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A Review on the Role of Induced Mutation in Crop Improvement

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Abstract: **With the continued increase in the world population especially in the income deficit nations coupled with environmental changes and increase in demand for agricultural produce, plant breeders have to be more precise in developing crops with desirable features that will benefit both the farmers and consumers worldwide. This review focuses on the past and assesses the present progress in mutation breeding for crop improvement. Mutations are now artificially induced by physical (e.g gamma radiation, fast neutron irradiation, X-rays Thermal e.t.c) and chemical (ethylmethane sulphonate, Sodium azide, e.t.c) mutagen treatment of both seeds and vegetative parts of crops. 3,222 induced mutants have been released in Cereals, Vegetables, Fruits, Ornamental plants and Oil crops according to the International Atomic Energy Agency (IAEA) mutant database. As such, there exist high possibilities of sustainable food production for both present and future generations. Through mutation breeding, desirable mutants with useful agronomic traits (e.g tolerance to biotic and abiotic stress, drought tolerance, disease resistance) can be achieved in a short period of time. Early maturity of genetically regenerated crops is highly desirable as a useful tool for feeding the ever growing population of the world, especially under climatic change and limited arable land.**

Keywords: **Mutation Breeding, Gamma irradiation, mutant Database.**

1. INTRODUCTION

Induced mutation or mutagenesis is the sudden heritable changes in the genome of an organism not caused by genetic recombination or segregation but induced by physical, chemical or biological agents (Roychowdhury and Tah, 2013).

The cultivation of different crops varieties has continued to be successful over the past five decades due to the advent of induced mutation which plays a vital role in the development of crop varieties with desirable features all over the world. The widespread use of induced mutants in plant breeding programme across the globe has led to the official release of 3,222 plant mutant varieties from 170 different plant species in more than 60 countries throughout the world (FAO/IAEA, 2015). The developed varieties improve biodiversity and serves as a baseline for conventional plant breeding thus directly contributing to the conservation and use of plant genetic resource.

The concept of induced mutagenesis for crop improvement dates back to the beginning of 20th century. During the past 89years, mutation breeding has been successfully used for the improvement of crops and also to support the strides made using traditional methods of plant breeding (Amin *et al*., 2015). Induced mutation serves as the fastest and most effective way to alter the genetics of crop plants that may be challenging to facilitate through cross breeding and other breeding procedures (Khan and Wani, 2004). Different mutagens have been used by various breeders to induce genetic variability in various crops. Falusi et al reported improved germinability in three Nigerian sesame after fast neutron irradiation treatment in 2013. In addition, Daudu *et al*., 2012 reported increase in yield of African long Pepper (*Capsicum annum var. accuminatum*) in 2012. Furthermore, the results of Muhammad *et a*l., 2013 proved that Fast Neutron irradiation can

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be used to increase yield parameters of Sesame. In addition, V. Ravichandran and Jayakumar, 2015 also reported that Sesame exposed to gamma irradiation and Ethylmethane sulfonate (EMS) are efficient in causing useful mutations, although gamma irradiation proves more effective than Ethylmethane sulfonate in causing genetic variability in Sesame. Other mutagens such as Sodium azide, high energy iron beams and Ethylmethane Sulfonate (chemical Mutagen) among others have been use to cause useful variability among different crops in the world.

In 1942, the first disease resistant mutant was reported in barley (Usharani and Kumar, 2015). This led to the further work on mutagenesis leading to the release of mutants in several crops. Among these varieties, 1468 were of cereals and 370 of legumes. In cereals majority of cultivars came from rice (434), barley (269) and wheat (197) (Malausnyzki *et al*, 2000). The induction of mutation by Lewis John Stadler in the 1920s has already been recognized as a potential technique for crop improvement since the discovery of mutation effects of X-rays (Shu *et al*., 2012).

Genetic variability is highly desirable for developing new cultivars, which is induced by mutagen treatments and natural spontaneous changes. Spontaneous mutation rate is very slow and can't be exploited for breeding. This is the major reason why mutations are artificially induced using physical and chemical mutagens treatments. Stadler showed the occurrence of a strong phenotypic variation in barley seedlings and sterility in maize tassels after X-ray exposure in combination with radium. Later on gamma and ionizing radiations which constitute the most commonly used physical mutagens like alpha (α) and beta (β) particles and neutrons were developed at newly established nuclear research centers (Mba *et al.*, 2012).) As Compared to radiations, chemical mutagens tend to induce gene mutations, single-nucleotide polymorphisms (SNPs) rather than chromosomal mutations. Among the chemical mutagens, the mo st widely used chemical mutagen is EMS (ethyl methane-sulphonate), an alkylating agent.

EMS selectively alkylates purines especially guanine causing a thymine base over a cytosine residue opposite to the O-6-ethyl guanine during replication, which results in a point mutation at random (Sikora *et al.*, 2012). A majority of the alterations in EMS-mutated populations are GC to AT base pair transitions (Till *et al.*, 2007).

The role of mutation breeding in increasing food production and providing sustainable nutrition is well established (Goyal and Khan 2009 and Wani *et al*., 2015).

Table 1: Officially released mutant varieties

Country	Registration Date	No.of released varieties	Country	Registration Date	No. of Released Varieties
Albania	1996	1	Korea	1970-2008	35
Algeria	1979	2	Malaysia	1993-2002	7
Argentina	1962-2010	6	Mali	1998-2000	15
Australia	1967-2010	9	Mexico	0	5
Austria	1959-1995	17	Moldova	2004-2007	7
Bangladesh	1970-2010	44	Mongolia	1984-2004	4
Belgium	1967-1987	22	Myanmar	1975-2004	8
Brazil	1974-2005	13	Netherlands	1958-1988	176
Bulgaria	1972-2010	76	Nigeria	1980-1988	3
Burkina Faso	1978-1979	2	Norway	1978-1988	2
Canada	1964-2000	40	Pakistan	1970-2009	53
Chile	1981-1990	2	Peru	1995-2006	3
China	1957--2011	810	Philippines	1970-2009	15
Congo	1972	3	Poland	1977-1995	31
Costa Rica	1975-1996	4	Portugal	1983	1
Cote D'ivoire	1976-1987	25	Romania	1992	1
Cuba	1990-2007	12	Russia	1965-2011	216
Czech Republic	1965-1996	18	Senegal	1968	2
Denmark	1977-1990	21	Serbia	1974	1
Egypt	1980-2011	9	Slovakia	1964-1995	19
Estonia	1981-1995	5	Spain	2010	1
Finland	1960-1981	11	Sri Lanka	1970-2010	4
France	1970-1988	38	Sudan	2007	1
Germany	1950-2010	171	Sweden	1950-1988	26

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Ghana	1997	1	Switzerland	198	1
Greece	1969-1970	2	Syria	2000	1
Guyana	1980-1893	26	Taiwan	1967-1973	2
Hungary	1969-2001	10	Thailand	2006	20
India	1950-2010	330	Tunisia	1977-2007	1
Indonesia	1982-2011	29	Turkey	1994-2011	9
Iran	2004-2008	4	Ukraine	1997-2007	10
Iraq	1992-1995	23	United Kingdom	1966-1990	34
Italy	1968-1995	35	United States	1956-2006	139
Japan	1961-2008	481	Ubzekistan	1966-1991	9
Kenya	1985-2001	3	Viet Nam	1975-2011	55
			Total		3,222

FAO/IAEA Mutant Varieties Database July, 2015

2. SOME MUTANT VARIETIES OF THE WORLD

2.1 Asia

The FAO/IAEA of 2015 database reveals that more than half of the mutant varieties of the world were developed in Asia. China, Japan and India stand out as the Asian countries that have released the highest number of mutant varieties. Major breakthroughs made through induced mutation of various crops in each of the aforementioned three Asian countries are highlighted below.

2.1.1 China

A high yielding mutant variety of rice "Zhefu 802" derived from var. "Simei No 2", induced by gamma ray has a earliness or short growing period of 105-108 days, high yield potential even under little or low management and poor soil fertility, wide adaptability, high resistance to rice blast and tolerance to cold (Ahloowalia *et al*., 2004). For this reason, it was the most extensively cultivated rice variety between 1986 and 1994 with a total planting area of 10.6 million hectares during that period (Shu *et al*., 1997).

Two other mutant rice varieties where develop and released in 1970 and 2000s (Yuanfengzao and Yangdao respectively. They were grown in annual scale of up to one million hectares (Ministry of Agriculture, China, unpublished data).

Another two high yielding and early maturing rice varieties (Jiahezazhan and Jiafuzhan) with resistance to blast and plant hopper and also adapted to varying environmental condition were developed using pollen irradiation technique. They are now planted annually on 363,000 ha in Fujian province of china (Wang *et al*., 2008).

Soya bean varieties with smart characteristics have also been released (in China) using mutation breeding. An example is the mutant Soya bean varieties released by Genetic institute of Chinese Academy Sciences with desirable traits such as high yield, good grain quality, disease/insect resistance and drought/salinity tolerance. The total area cultivated with these varieties was more than $1 * 10^7$ ha (Zhu, 2008). Another Soya bean mutant cultivar "Heng series" and "Tiefeng18" were developed and released by the Soya bean Institute of Heilongjiang Academy of Agricultural sciences and cultivated on an area of more than 2.33×10^6 and 4×10^6 ha respectively (Ministry of Agriculture, China, unpublished data).

China have also successfully developed and released a vast amount of high yielding groundnut mutant varieties during the last few decades. The total cultivated area of more than 35 released mutant cultivars represent about 20% of the total area under groundnut cultivation in china (Qui *et al*., 1997).

2.1.2 India

Crop improvement efforts through induced mutation gained momentum in India in mid 1950's. Although the word's first variety of mutant cotton MA-9 induced by X-Rays with drought tolerance was released in 1948 by India (kharkwal et *al*., 2004). The Indian Agricultural Research Institute (IARI) in New Delhi, Bhaabha Atomic Research centre (BARC) in Mumbai, Tamil Nadu Agricultural University (TNAU) in Coimbatore and the National Botanical Research institute (NBRI) in Lucknow are the major centers for induced mutations for many crops and have been responsible for the development and release of vast amount of mutant varieties. Kharkwal *et al*., 2004 reported a total of 309 mutant cultivars of different crops belonging to 56 plant species were approved and/or released in India in the 20th century. The largest number of mutant cultivars was produced in ornamentals (119), followed by legumes (85) and cereals (74).

The mutant cultivars have contributed immensely towards India's food security and economic growth. Through mutation breeding, India has been able to successively increase the production of certain crops such as rice, groundnut, chickpea, mungbean, urdbean and castor in the Indian sub-continent.

The mungbean varieties Co-4, Pant Mung-2 and TAP-7 are still being widely grown around the country even though they were released in 1980s. The TARM-1, resistant to powdery mildew and yellow mosaic virus diseases is the first mutant variety of rabi/rice fallow to be released for fallow cultivation. Four of the nine mutant varieties of Blackgram (urdbean) released in India have been developed at Bhabha Atomic Research Center (BARC) in Mumbai. One of the mutant varieties, TAU-1 has become the most popular variety in Maharashtra state occupying over an area of about 500,000 hectares (over 95% of the total area under urdbean cultivation in Maharashtra). Since 1990, the Maharashtra Seed Corporation, Akola, has released 200,000 quintails of certified seeds of OATU-I to farmers, which in turn increased production to 129,000 quintails of Urdbean annually in Maharashtra. The national income generated amounts to Rs 300 crores (about 60 million US dollars) annually (Kharkwal *et al*., 2004).

Several varieties of mutant rice with increased yield have been released under the 'PNR' series; some of the varieties were dwarf and matured early (Chakrabarti, 1995). Two early maturing and ripening varieties, 'PNR 381' and 'PNR 102' were more prominent among farmers in Haryana and Uttar Pradesh states. Based on the data obtained from International Atomic Rice Institute (IARI), the value of rice (Paddy) is about 1.748 billion dollars per year (Ahloowalia *et al*., 2004).

2.1.3 Japan

The International Atomic Energy Agency Database regarding the number of mutant varieties in 2007 shows china as the country with highest number of induced mutant varieties with 638 released mutants, followed by China with 272 released mutant varieties and Japan with 233 released mutant varieties.

A number of induced mutagens amounting to a total of two hundred (200) mutant varieties through gamma ray, chemical mutagens and somaclonal variations have been registered in Japan (Nakagawa and Hitoshi, 2008). 61% of the two hundred mutants were developed through gamma ray irradiation at the Institute of Radiation Breeding. In 2005, two (2) direct- use cultivars and ninety seven (97) indirect use cultivars make up approximately 12.4% of total cultivated area in Japan.

2.2 Africa

Africa is blessed with vast amount of land covering three billion hectares out of which 1.3 billion is the agricultural land but unfortunately only 252 million hectares is arable (FAO, 2011). Africa is the centre of origin and also major producer of crops such as sorghum, millet, pearl millet, finger millet and African rice.

2.2.1 Egypt

The release of two semi dwarf mutants of rice 'Giza 176' in 1986 and 'Sakha 101' in 1997 led to increased rice yield to 8.9 tones/hectare, compared to 3.8tones/hectare in the rest of the world. 'Giza 176 was a more promising variety, with a potential yield of 10t0nes/hectare (Badawi, 2001).

2.2.2 Sudan

The advent of what is now mutation breeding in Sudan started twenty years ago with crops like cotton, sugar cane, banana, tomato, groundnuts and cereals. A mutant banana cultivar (Albeely) was released in 2003. It improved banana yield by 40% and has better crop stand and fruit quality. Albeely has gained wide acceptance by farmers because of its improved qualities. Drought tolerant groundnut mutant (Barberton- B-30-3) and tomato mutant varieties with resistance to tomato yellow leave curl virus (TYLC) are being evaluated in multi-location trials for their commercial release. More mutant varieties have been released, e.g. cotton mutant germplasm with resistance to bacterial blight and *Fusarium* wilt disease. These lines are being considered in the breeding program and promising lines are under field evaluation for release (Ali, 2008).

2.2.3 Ghana

Ghana as a country have also been making substantial efforts towards induced mutation breeding in the last two decades in order to achieve smart crops with desirable qualities. This led to the release of mutant varieties in two crops; cassava and cocoa. The use of gamma irradiation particles on the stem cuttings in cassava led to the production of "Tek bankye"; a mutant variety with high dry matter content of 40% and good pounding ability which was derived from a cross between Nigerian landrace Isunikaniyan (ISU) and the breeder's line TMS4(2) 1425, both from IITA, Nigeria. Similarly, efforts were also made at developing a breed of cocoa that would be resistant to swollen shoot virus (CSSV); this was achieved by the irradiation of vegetative buds of 'Almendo' (P30), 'Trinatario' (K.5) and 'upper Amazon (T85/799). Multi-location farm trials revealed increase in yield for farmers without symptoms of disease (Danso *et al*., 2008).

Table 2: Number of Officially released mutant cultivars with different types of mutagens

Mutagen used	Number of released mutant cultivars
Gamma rays	910
X-rays	311
Gamma chronic	61
Fast neutrons	48
Thermal neutrons	22
Ethylmethane sulphonate	106
Sodium azide	11
N-Nitrose-N-nitrosourea	57
N-Nitroso-N-methylurea	46

FAO, 2015

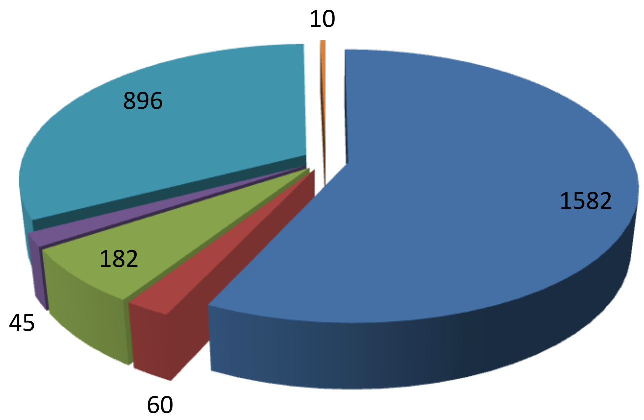

Figure 1: Number of induced mutants released in different continents

FAO/IAEA, 2008

Key: Asia -1582

Australia and the pacific – 10

Europe - 896

Latin America - 45

North America -182

Africa- 60

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3. APPLICATION OF MUTATION BREEDING IN BASIC RESEARCH

Globally, thanks to the "Green resolution" in the 1960 which presented a solution to world famine; developing countries like India and Pakistan were hit by serious food shortage. This played a tremendous role in curbing large scale starvation for about four decades. However, the world especially developing country is facing another major food crisis as a result of population explosion, rapidly increasing food prices, depletion of food reserves. All of these have resulted in malnutrition among the very large population of poor people around the world and the main reason for food security deterioration; increasing fertilizer and fuel prizes, unstable rainfall, severe drought conditions, divert of food gains into biofuel will remain for decades to come. According to the international summit of food reserve "the world will need three times the parent food reserve by 2050. Researchers are becoming worried that food reserve will get worse with population explosion especially among developing countries of the world and no measurable or significant increase in food production. It is also feared that the impact of global climate change will be a major threat to food security in the world (IRRI, 2006) especially countries vulnerable to high impacts of global warming and extreme temperatures. Temperature changes have a negative impact in food production, thereby increasing the risk of catastrophic food crises as well as changes in disease and pest distribution patterns.

The success of plant breeding in producing highly resistant varieties to abiotic stresses is dependent on research efforts related to physiology and molecular genetics (Khush, 2013).

The advent of induced mutation breeding is anticipated to give a realistic and feasible solution to further increase food production by increasing both grain production and stability. In this regard, induced mutagenesis is gaining grounds in plant molecular biology as a tool to identify and clone genes and to study their function and structure (FA0, 2009).

The application of mutation breeding has generated a large amount of genetic variability and is playing a significant role in plant breeding, genetics and advanced genomics studies. Mutation breeding has recently been integrated with molecular studies such as molecular marker techniques or high mutation rate screening techniques are becoming more powerful and effective in breeding crop varieties.

The field of mutation breeding is improving by the day: molecular breeding. Therefore induced mutation breeding will continue to play a major role in improving world food security in years to come. The widespread use of induced mutation techniques in plant breeding programs throughout the world has generated thousands of novel varieties in hundreds of crop species and billions of dollars in additional revenue (FAO/IAEA, 2005).

"The widespread use of induced mutation in plant breeding programmes has led to the release of elite mutant plant varieties. Such mutants play a significant role in contributing traits, quality and longer shelf life, enhanced stress tolerance and reduced agronomic input. The understanding mechanism of cytokinin action was elucidated with the identification of mutants with elevated cytokinin level (amp1), photomorphogenic mutant (det1, corp) cytokinin resistant and cell division mutants (Miklashevichs E. and)." Schmulling et al in 1997 identified cytokinin mutants such as Ckr1, ein2, cry1, stp1 and zea3 in *Arabidopsis thaliana* (Schmulling *et al.*, 1997). These mutants have elucidated the role of cytokinin regulated genes in diverse biological processes, ranging from cell division, photosynthesis, chloroplast development, disease resistance and nutrition metabolism.

4. CONCLUSION

Global food security continues to decline especially in the developing countries and plant breeders are under pressure to provide alternative means of food that will sustain the ever growing human population. Genetic variability is very slow with conventional breeding techniques; It may take long years of waiting before the variability can be achieved. Induced mutation provides a template for breeding crops with both agronomic and economic quality within a short period of time. Food crops generated through induced mutation breeding are significantly contributing to the global food production, nutritional security and improved livelihood.

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REFERENCES

[1] Ahloowalia, B.S., Maluszynski, M., Nichterlein, K. (2004). Global Impact of mutation derived varieties, *Euphytica* 135, 187- 204

[2] Ali, A.M. Overview of mutation breeding in Sudan. (2008). In: Book of Abstracts, FAO/IAEA *International Symposium on Induced Mutations in Plants*, Vienna, Austria, Abstract Page 8.

[3] Amin R, Laskar RA, & Khan S. (2015). Assessment of genetic response and character association for yield and yield components in Lentil (*Lens culinaris* L.) population developed through chemical mutagenesis, *Cogent Food & Agriculture*. 31(1): 1000715.

[4] Badawi, A.T. (2001). Yield gap and productivity decline in rice production in Egypt. In: Yield Gap and Productivity Decline in Rice Production, *International Rice Commission, FAO, Rome,* 429-441

[5] Chakrabarti, S.N. (1995). Mutation breeding in India with particular reference to PNR rice Varieties. *Journal of Nuclear Agriculture*, Biol. 24:73-82.

[6] Danso, K.E., Safo-Katanka, O., Adu-Ampomah, Y., Oduro, V., Amoatey, H.M., Asare, O.K., Ofori Ayeh, E., Amenorpe, G., Amiteye, S., & Lokko, Y. (2008). Application of induced Mutation techniques in Ghana: Impact, challenges and the future. Abstract p.108. In: Book of Abstracts, *FAO/IAEA International Symposium on Induced Mutations in Plants. Vienna, Austria,* 12-15.

[7] Daudu, O.A.Y., Falusi, O.A., Dangana, M.C., Bello, I.M. & Muhammad, L.M. (2012). Mutagenic effects of fast neutron irradiation on Morphological & yield characters of the African long Pepper (Capsicum annum var. accuminatum). *International Journal of Biological Research*,4,1 & 2, 19 & 245.

[8] Falusi, O.A., Muhammad, L.M. & Teixeira da Silver, J.A. (2015). Improvement of three Sesame varieties after fast neutron irradiation treatment. *Journal of Plant Development*. 22:5-77,

[9] FAO/IAEA. (2005). Induced plant mutations in the genomics era. *Food and Agriculture Organization of the United Nations, Rome*, 262-265.

[10] Goyal S, Khan S. A. (2009). Comparative study of chromosomal aberrations in *Vigna mungo* induced by ethylmethane sulphonate and hydrazine hydrate *Thai Journal of Agricultural Science*, 42(3):177-82.

[11] IAEA. (2015). IAEA mutant database. Vienna: *International Atomic Energy Agency*. (Accessed july 2015), Available from http://mdv.iaea.org/.

[12] IRRI. (2006). Bring Hope, Improving lives. Strategic plan, Manila.

[13] Khush, G. S. (2013). *Strategies for increasing the yield potential of Cereals*, case of rice as an example of Plant Breeding, 132: 430, 439.

[14] Khan S, Wani MR. (2004). Isolation of high yielding mutants in mungbean (*Vigna radiata* (L.) Wilczek). *Tropical Agriculturist*, 154, 51-59.

[15] Kharkwal, M.C., Pandey, R.N., Pawar. (2004). S.E. *Mutation Breeding for Crop Improvement*. In: Jain, H.K. and Kharkwal, M.C. (ed.) Plant Breeding – Mendelian to Molecular Approaches. *Narosa Publishing House, New Delhi*, 601-645.

[16] Maluszynski M, Nichterlein K, Van ZantenL, Ahloowalia BS. (2000). Officially released mutant varieties–the FAO/IAEA database mutation breeding reviews. The *JointFAO/IAEA Programme of Nuclear Techniques in Food and Agricultur*e, International Atomic Energy Agency Vienna, Austria, 88.

[17] Mba C, Afza R, Shu QY, Forster BP, Nakagawa H. (2012). Mutagenic radiations: Xrays, ionizing particles and ultraviolet. *Plant Mutation Breeding and Biotechnology*, 83-90.

[18] Qui, Q., Li, Z., Shen, F., Wang, Ch., Miao, H. (1997). Peanut breeding through mutation techniques in China, MMBNL 43, 6-7.

ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 7, Issue 3, pp: (29-36), Month: July - September 2020, Available at: www.paperpublications.org

[19] Roychowdhury, R. & Tah, J. (2013). A potential for crop improvement. In: Hakeem, H.R., Ahmad, P., Ozturk, M. editiors. Crop improvement: New approaches and modern techniques. *New York (NY): Springer*, 149-187.

[20] Schmülling T, Schäfer S, Romanov G. (1997) Cytokinins as regulators of gene expression. Physiologia Plantarum, 100(3):505-19.

[21] Shu, Q., Wu D., Xia, Y. (1997). The most widely cultivated rice variety 'Zhefu 802' in China and its geneology, MBNL 43, 3-5.

[22] Shu, Q.Y., Forster, B.P., & Nakagawa, H. (2012). Principles and Applications of Plant mutation Bredding. In: Shu, Q.Y., Forster B.P., Nakagawa, H. editors. *Plant Mutation breeding and biotechnology. Wallingford*: CABI; 301-325.

[23] Sikora P, Chawade A, Larsson M, Olsson J, Olsson O. (2012). Mutagenesis as a tool in plant genetics, functional genomics, and breeding. *International Journal of Plant Genomics.*

[24] Till BJ, Cooper J, Tai TH, Colowit P, Greene EA, Henikoff S, Comai L. (2007) Discovery of chemically induced mutations in rice by TILLING. BMC Plant Biology. 7(1):1.

[25] Usharani, K.S & Kumar, C.A. (2015). Mutagenic effects of gamma rays and EMS on frequency and spectrum of chlorophyll mutations in Urdbean (*Vigna mungo L*. Hepper). *Indian journal of Science and Technology.* 8(10):927.

[26] Wang, H.C., Qiu, S.M., Zheng, J.S., Jiang, L.R., Huang, H.Z., Huang, (2008). Y.M. Generation of new rice cultivars from mature pollens treated with gamma radiation. In: Book of Abstracts, *FAO/IAEA International Symposium on Induced Mutations in Plants*. P.89.

[27] Wani MR, Khan S, Kozgar MI. (2008). Induced chlorophyll mutations. Mutagenic effectiveness and efficiency of EMS, HZ and SA in mungbean. *Frontiers of Agriculture in China*. 12-15 Vienna, Austria.