have lead to a genetic bottle-neck in the genetic base of plants. Plant breeders have been used new techniques like as genetic engineering and mutation breeding to overcome the genetic bottle-neck problem. It was aimed that characters which were lost during evolution or suppressed to reveal with various breeding methods. Gene transfer is not been made in the mutation breeding but chromosomes are broken or genes are changed in the DNA structure. The occurrence of a natural mutation takes years. Therefore, creating a mutation with physical and chemical mutagens has been redounded to breeding studies. Induction of mutations provides the possibility to produce on a limited basis of desired genetic changes in germplasms. Gamma ray, which is a physical mutagen, is a widely used method of having diversity on many plant species and creating new variations. In the compilation, different gamma ray practices on multifarious plant species were studied.

***Keywords*—**Mutation breeding, gamma ray, plant, radiation practice.

## I. Mutation And Mutation Breeding

MUTATION is the process, in which genes are permanently alternated under environmental conditions while being transferred between generations [1]. As an addition to these alternations in nature, developing science also have provided a chance for mankind to create artificial mutations by using multi techniques. Chemical or physical factors that lead to mutation are called mutagens and living creatures that have had permanent hereditary changes are called mutants.

Mutations might occur in two ways; as alternations in amount or structure of chromosomes (Genome Mutation) and/or alterations on gene bases [1]. According to Van Harten, history of plant mutation spans back to 300 BC and the term mutation was used in 1901 for the very first time by Hugo De Vries. Hugo De Vries, at the final of his studies, reported that, heredity might be changed by another mechanism that is different than recombination and segregation [2]. However, the founder of mutation is Hermann J. Muller, who is a Nobel prize winner researcher [3,4].

Kamile Ulukapi, Akdeniz University, Vocational School of Technical Sciences, Organic Agriculture Programme, 07100, Antalya, Turkey

Ayse Gul Nasircilar, Akdeniz University, Faculty of Education, Department of Biology Education, 07100, Antalya, Turkey

Term 'Mutation Breeding' was firstly used in 1944 by Freisleben and Lein to explain the use of induction for product development on plants and development of mutant lines [5]. Classical breeding methods are still used effectively for the development of new species and to obtain expected superior features. Yet, use of current populations leads to a contraction in genes. This situation heads breeders on to new breeding technologies. Mutation breeding have been one of the alternative method for breeders as it provides the chance of obtaining some desired features that do not exist in the nature or got lost during the evolution.

## II. Mutation Breeding Methods And Advantages Of Gamma Ray Application

Mutation breeding techniques are grouped as chemical, physical and biological. The most used mutation breeding technique is physical mutagens, which leads to breaks on DNA double strand and have high energy radiation applications such as ultra-violet (UV) light, gamma rays and neutrons. The technique in which chemicals are used, causes some DNA bases to substitute [6]. Thus, chemical agents such as nitrous acid (a determining agent), intercalating agent (causes deletions, reading frame shifts or random base insertions) and alkylating agents (adding an ethyl group which causes the modified base formation) are used. The most used chemical among these is ethyl methane sulfonate (EMS), which is an alkylating chemical that causes gene mutation in high frequency and chromosome aberration in low frequency [7, 2]. Consequently, tissue culture techniques that causes somaclonal variations are used as biological mutagens. Although mutant frequency obtained from somaclonal variations are lower than classical mutagens, it is considered as a useful method as it causes the formation of mutant frequency in efficient highness and mutant development in a different spectrum [6].

Mutation breeding practices are an alternative breeding method against genetically modified organism (GMO's) practices and classical breeding methods as it is safe and easily affordable [8]. According to FAO and IAEA (2011) data, there are at least 3212 mutant species. According to FAO and IAEA (2012) data,maximum plant production is done in Asia ( 60%). This rates are followed by Europe (30%), North America (6%), Africa (2%) and Latin America-The Caribbean (2%) [9]. Considering on production lines, maximum mutant species are, cereals (48%), flowers (20%), legumes and pulses (14%) and vegetables, forge, edible oil plants and trees (3% portions) [10]. Ionized radiation method,

http://dx.doi.org/10.15242/IICBE.C0715044 

which was began to use in early 20th century, has a major role in breeding practices for the development of plants with superior features, more than 50 years [4]. Physical mutagens means less risk than chemical mutagens as any practices are not needed for cleaning the mutagens from the material [11], as it is non-toxic, and does not need detoxification after the practice [10].

## III. Gamma Ray Application On Plants

The most widely used physical mutagens are Gamma and X-rays [12, 13]. Being easily used has an important role on this applications spreading. New species have been obtained in many species such as Coriander [14], tomato [15], *Anthurium* [16] and mungbean [17] with gamma practices. It is seen in the study held in Urd bean (*Vigna muno* L.) in 2010 that, gamma application under low rates have been more effective, yet, mutant plants are only obtained as it is used with sodium azide [18]. The use of radiation technique with in vitro propagation over plants to outnumbered vegetatively is an effective technique in terms of obtaining variation, quick proliferation of mutants and obtaining disease-free mutants. This combination have been successfully applied over date palm, apple, potato, sweet potato and pineapple [19]. Gosal et al [20], have applied 20 and 40 Gy gamma rays over potato seedlings being seedled under in vitro conditions. Comparing to second year data of species under field application, these species under application have a higher resistance against late blight as 72%. Over the same species, on which 40 Gy gamma ray application is more effective, it is reported that, 40 Gy application has positively resulted through heat tolerance studies. Khan et al [11], have applied gamma ray on sugarcane calluses and reported that the 0.05 Kr gamma ray had a positive effect on some features that directly effecting yields and sugar content, such as plant height, cane thickness, green leaves per plant and tillers amount. On another study conducted on eggplant, chemical (Ethyl Methane Sulphonate and Diethyl Sulphate) and physical mutagens' effectiveness were compared over 5 eggplant species and it was determined that gamma rays, which were used as physical mutagens were more effective [21]. Turkish Atomic Energy Authority has determined the optimum dose for some species of wheat, barley, tobacco, safflower, cherries, rye, soybeans, canola, lentils, peppers, chickpeas, garlic, grapes and ac. As an addition , by doing gamma practices, they developed soy beans with high rates of efficiency and fat, tobacco varieties that resistant to blue mold disease, and chickpea lines that has high protein rates and is resistant to *Ascochyta blight*' [*Ascochyta rabiei* (Pass.) Labr.] [22, 23]. As an addition, new development studies for many species such as peas, wheat, barley, safflower, potato, melon, garlic, pepper, cherry and grape, continues. Saleem et al [24], have applied 50 Gy gamma ray on embryonic calluses of Basmati rice (*Oryza sativa* L.) species. While non-mutated calluses did not regenerate, mutated calluses' $M_2$ generation was seen to have resistance to salt and tolerance of these genotypes' have increased to 6 d/Sm from 2 d/Sm. In a similar way, Yaycılı and Alikamanoğlu [25] obtained plants from salt tolerated potato by applying gamma rays. As reported by Jain (2010), Gamma rays are used for the development biotic stresses, abiotic stresses and plant features in plants that reproduced from seeds; abiotic stresses and plant features in vegetatively reproduced plants. Jain [8] also reported that gamma rays could be used for many features of fruits (Table 1).

Table I
Improved Features In Some Fruits By Gamma Ray Application
(Directly Taken From Jain 2010).

| Fruit | Mutant Trails |
|---|---|
| Apple | Early maturing, red fruit skin colour, compact tree, russet-free fruit skin, variegated leaf, dwarf |
| Apricot | Earliness |
| Banana | Earliness, bunch size, reduced height, Tolerance to Fusarium oxysporu f sp. cubense (FOC) race 4, large fruit size, putative mutants resistant to Black sigatoka disease |
| Citrus | Seedless, red colour fruit and juice, Xanthomonas citri disease resistant, resistant to Tristeza virus |
| Japanese pear | Black spot disease resistance |
| Indian jujube | Fruit morphology, earliness |
| Loquat | Fruit size |
| Pineapple | Spineless, drought tolerant producing unmarketable fruits |
| Plum | Early flowering |
| Pomegranate | Dwarf |
| Papaya | Short, striated fruits, malformed top disease resistance, split stem |
| Pear | Disease resistance |
| Peach | Disease resistance, fruit size and yield |
| Date palm | Bayoud disease resistance |
| Mulberry | Tetraploids and cytochimeras, high rooting ability |
| Guava | Seedless, low seeded fruits, cluster fruiting, segmented fruits, cylindrical fruit shape |
| Jujube | Fruit shape, leaf shape and size variation |
| Strawberry | Thick and small leaf, light leaf colour, white flesh, and long fruit; Phytophthora cactorum resistance |

Malek et al [26] have developed two efficient and new mustard species as a result of their 700 Gy gamma application and mutation taken place through this practice. Sutarto et al [27], with their 20 Gy and 40 Gy gamma application, determined two mandarin and one pummelo species to have potencial in terms of being seedless plants and offered field practices over these species. Balloch et al [28], developed a high yield rice species as a result of their 150 Gy application. Another research group have developed a rice species that has lodging resistance, late maturity cycle, moderate resistance to blast, high yield potential, long grains and very high cooking quality [29]. Javed et al [30], at the end of their several dose application on *Brassica campestris* L. species, obtained a genotype and examined it for 2 years in terms of yield and yield-related features and reported that they obtained a hopeful genotype. Kavithamani et al [31], have developed two new soybean species that has high protein and less fiber content, by using this method. Okamura et al [32], have developed three new carnation varies as red, dark pink and double colored by using ion mutation and they reported that it is possible to reach a result by using this method in a short term. As an addition, there are more breeding studies of radiation applications on ornamental plants such as rose [33], chrysanthemum [34, 35] and African violets [36]. Majeed et al [37] have applied several doses gamma ray applications on *Lepidium sativum* L. species and they determined the optimum dose. In The Institute of Radiation Breeding in Japan, 146 mutant species that have exposed to gamma ray application were recorded and chrysanthemum has formed the majority (32) of these [38].

## IV. Result And Suggestions

Gamma ray applications are used widely to develop new species in plant breeding. Although researches are dense among field plants, ornamental plants fruit and limited vegetable studies also take place. As classical breeding studies take too much time, it is obvious that, mutation practices should spread among field plants and ornamental plants, as well. As an addition, as gamma rays do not pose a threat for humankind and environment and they are easily resulted, thus there has been a strong consideration that this application should be preferred.

Consequently;

The following reasons;

1. As being a supportive method for classical breeding methods,
2. Being safe for human and environment
3. Unlike GMO's, not transferring any foreign, new genes from outside,
4. Being available for several plant species
5. Not needing for after-application processes such as detoxification
6. Being available for mutual use with other mutation techniques and modern technologies such as in vitro propagation, leads gamma applications to be preferred. Future support will form an initiate for development of plant species groups, especially groups that have been worked on less, so far.

## References

[1] B. A. Tüylü, H. Sivas, Z. İncesu and E. Ergene, "Genetik", *TC. Anadolu Üniversitesi Yayını* No: 1953, Eskişehir, TÜRKİYE, p: 237, 2009.

[2] A. M. Van Harten, "Mutation Breeding Theory and Practical Applications". *Cambridge University Press*, London, UK, 1998.

[3] W-E Lönning, "Mutation Breeding, Evolution, and the Law of Recurrent Variation", *Recent Res. Devel. Genet. Breeding*, 2: 45-70, 2005.

[4] M. C. Kharkwal, "A Brief History of Plant Mutagenesis", Plant mutation breeding and biotechnology, Edited by Q. Y. Shu,, B. P. Forster, H. Nakagawa, Chapter, 2, p: 21, 2012 http://dx.doi.org/10.1079/9781780640853.0021

[5] B.P.Forstera and Q.Y.Shu, "Plant Mutagenesis in Crop Improvement: Basic Terms and Applications", Plant mutation breeding and biotechnology, Edited by Q. Y. Shu,, B. P. Forster, H. Nakagawa, Chapter, 1, p: 9, 2012. http://dx.doi.org/10.1079/9781780640853.0009

[6] M. Koornneef, "Gene Identification: Classical Mutagenesis in Higher Plants", *Molecular Plant Biology*, Edited by Philip M. Gilmartin and Chris Bowler, Oxford University Press, p: 1-13, 2002.

[7] Y-P. Lai, J. Huang, J Li and Z-R. Wu, "A New Approach to Random Mutagenesis In Vitro", *Biotechnology and Bioengineering*, vol: 86 (6), p: 622-627, 2004.

[8] S. M. Jain, "Mutagenesis in Crop Improvement under the Climate Change", *Romanian Biotechnological Letters*, vol. 15, no. 2, p: 88-106, 2010.

[9] Anonymous, *International Atomic Energy Agency Report 2011*, (https://www.iaea.org/sites/default/files/publications/reports/2011/anrep2011_full.pdf), 2012.

[10] C. Mba, "Induced Mutations Unleash the Potentials of Plant Genetic Resources for Food and Agriculture", *Agronomy*, 3, p. 200-231, 2013. http://dx.doi.org/10.3390/agronomy3010200

[11] S. J. Khan, H. U. Khan, R. D. Khan, M. M. Iqbal and Y. Zafar, "Development of Sugarcane Mutants Through *in vitro* Mutagenesis", *Pakistan Journal of Biological Sciences*, vol. 3, no. 7, p: 1123-1125, 2000. http://dx.doi.org/10.3923/pjbs.2000.1123.1125

[12] C. Mba, R. Afza and Q.Y. Shu, "Mutagenic radiations: X-rays, ionizing particles and ultraviolet", *In Plant Mutation Breeding and Biotechnology*, Edited by Q. Shu, , B.P. Forster, H. Nakagawa, Oxfordshire, UK, p. 83–90, 2012a http://dx.doi.org/10.1079/9781780640853.0083.

[13] C. Mba and Q.Y. Shu, "Gamma Irradiation", In Plant Mutation Breeding and Biotechnology", *In Plant Mutation Breeding and Biotechnology*, Edited by Q. Shu, B.P. Forster, H. Nakagawa, Oxfordshire, UK, p. 91–98, 2012b. http://dx.doi.org/10.1079/9781780640853.0091

[14] K. M. Salve and A. D. More, "Effect of Gamma radiation on Seed Germination, Seedling Height and Seedling Injury in *Coriandrum sativum* Linn." *International Journal of Life Sciences*, 2(3), p. 223-225, 2014.

[15] S Sikder, P. Biswas, P. Hazra, S. Akhtar, A. Chattopadhyay, A. M. Badigannavar and S. F. D'Souza, "Induction of mutation in tomato (*Solanum lycopersicum* L.) by gamma irradiation and EMS", *Indian Journal of Genetics and Plant Breeding*, 73(4), p. 392-399, 2013. http://dx.doi.org/10.5958/j.0975-6906.73.4.059

[16] D. Puchooa, "In Vitro Mutation Breeding of *Anthurium* by Gamma Radiation", *International Journal of Agriculture and Biology*, 7(1), 2005.

[17] C. Sangsiri, W. Sorajjapinun and P. Srinivesc, "Gamma Radiation Induced Mutations in Mungbean", *ScienceAsia*, 251-255, 2005. http://dx.doi.org/10.2306/scienceasia1513-1874.2005.31.251

[18] K. Makeen and S. Babu, "Mutagenic Effectiveness and Efficiency of Gamma Rays, Sodium Azide and Their Synergistic Effects in Urd Bean (*Vigna mungo* L.)", *World Journal of Agricultural Sciences*, 6 (2), p. 234-237, 2010.

[19] Anonymus, " *In Vitro* Techniques for Selection of Radiation Induced Mutations Adapted to Adverse Environmental Conditions". *Proceedings of a final Research Co-ordination Meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Shanghai*, China, 17–21 August 1998, 2001.

[20] S.S. Gosal, A. Das, J. Gopal, J.L. Minocha, H.R. Chopra and H.S. Dhaliwal, "In vitro induction of variability through radiation for late blight resistance and heat tolerance in potato". *Proceedings of a final Research Co-ordination Meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Shanghai*, China, 17–21 August 1998, p.7-13, 2001.

[21] J. Aruna, M. Parakash and B. S. Kumar, "Studies on Effect of Physical and Chemical Mutagens on Seedling Charecters in Brijal (*Solanum melongena* L.).", *International Journal of Current Research*, vol. 3, p.038-041, 2010.

[22] Z. Sağel, H. Peşkircioğlu and M. İ. Tutluer, "Nükleer Tekniklerin Bitki Islahında Kullanılması", *VIII. Ulusal Nükleer Bilimler ve Teknolojileri Kongresi*, 15-17 Ekim, p. 14, Kayseri, Türkiye, 2003.

[23] Z. Sağel, M. İ. Tutluer, H. Peşkircioğlu, Y. Kantoğlu and B. Kunter, "Nohutta Mutasyon Islahı", *X. Ulusal Nükleer Bilimler ve Teknolojileri Kongresi*, 6-9 Ekim, p. 313-320, 2009.

[24] M. Y. Saleem, Z. Mukhtar, A. A. Cheema and B. M. Atta, "Induced Mutation and *In Vitro* Techniques as a Method to Induce Salt Tolerance in Basmati Rice (*Oryza sativa* L.)", *Int. Journal Environment Sciences Tech*, 2 (2), p. 141-145, 2005. http://dx.doi.org/10.1007/BF03325868

[25] O. Yaycılı and S. Alikamanoğlu, "Induction of Salt-Tolerant Potato (*Solanum tuberosum* L.) Mutants with Gamma Irradiation and Characterization of Genetic Variations via RAPD-PCR Analysis", *Turkish Journal Biol*, 36: 405-412, 2012.

[26] M. A. Malek, H. A. Begum, M. Begum, M. A. Sattar, M. R. Ismail and M. Y. Rafiiv, "Development of Two high Yielding Mutant Varieties of Mustard [*Brassica juncea* (L.) Czern.] Through Gamma Rays Irradiation", *Australian Journal of Crop Science*, 6 (5): 922-927. 2012.

[27] I. Sutarto, D. Agisimanto and A. Supriyanto, "Development of Promising Seedless Citrus Mutants through Gamma Irradiation", Q.Y. Shu (ed.), *Induced Plant Mutations in the Genomics Era*. Food and Agriculture Organization of the United Nations, Rome, 2009, 306-308, 2009.

[28] A. W. Balloch, A. M. Soomro, M. A. Javed, H. R. Bughio, M. S. Bughio, T. Mohammed and N. N. Mastoi, "Development of High Yielding Rice

Mutant Variety Through Gamma Rays Irradiation", *The Nucleus*, 39 (3-4): 227-231, 2002.

[29] M. A. Schiocchet, J. A. Noldin, J. V. Raimondi, A. T. Neto, R. Marschalek, E. Wickert, G. N. Martins, E. Hickel, R. Knoblauch, K. K. Scheuermann, D. S. Eberhardt and A. De Andrade, "SCS118 Marques - New Rrice Cultivar Obtained Through Induced Mutation", *Crop Breeding and Applied Biotechnology*, 14: 68-70, 2014. http://dx.doi.org/10.1590/S1984-70332014000100012

[30] M. A. Javed, M. A. Siddiqui, M. K. R. Khan, A. Khatri, I. A. Khan, N. A. Dahar, M. H. Khanzada and R. Khan, "Development of High Yielding Mutants of *Brassica campestris* L. cv. Toria Selection Through Gamma Rays Irradiation", *Asian Journal of Plant Sciences*, 2 (2): 192-195, 2003. http://dx.doi.org/10.3923/ajps.2003.192.195

[31] D. Kavithamani, A. Kalamani, C. Vanniarajan and D. Uma, "Development of New Vegetable Soybean (*Glycine max* L. Merill) Mutants with High Protein and Less Fibre Content", *Electronic Journal of Plant Breeding*, 1(4): 1060-1065, 2010.

[32] M. Okamura, N. Yasuno, M. Ohtsuka, A. Tanaka, N. Shikazono, Y. Hase, "Wide Variety of Fower-Color and Shape Mutants Regenerated From Leaf Cultures Irradiated With Ion Beams", *Nuclear Instruments and Methods in Physics Research B,* 206, p. 574–578, 2003. http://dx.doi.org/10.1016/S0168-583X(03)00835-8

[33] H. Yamaguchi, S. Nagatomi, T. Morishita, K. Degi, A. Tanaka, N. Shikazono and Y. Hase, "Mutation Induced With Ion Beam Irradiation in Rose", *Nuclear Instruments and Methods in Physics Research B* 206, p. 561–564, 2003. http://dx.doi.org/10.1016/S0168-583X(03)00825-5

[34] A. Matsumara, T. Nomizu, N. Furutani, K. Hayashi, Y. Minamiyama, Y. Hase, “Ray Florets Color and Shape Mutants Induced by 12c5+ Ion Beam Irradiation in Chrysanthemum” , Scientia Horticulturae, 123, p. 558-561, 2010 http://dx.doi.org/10.1016/j.scienta.2009.11.004

[35] S. Salleh, Z. Ahmad, A.A. Hassan, Y. Awang, A.K. Sandrang and T.L. Abdullah, “Effect of Ion Beam Irridation on Morphological and Flowering Characteristics of Chyrsanthemum”http:// www.iaea.org/inis/ collection/NCLCollectionStore/_Public/44/096/44096857.pdf (available 22.05.2012), 2012

[36] L.B. Zhou, W.J. Li, S. Ma, X.C. Dong, L.X. Yu, Q. Li, G.M. Zhou and Q.X. Gao, "Effects of Ion Beam Irradiation on Adventitious Shoot Regeneration From In Vitro Leaf Explants of Saintpaulia ionahta", Nuclear Instruments and Methods in Physics Research B 244, p. 349–353, 2006 http://dx.doi.org/10.1016/j.nimb.2005.10.034.

[37] A. Majeed, A. Ur Rehman Khan, H. Ahmad and Z.Muhammad, "Gamma Irradiation Effects on Some Growth Parameters of *Lepidium sativum* L.", *Journal of Agricultural and Biological Science*, vol. 5, no. 1, p. 39-42, 2010.

[38] H. Nakagawa, "Induced Mutations in Plant Breeding and Biological Researches in Japan". Q.Y. Shu (ed.), *Induced Plant Mutations in the Genomics Era. Food and Agriculture Organization of the United Nations*, Rome, p: 48-54, 2009.