REVIEW ARTICLE

Mutation Breeding: A Way Forward for Genetic Improvement in Mungbean

Ravinder Kumar[1]*, Nand K. Sharma[1], Savita Meena[2], Adithya P. Balakrishnan[3]

DOI: 10.18811/ijpen.v7i04.3

Abstract

Mungbean is a major food leguminous crop mainly cultivated in Asia. It is famous for its high protein, carbohydrate, and nutritional content. With the help of microorganisms located in their root nodules, the crop also maintain soil fertility through biological nitrogen fixation. This not only allows them to meet their own nitrogen needs, but it also improves the production of succeeding crops. One of the prerequisites for crop improvement is the availability of genetic variability. The capability to select improved genotypes in mungbean is limited by a lack of necessary diversity. Chemical and physical mutagens are frequently employed in Plant Mutation Breeding to boost crop productivity and resistance to diseases, insects, drought, and salt by creating genetic variability in crop plants. Mungbean is an early maturing crop often cultivatedon low-fertility land with minimal inputs. In the case of these crops, the selection pressure has been focused on stress adaptation rather than yield. As a result, improving the genetics of such crops to increase yield necessitates genetic reconstitution to generate diverse plant types. Induced mutations can contribute to the regeneration and restoration of diversity thathas been lost during the evolutionary process because of various pressures or adaptations. Thus, induced mutation or mutation breeding has a lot of potential for improving traditional agricultural crops like mungbean. In this paper, we look at many forms of mutations identified inmungbean crops by various scientists.

Keyword: EMS, Gamma Radiation, Mungbean, Mutation, Mutation Breeding.

International Journal of Plant and Environment (2021); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

Mungbean [*Vigna radiata* (L.) R. Wilczek] belongs to family Fabaceae and sub family papilionaceae with chromosome number 2n=2x=22 and estimated genome size of 579 Mb (Kang *et al*., 2014). It falls in the group of Asiatic species of the genus Phaseolus. The origin of crop is considered in India from where it had spread to Indo-china, Java, Eastern and Central Africa, West Indies, warmer parts of China and U.S.A. (Janoria *et al.* 1984). Mungbean is one of India's thirteen food legumes and, after chickpea and pigeonpea, the countries third most important pulse crop (Singh *et al.* 2015). India is the world's top producer of pulses (25% of global production), consumer (27% of global consumption), and importer (14%). Bangladesh, Pakistan, Sri Lanka, Thailand, China, Philippines, Myanmar, Indonesia, East Africa, Nepal, and Bhutan are the world's leading mungbean growers. Mung beans are a low-fat, cholesterol-free, moderately calorie, protein-rich food item. Unlike other beans and pulses, they have less antinutrient chemicals and no glycosides (Mishra *et al*., 2013). Mungbean has a protein content of 24-26 per cent, about 2.5 times that of cereals. 100 gram of dry seeds contain 347 calories and 23.86 gram of protein, or 43% of the daily protein requirements. Whole mung beans have greater dietary fibre content for their size, with 16.3 gram (43%) of fibre per 100 gram (Roshlim *et al.* 2015).

Mutation contributes in the creation of heritable changes in genetic material. Variation in numerous features like as growth habit, profuse podding, seed size, and extra earliness has also been achieved by mutation breeding (Kumar and Sing, 2009). The effectiveness of mutant breeding consists in the creation of suitable genetic variability in plant type and performance in terms of productivity and nutritional alternations without many related adverse effects (Wani *et al.,* 2017).

[1]Department of Genetics and Plant Breeding, COA, SKRAU, Bikaner-334006, Rajasthan, India

[2]Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology Udaipur-313001, Rajasthan, India

[3]Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi-110012

***Corresponding author:** Ravinder Kumar, Department of Genetics and Plant Breeding, COA, SKRAU, Bikaner-334006, Rajasthan, India, Email: rkjalandhara19397@gmail.com

How to cite this article: Kumar, R., Sharma, N.K., Meena, S., & Balakrishnan, A.P. (2021). Mutation Breeding: A Way Forward for Genetic Improvement in Mungbean. International Journal of Plant and Environment. 7(4), 255-262.

Conflict of interest: None

Submitted: 11/10/2021 **Accepted:** 20/11/2021 **Published:** 31/12/2021

Significance of Mutation Breeding In Mungbean

The presence of significant genetic variability, which allows for effective selection, is a primary requirement for any breeding programme (Roshlim *et al*., 2015). In recent years, induced mutations have been used as an important supplement to other traditional methods of plant breeding for crop improvement by developing new plant types (Girija *et al.,* 2013). Mungbean is a semi-arid and subtropical pulse crop, and information on

mutagenesis-induced population is limited (Singh, 2009). Even though the majority of the induced mutations are recessive and deleterious from a breeding point of view, induced mutations have made significant contributions to plant improvement programmes (Maluszynski *et al*. 1995).

Mutation breeding in mungbean is useful for recovering agronomically desirable characters or defected traits (Kharakwal, 2004). Many scientists have reported using induced genetic variability to develop new plant types. The primary goal of mungbean improvement in

India is to generate widely adapted, high-yielding, biotic stress resistant varieties that are responsive to improved cultural practises and have tolerance to adverse climatic conditions in locally adapted varieties (Singh and Chaturvedi, 1982). Pulse crops, including mungbean, have a lot of dry matter that go into stalk production, so the harvest index is very low. Mungbean and other pulses have traditionally been grown on low fertility land with low productivity using minimal inputs (Khan and Goyal, 2009). In the case of these crops, selection pressure has been focused on adaptation to stress conditions rather than yield. As a result, genetic improvement of such crops for increased yield necessitates their genetic reconstitution to evolve different plant types (Sadiq *et al.* 1999). Induced mutations can aid in the regeneration and restoration of diversity that has been lost during evolution as a result of adaptation to various stresses or adaptations (Haq and Shakoor 1980). Thus, mutation breeding or induced mutation has tremendous potential for improving traditional agricultural crops such as mungbean.

Induced Mutations in Mungbean

Many researchers believe that genetic variability in mungbean is limited and that breeding efforts would be more effective if the range of variability could be enlarged. This viewpoint has resulted in mutation research aimed at identifying mutagenic agents that are effective on mungbean and producing variant mutant forms that can be used in breeding programmes. In mungbean, mutation breeding has shown to be one of the most important approaches for developing and releasing new genotypes and high yielding cultivars. Various scientists have reported the use of chemical and physical mutagens to induce various types of mutations in mungbean (Table 1). In the case of mungbean, mutation breeding is a form of traditional breeding strategy that can be used to create desirable variety in a crop and could be a driving factor for evolution in addition to selection. Total 3,365 Mutant varieties are registered since 1950 in entire world. Among them 1703 and 108 varieties are developed using gamma rays and EMS, respectively (MVD, 2021). Mutation breeding in India has yielded considerable dividends, both in enhancing our knowledge on various mutagenesis processes relevant to crop improvement and for developing more than 345 improved mutant varieties belonging to 57 crop species. A close examination of the type of mutagens used and the number of mutant cultivars released in India indicates that largest number of mutant varieties (70 %) have been induced by physical mutagens, gamma rays being the most commonly used and also found to be highly successful (Kharkwal, 2004).

Total 39 mutant varieties in the world and 16 mutant varieties in India are released in Mungbean (Table 2 and Fig. 1). Among them 11 varieties in the world and 7 varieties in India are MYMV resistant (IAEA, 2021). In Mungbean, total 8 varieties have been developed using mutation breeding by B.A.R.C., Trombay (BARC, 2021). Khan (1983), Kulthe (2019), Haq and Shakoor (1980), Vairam *et al.* (2017), Sangsiri *et al.* (2005) and Vairam and Ibrahim (2014) reported significant induced morphological, quantitative, and genetic variability among various mungbean genotypes for various traits such as pollen fertility, leaf, flower, growth, height, pod number, seeds per pod, protein content, disease (MYVM) resistance and yield per plant using chemical and physical mutagenesis.

Flower Mutation

Flower mutations are difficult to recognize because mungbean flowers have a small degree of variation in shape and structure. Sangsiri *et al.* (2005) exploited 500 Gy gamma radiation to generate a cock's comb mutant with pollen sterility in two mungbean types, KPS 2 and VC 6468-11-1B. In a mutant population of mungbean generated by (30 kR, 40 kR, 50 kR, and 60 kR) gamma radiation, Singh and Rao (2007) observed large bracts flower. The structure of compound trifoliate leaves has also been connected to this trait. Auti (2012) used doses of gamma radiation of 30, 40, and 50 KR to induce mutation in the mungbean var. Vaibhav. A 50 KR dose efficiently produced a new mutant (*Lhb* mutant) such as large flower with dark yellow petals, dense and thick hairy pods, and black seeds. Girija *et al.* (2013) employed gamma radiation (20, 25, and 30 KR) and EMS to induce macro and micro mutations. All mutagenic treatments produced early flowering, white color flower, blue color flower, and pink color flower mutants. Kumar (2014) exploited gamma radiation (500 Gy) to treat the seeds of the F1 and F2 populations. Pollen sterility was seen in flower mutants that resembled a cock's comb.

Chlorophyll Mutation

Albina, xantha, viridis, and *maculata* were the four types of chlorophyll mutations exposed by Dahiya (1973) in two mungbean cultivars, Pusa Baisakhi and Hybrid-45, which were treated with gamma radiation. Khan (1981) produced *albino, xantha, chlorine, viridis, chlorotica*, and *virescenl* chlorophyll mutants using gamma radiation (30 kR) and EMS (0.1–0.4%) alone and in combination. Bahl and Gupta (1982) used

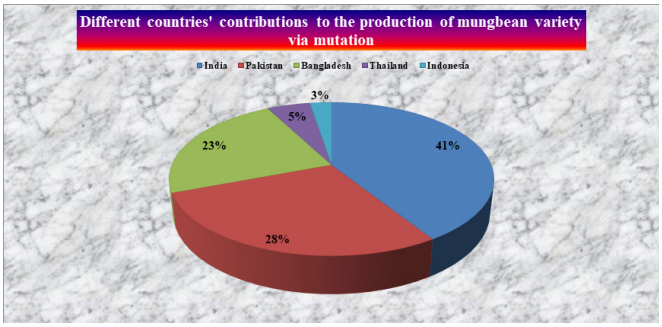

Fig. 1: Different countries' contributions to the production of mungbean variety via mutation

Table 1: Induction of various types of mutations in mungbean using chemical and physical mutagens

Mutations	*Mutagen*	*Reference*
Chlorophyll mutants	Gamma Radiation	Dahiya (1973), Sangsiri *et al* (2005), Mishra *et al.* (2013), Kumar (2014), Mishra and Singh (2014) and Arulselvi *et al*. (2019)
	Gamma Radiation and EMS	Wongpiyasatid *et al* (1998), Arulbalachandran and Mullainathan (2009[a]) and Gandhi *et al.* (2014)
	Gamma Radiation, EMS and its combination	Khan (1981), Bahl and Gupta (1982), Singh and Singh (2007) and Kumar *et al.* (2009)
	EMS, MMS and SA	Khan and Siddiqui (1993)
	Gamma Radiation, EMS , NG and MH	Das and Baisakh (2011)
Leaf mutants	Gamma Radiation	Malik *et al* (1986), Sangsiri *et al* (2005), Singh and Rao (2007), Mishra *et al*. (2013) and Kumar (2014)
	EMS and SA	Wani *et al*. (2004)
Flower mutants	Gamma Radiation	Sangsiri *et al* (2005), Singh and Rao (2007), Auti (2012) and Kumar (2014)
	Gamma Radiation and EMS	Girija *et al.* (2013)
Pod mutants	Gamma radiation	Rajput (1974), Shakoor *et al*. (1978), Khan (1982), Sangsiri *et al* (2005) and Auti (2012)
	Gamma Radiation and EMS	Vairam *et al.* (2017)
	EMS, HZ and SA	Wani *et al*. (2017)
Seed type mutants	Gamma Radiation	Dahiya (1973), Auti (2012) and Roshlim *et al*. (2015)
	EMS, HZ and SA	Wani *et al*. (2017)
Plant type and plant height mutants	Gamma radiation	Rajput (1974) and Rukesh *et al*. (2017)
	Gamma Radiation and EMS	Vairam and Ibrahim (2014)
Early and late flowering mutants	Gamma radiation	Rajput (1974)
Maturity type mutants	Gamma radiation	Tah and Saxena (2009) and Dewanjee and Sarkar (2018)
High and lower yielding mutants	Gamma Radiation	Dahiya (1973), Malik (1987), Sadiq *et al* (1999), Chavan *et al* (2000), Khattak *et al.* (2008) and Sarkar and Kundagrami (2018)
	Gamma rays and EMS	Gupta and Singh (1966), Wongpiyasatid *et al* (2000) and Khan and Goyal (2009)
	Gamma Radiation, EMS and its combination	Gupta *et al* (1996)
	EMS, HZ and SA	Wani *et al.* (2011)
	Gamma Radiation, EMS, NG and MH and its combination	Das and Baisakh (2013)
Protein mutants	Gamma Radiation	Dahiya (1973) and Tah (2006)
	Gamma Radiation and EMS	Arulbalachandran and Mullainathan (2009b) and Swain *et al*. (2014)
Disease (MYMV) resistance	Gamma Radiation	Haq and Shakoor (1980), Singh and Sharma (1983), Sadiq *et al* (2007) and Khattak *et al*. (2008)
	EMS	Raihan *et al*. (2018)
	Gamma Radiation and EMS	Vairam *et al*. (2016)
	Gamma Radiation, EMS and its combination	Gupta and Singh (1982)
Pollen fertility	Gamma Radiation	Tah (2006)
	Gamma Radiation and EMS	Khan and Goyal (2009)
	EMS and SA	Kulthe (2019)
	Sodium Azide	Khan *et al* (2006)
	Gamma Radiation, EMS and its combination	Khan (1981)
	Gamma Radiation, EMS, NG and MH	Das and Baisakh (2020) and Das *et al*. (2021)

EMS, Ethyl methane sulphonate; HA, Hydroxylamine; kR, kilorad; NG, Nitroguanidine; MMS, Methylmethane sulphonate SA, Sodium Azide; HZ, Hydrazine.

Table 2: Mungbean mutant cultivars have been released in India and have been certified for cultivation

Mutant Variety	*Year of release*	*Mutagen*	*Type of Mutant development*	*Details about character improvement*
Dhauli (TT9E)	1979		F1 with one mutant	High yield, MYMV resistance with early maturity
Pant Moong 2	1982	Gamma rays	Use of an induced mutant directly	MYMV resistance, Higher pods and yield
Co 4	1982	Gamma rays	Use of an induced mutant directly	High yield, early maturity and resistance to drought
ML 26-10-3	1983	Gamma rays	Use of an induced mutant directly	MYMV resistance and high yield
TAP-7	1983	Gamma rays	Use of an induced mutant directly	Early maturity, resistance to mildew and leaf spot, higher yield
MUM-2	1992	EMS	Use of an induced mutant directly	Disease resistance and high yield
BM 4	1992	EMS		High yield, MYMV resistance with early maturity
LGG 450	1993	Gamma rays		High yield, MYMV resistance with early maturity
LGG-407	1993	Gamma rays		High yield, MYMV resistance with early maturity
TARM-2	1994	Gamma rays	Use of an induced mutant directly	High yield and powdery mildew disease resistance
TARM-18	1996	Gamma rays	F1 with one mutant	High yield and resistance to powdery mildew disease
TARM-1	1997	Gamma rays	Use of an induced mutant directly	High yield, resistance to powdery mildew disease and medium maturity
TMB-37	2005		F1 with one mutant	
TM-96-2	2007	Gamma rays	F1 with one mutant	
TJM-3	2007		F1 with one mutant	MYMV resistance with early maturity, resistance to powdery mildew, Rhizoctonia root-rot disease resistance, and large seeds
TM 2000-2	2010			Resistance to powdery mildew and suitable for rice fallows

EMS, Ethyl methane sulphonate
Source: http://nucleus.iaea.org/sso/NUCLEUS.html?exturl=http://www-mvd.iaea.org/MVD/default.htm

gamma radiation (20 kR, 30 kR, 40 kR, and 50 kR), EMS mutagens (0.2 and 0.4%), and their combinations on the seeds of two mungbean types, ML-5 and K-851. Among the more than 100 M1 plants studied, albina and xantha types are more common than those seen in the M2 generation. When subjected to gamma rays and EMS, chlorophyll mutations were not found in variety 'K-851,' but they were found in variety 'ML-5' when exposed to high doses of gamma rays (40 kR) and EMS (0.2 %, 12 h). Three distinct chlorophyll (*albino, chlorina,* and *viridis*) mutants were identified by Khan and Siddiqui (1993) as the concentration of various mutagens increases, so does the frequency of chlorophyll mutants. Wongpiyasatid *et al.* (1998) used gamma radiation and EMS mutagens to induce mutation in mungbean variety. The first pair of single leaf *albina, xantha, chlorina, viridis*, and dark green appeared. Sangsiri *et al*. (2005) employed 500 Gy gamma radiation to induce chlorophyll mutations in *albino*, coppery leaf, light-green leaf, variegated leaf, waxy leaf, white streak leaf, and xantha leaf mungbean varieties. The four chlorophyll mutations discovered by Kumar *et al*. (2009) were *Xantha* > *Chlorina* > *albina* > *viridis* in PS 16 and *Xantha* > *albina* > *chloria* > *viridis* in Sona variety of mungbean, respectively. EMS generates more chlorophyll and morphological mutants than gamma rays, according to Arulbalachandran and Mullainathan (2009[a]). EMS was reported to be the most effective in causing chlorophyll mutation in *albina, xantha, chlorina, straita,* and *viridis* by Das and Baisakh (2011). Chlorina has the highest frequency of mutations, followed by xantha. Mishra *et al*. (2013) employed gamma radiation at different doses (20, 30, 40, 50, and 60 kR) to induce mutation in two mungbean varieties, Sujata and TARM-1. Both varieties exhibited chlorina, xantha, albina, viridis, and sectorial chlorophyll macro-mutations. Using gamma radiation (20, 30, 40, 50, and 60kR) and EMS (10, 20, 30, 40, and 50 mM) mutagens, Gandhi *et al*. (2014) identified four forms of chlorophyll mutations: albina, xantha, chlorina, and viridis. Kumar (2014) identified albino, coppery leaf, lightgreen leaf, variegated leaf, waxy leaf, white streak leaf, and *xantha* leaf mutations in F1 and F2 mutant populations (500 Gy) resulting from mating between two cultivars K-851 and MM-6468-1. Mishra and Singh (2014) found a wide range of chlorophyll mutations, including *albino, xantha, chlorina, viridis,* and *sectorial*, using five different gamma ray dosages (20, 30, 40, 50, and 60 kR). Arulselvi *et al*. (2019) identified chlorophyll mutations in three green-gram varieties, CO5, CO(Gg)7, and VBN(Gg)3, after gamma irradiation at 550 Gray and 600 Gray. Five different types of chlorophyll deficient mutants were found in some of the mutant lines.

Leaf Mutation

Malik *et al* (1986) identified three types of leaf mutants. The serrated leaf mutant was obtained at 60 KR in cultivar Pak 32, whereas the unifoliate and narrow leaf mutants were obtained at 30 KR and 60 KR doses in cultivar 6601. Sangsiri *et al* (2005)

observed leaf mutants such as lanceolate leaflet, narrow rugose leaflet, multiple leaflet, round-cuneat leaflet, unifoliate leaf and wrinkled leaf in munbean varieties by using 500 Gy gamma rays. Singh and Rao (2007) employed four dosages of gamma radiation (30 kR, 40 kR, 50 kR, and 60 kR) to induce mutation in two mungbean varieties (TARM 1 and Sujata). Leaf mutants with unifoliate, bifoliate, quadrifoliate, and pentafoliate leaves have been identified. Sujata had a wider spectrum of morphological alterations than TARM 1. Mishra *et al*. (2013) used gamma radiation (20, 30, 40, 50, and 60 kR) to induce morphological variation in the seeds of two mungbean varieties, Sujata and TARM-1. The most common morphological mutations in variety Sujata were quadrifoliate, and mutations such as trailing type, modified inflorescence, and simple leaf mutants emerged with the least frequency. Kumar (2014) produced leaf mutation such as lanceolate leaflet, narrow rugose leaflet, multiple leaflet, round-cuneat leaflet, unifoliate leaf and wrinkled leaf in F1 and F2 mutant population by using gamma radiation (500 Gy). Wani *et al*. (2014) treated the seeds of the mungbean variety Pusa Baisakhi with 0.3 per cent and 0.4 per cent ethylmethane sulphonate (EMS) and 0.03 per cent and 0.04 per cent sodium azide (SA) for 6 hours. Leaf abnormalities in shape, size, and number were found (bi-, tetra- and pentafoliate). The EMS treated population had the most leaf abnormalities (7.10%), followed by the SA treated population (4.20 per cent). EMS and SA treatments resulted in bifoliate leaves.

Pod Mutation

In a mungbean crop, Rajput (1974) noticed that pods per plant increased in all treatments (except 15 kR) as compared to the control. In the 25 kR treatment, one plant with lengthy pods was discovered. When compared to the control, this plant produced more beans per pod. However, according to Shakoor *et al.* (1978) irradiation decreases the number of pods per plant. Higher exposures significantly reduced the number of pods per plant in variety 6601. Khan (1983) treated seeds of the mungbean variety PS-16 with gamma radiation. In the M*2* generation, both the number of seeds per pod and the length of the pods were reduced. Sangsiri *et al.* (2005) identified a lobed pod mutation in mutant populations generated by 500 Gy gamma radiation, with fewer seeds per pod. Vairam *et al.* (2017) observed that out of 100 mutants of two greengram genotypes *viz*; Co (Gg) 7 and NM 65, produced by gamma irradiation (400, 500, and 600 Gray) and Ethyl Methane Sulphonate treatments (10, 20, and 30 milli Molar), 22 mutants were tolerant, 42 mutants were medium shattering, 29 mutants were highly shattering, and 7 mutants were very highly shatter. To treat the seeds of the mungbean variety, Wani *et al.* (2017) used three chemical mutagens. Pod mutations with increased length and girth over the control were detected in the M3 generation. The plants appeared to be normal, with larger pods.

Seed Type Mutation

Out of a total of 1020 grains, only two M2 progenies were found to be segregated for grain size and seed color Dahiya, 1973. On a weight basis, the grain size of these mutants was double than that of the control. Seed colour changes were most common in mutants. Roshlim *et al*. (2015) employed seven dosages of gamma radiation to treat the seeds of the Kampar mungbean cultivar (100, 200, 300, 400, 500, 600, and 700 Gray). The colour of the seeds varies from green to brownish-green, brown, and finally black. The LD50 treatment not only changed the colour of the seed but it also changed the morphology of the seed, which went from rounded- box to wrinkle. Auti and Apparao (2009) used gamma radiations, EMS, and SA to treat the seed of the mungbean cultivars *viz*; Vibhav and Kopargoan and found a wide range of differences in the seed shape (round, wrinkled, and elongated), seed size (little, bold), and seed colour (brown, dark green, yellowish green, and black). Mungbean seed size was observed to vary when treated with EMS and nitrozomethyl carbamide (Singh and Chaturvedi 1982).

Plant Type And Plant Height Mutation

Plant height variation in mungbean was observed by Rajput (1974) as a result of gamma radiation. The plant height was reduced from 25 kR and higher doses of radiation. There was a probable stimulatory effect at 10 and 20 kR. There is a decrease at 15 kR. Three dwarf plants with narrow, dark green leaves were found the 40 kR treatment. Vairam and Ibrahim (2014) found in the case of EMS treatment, mean plant height decreased from 10mM (8.26) to 30mM (18.30) in CO (Gg) 7 and from 10mM (5.62) to 30mM (28.27) in NM 65, with a decreasing trend as EMS doses were increased. Rukesh *et al.* (2017) irradiated the seeds of two mungbean cultivars, CO 6 and CO 8, with 350, 450, and 550 Gy of gamma rays. The M1 plant height on the 30th day decreased as the mutagen dose increased. The height loss in CO 8 was greater than in CO 6. When mutagen treatment doses were compared, 550 Gy of gamma ray caused the greatest reduction in plant height in CO 6 and CO 8.

Early and Late Flowering Mutation

Early maturity mutants are created as a result of physiological alterations and enhanced production of flowering hormones, which are generally associated with mutagens, according to Jana (1962). When the dose of gamma radiation was increased, Rajput (1974) observed that mungbean flowering was delayed. Excessive and continuous vegetative growth or mitotic arrest in the floral primordia can cause flowering to be delayed.

Maturity Type Mutation

The main causes of early and late maturity in mutants (Sparrow, 1966), changes in phytohormones and a reduction in the photoperiodic cycle. Priya Tah (2009) used 10, 20, 30, and 40 Gy to create novel mungbean mutants with synchronized maturity in two mungbean genotypes, K851 and Sona. Tah and Saxena (2009) found synchronously growing plants mostly at 30 Gy doses of -radiation, but to a lesser extent at 10, 20, and 40 Gy doses. Flowering in 'K851' took a week less (12 days) than in the control (18 days). Late pod maturity was found in both 'K851' and 'Sona' at higher doses, with the exception of early pod maturity in 10 Gy. Dewanjee and Sarkar (2018) used four gamma ray doses to create mutations in two mungbean varieties: K-851 and Sona mungbean (100, 200, 300 and 400 Gy). Mutants with synchronous maturity for more than 85 per cent of pods were

found in the S14 family of K-851, which could allow for crop harvesting within the same period, reducing crop harvesting cost.

High and Lower Yielding Mutation

According to Dahiya (1973), which is connected to a decrease in seed yield due to poor seed setting and more foliage produced on the plants. MUM-1, MUM-2, MUM-3, and MUM-4 have been found as higher yielding mutants that have also been released as a variety by Gupta *et al* (1996) using gamma rays, EMS, and a combination of gamma rays and EMS mutagens. In the munbean varieties Pak 22 and RC71-27, Malik *et al* (1986) found two higher yielding mutants caused by gamma radiation (5 KR to 80 KR). The mutants were released as commercial varieties in 1986 by the Punjab Seed Council under the names "NIAB Mung 121-25" and "NIAB Mung 19-19," respectively. Sadiq *et al.* (1999) established the NIAB MUNG 98 as a new high producing mungbean variety using gamma radiation-induced mutation. That variety was MYVM resistant and produced more pods per plant. In a mungbean crop, Chavan *et al.* (2000) used three doses of gamma radiation (10, 15 and 25 kR). A new higher yielding mutant was discovered in this crop and introduced as BM 4, a new variety. Mutant lines M5-5, M5-1, and M4-2 were discovered to produce excellent yields, developed using 500 Gy and 1% EMS to treat two mungbean varieties' (KPS1 and CN36) seeds by Wongpiyasatid *et al*. (2000). Using 0.20, 0.30, and 0.40 KGy doses of gamma rays, Khattak *et al.* (2008) isolates higher yielding plants in two varieties of mungbean (NM 92 and NM 98). In the M4 generation, Khan and Goyal (2009) found that the mutants K-851-B (0.2 % EMS) and PS-16-B (20 kR gamma rays) yielded the highest seed yields of 17.30 and 20.16g, respectively, as compared to their respective controls, which yielded 8.85 and 12.85 g. Wani *et al.* (2011) found mutants NM-1-A, NM-1-B, NM-1-C, and NM-1-D, which exceeded the untreated control population in terms of yield and yield components. Sujata and OBGG 52 mungbean varieties were mutated by Das and Baisakh (2013). In 10 plants and twelve plants, Sujata and OBGG 52 yielded significantly more than their parent varieties. For mutant breeding, Sarkar and Kundagrami (2018) chose three mungbean varieties: B1, Pusa-9632, and K-851. They found that the plants had shorter plant heights (13-40 % lower than controls) and more branches than the controls.

Pollen and Seed Fertility

Khan (1983) found that as the doses of gamma rays and EMS were raised, pollen and seed fertility decreased, both individually and in combination. Tah (2006) found pollen fertility in two mungbean varieties (K851 and Sona) exposed to gamma radiation at 10, 20, 30, and 40 KR. The highest reduction in pollen fertility was observed at 40 KR gamma radiations. In both the K-851 and PS-16 mungbean cultivars, Khan and Goyal (2009) discovered that EMS (0.1 and 0.2 %) had a more severe effect on pollen fertility than gamma radiation (20 and 40 KR). In comparison to var. Pusa Baisakhi, Khan *et al*. (2004) found that var. K-851 had the highest reduction in pollen fertility. A failure of homologous pairing during meiosis could lead to high pollen sterility. Pollen sterility was found to be highest at 11.52 per cent in 0.15 per cent concentrations, lowest at 0.05 per cent, and highest at 9.86 per cent in 0.10 per cent concentrations of EMS, according to Kulthe (2019). Swain *et al*. (2019[a]) used physical and chemical mutagens and found that pollen sterility and seed sterility in both genotypes were considerably reduced in all treatments when compared to the control. At 60kR, Das and Baisakh (2020) found 7.81 per cent pollen sterility, while at 20kR, minimum lethality was 16.5 per cent and pollen sterility was 2.11 per cent. For seed treatment of the OBGG-52 variety of green gramme, Das *et al*. (2021) utilized three doses of Gamma rays, Ethyl methane sulphonate, Nitrosoguanidine, and Maleic hydrazide individually and in combination. Pollen sterility increased with increasing EMS dosages, from 1.62 per cent at a low dose to 5.89 per cent at a high dose (0.6 %). Pollen sterility is 6.71 per cent at 60 kR and 1.06 per cent at 20 kR.

Protein Mutants

Radiation treatments, according to Dahiya (1973), were ineffective in creating significant variations in protein quality. The variety of methionine and tryptophan content in the control and irradiated plants shows this. Tah (2006) employed two mungbean cultivars (K851 and Sona) to analyse increased protein mutations generated by gamma radiation (10, 20, 30, and 40 KR). Swain *et al*. (2014[b]) used SDS PAGE to analyse seed protein (albumin and globulin) from 30 genotypes of mungbean, comprising 22 mutants, two parents, two improved varieties, and four Odisha land races. In comparison to the control, seed protein content increased progressively as the concentration of both gamma rays and EMS increased, according to Arulbalachandran and Mullainathan (2009[b]). At 0.1 % EMS, seed protein content was higher than control, followed by 60 kR of gamma rays.

Disease (MYMV) Resistance

According to Haq and Shakoor (1980), six mutant lines were confirmed in the Mutant population after 128 single plant selections. The moderately resistant mutant line 3854 kg/ha has an excellent yield potential. MUM-1, MUM-2, and MUM-3 were found to be extremely tolerant of MYMV, however MUM-4 was only moderately tolerant of MYMV, according to Gupta *et al* (1996). MUM-1, MUM-2, and MUM-3 were developed by seed treatment with 0.2 % EMS. An ML 26/10/3 Line with moderate MYMV resistance was discovered by Singh and Sharma (1983). It was evaluated with a 10 KR gamma radiation dose. Sadiq *et al*. (2007) developed high yielding mungbean cultivars with big seed size and tolerance/resistance to mungbean yellow mosaic virus (MYMV) by crossing a local small seeded cultivar 6601 that is tolerant to MYMV with alien, large seeded kinds that are very vulnerable to MYMV. The reciprocal crosses between both kinds, as well as F1, were also exposed to 100 Gy gamma radiations. Khattak *et al.* (2008) used three doses (0.20, 0.30 and 0.40 KGy) of gamma radiation to induced mutation in two varieties (NM 92 and NM 98) of mungbean for selection of MYMV resistant plant. Based on field scoring, Vairam *et al.* (2016) identified yellow vein mosaic virus resistant mutants M5, M18, M26, M46, M54, M58,

M70, M71, M92, and M98. Raihan *et al.* (2018) found 13 potential M4 generation lines that were MYMV resistant and tolerant, as well as high yielding.

Conclusions

Mungbean breeding progress has been restricted by a narrow genetic base. In the case of mungbean, mothbean and other highly self-pollinated crops, the selection pressure has been focused on stress adaptation rather than yield. Induced mutations have been utilized as an useful supplement to other traditional plant breeding strategies for improving crops and establishing novel plant varieties in recent years. Induced mutations can help in the regeneration and restoration of diversity that has been lost during evolution as a result of various pressures or adaptations. But some time induced mutation causes more drastic effect in most of crops.

References

Arulbalachandran, D., and Mullainathan, L. 2009[a]. Changes on protein and methionine content of black gram (*Vigna mungo* (L.) Hepper) induced by gamma rays and EMS. *American- Eurasian Journal of Scientific Research*, **4**:68-72.

Arulbalachandran, D., and Mullainathan, L. 2009[b]. Chlorophyll and morphological mutants of black gram (*Vigna mungo* (L.) Hepper) derived by gamma rays and EMS. *Journal of Phytology*, **1**(4).

Arulselvi, S., Suresh, S., and Dhole, V. J. 2019. Occurrence of chlorophyll deficient mutants in the mutated populations of greengram (*Vigna radiata* (L.) Wilczek). *Electronic Journal of Plant Breeding,* **10**:303-306.

Auti, S. G. 2012. *Lhb* Mutant–A Novel Mutant of Mungbean (*Vigna radiata* (L.) Wilczek) Induced by Gamma Radiation. Bioremediation, *Biodiversity and Bioavailability*, **6**: 87- 93.

Auti, S. G., and Apparao, B. J. 2009. Induced mutagenesis in mungbean (*Vigna radiata* (L.) Wilczek). Induced plant mutations in the genomics era. *Food and Agriculture Organization of the United Nation, Rome, Italy*, 97-100.

Bahl, J. R., and Gupta, P. K. 1982. Chlorophyll mutations in mungbean (*Vigna radiata* (L.) Wilczek). *Theoretical and Applied Genetics*, **63**:23-26.

Bhabha Atomic Research Station (BARC) 2021. http://www.barc.gov.in/ pubaware/ agri_crop_ varieties. html

Chavan, A. A., Patil, V. D., and Pawar, R. B. 2000. Induced mutations in mungbean-variety BM-4. In Proceedings of the DAE-BRNS Symposium on the use of nuclear and molecular techniques in crop improvement, 149-155

Dahiya, B. S. 1973. Improvement of mungbean through induced mutations. *Indian J. Genet. Plant Breed*, **33**:460-468.

Das, T. R., and Baisakh, B. 2011. Effects of mutagenic treatments on chlorophyll mutation in green gram. *e-planet*, 17.

Das, T. R., and Baisakh, B. 2013. Efficacy of physical and chemical mutagenic treatments for developing superior mutants in greengram (*Vigna radiata*). *Indian Journal of Agricultural Sciences*, **83**:595-598.

Das, T. R., Baisakh, B., and Prusti, A. M. 2021. Studies on Mutagenic Effectiveness and Efficiency of Gamma Rays, Ethyl Methane Sulphonate, Nitrosoguanidine, Maleic Hydrazide and their Combination in Greengram (*Vigna radiata* L. Wilczek). *Int. J. Curr. Microbiol. App. Sci,* **10**:3354-3362.

Das, T., and Baisakh, B. 2020. Effectiveness and efficiency of physical and chemical mutagens in greengram [*Vigna radiata* (L.) Wilczek]. *e-planet* **18**:6-12.

Dewanjee, S., and Sarkar, K. K. 2018. Evaluation of performance of induced mutants in mungbean [*Vigna radiata* (L.) Wilczek]. *Legume Research-An International Journal*, **41**:213-217.

Gandhi, S., Umavathi, S., and Mullainathan, L. 2014. Studies on induced chlorophyll mutants in green gram (*Vigna radiata* (L.) Wilczek). *International Journal of Advanced Research*, **2**:00-04.

Girija, M., Dhanavel, D., and Gnanamurthy, S. 2013. Gamma rays and EMS induced flower color and seed mutants in cowpea (*Vigna unguiculata* L. Walp). *Advances in Applied Science Research,* **4**:134-139.

Gupta, P. K., Singh, S. P., and Bahl, J. R. 1996. A new mungbean variety through induced mutations. *Mutation Breeding Newsletter* , **42**:6

Haq, M. A., and Shakoor, A. 1980. Use of induced mutations for improving resistance against Ascochyta blight in chickpea (*Cicer arientinum*) and yellow mosaic virus in mungbean (*Vigna radiata*) (No. IAEA-TECDOC-234).

International Atomic Energy Agency (IAEA). 2021. https://www.iaea.org/ topics/ mutation- induction

Jana M.K. 1962. X-ray induced mutants of *Phaseolas mungo* L. sterility and vital mutants. *Genetica Iberica* **14**:71-104

Janoria, M. P., Gour, V. K. and Sing, C. B. 1984. Prespective in grain legumes. J. N. Krishi Vishwa Vidyalaya, Jabalpur.

Kang, Y. J., Kim, S. K., Kim, M. Y., Lestari, P., Kim, H., Ha, B., Jun, T., Hwang, W. J. and Doyle, J. 2014. Genome sequence of mungbean and insights into evolution within Vigna species. Doi: 10.1038/ncomms6443.

Khan, I. A. 1981. Mutation studies in mungbean. *Bot. Bull. Acad. Sci*, **22**:113-121.

Khan, I. A. 1983. Mutation studies in mung bean (*Phaseolus aureus*). V. Induced polygenic variability after seed irradiation. *Canadian Journal of Genetics and Cytology*, **25**:298- 303.

Khan, I. A. 1984. Mutations induced by gamma-irradiation, ethyl methane sulfonate and hydrazine hydrate in mung bean (*Phaseolus aureus* Roxb.). *Bot. Bull Academia Sinica*, **25**:103-110

Khan, S., and Siddiqui, B. A. 1993. Chlorophyll mutations in *vigna radiata* wilczek., mutagenic effectiveness. *Pak.. J. Bot*, **2**:161-166.

Khan, S., and Goyal, S. 2009. Improvement of mungbean varieties through induced mutations. *African Journal of Plant Science*, **3**:174-180.

Khan, S., Wani, M. R., and Parveen, K. 2006. Quantitative variability in mungbean induced by chemical mutagens. *Legume Research-An International Journal,* **29**:143-145.

Khan, S., Wani, M. R., and Parveen, K. O. U. S. E. R. 2004. Induced genetic variability for quantitative traits in *Vigna radiata* (L.) Wilczek. *Pakistan Journal of Botany*, **36**:845- 850.

Kharkwal M. C. 2004. Mutation breeding for crop improvement. *In: Jain HK, Kharakwal MC (Eds) Plant Breeding - Mendelian to Molecular Approaches*, 601-645

Khattak, G. S. S., Saeed, I., and Shah, S. A. 2008. Breeding high yielding and disease resistant mungbean (*Vigna radiata* (L.) Wilczek) genotypes. *Pak. J. Bot*, **40**:1411-1417.

Kulthe, M. P. 2019. Effect of EMS and SA on Pollen sterility in *Vigna radiata* (L.) Wilczek (Mung bean). *Plantae Scientia*, **2:**40-41.

Kumar, A., Parmhansh, P., and Prasad, R. 2009. Induced chlorophyll and morphological mutations in mungbean (*Vigna radiata* L. Wilczek). *Legume Research-An International Journal,* **32**:41-45.

Kumar, S. and Singh, M. 2009. 25 Years of Pulses Research at IIPR. *Indian Institute of Pulses Research, Kanpur.*

Kumar, S. 2014. Gamma Radiation Induced Mutations in Mungbean (*Vigna radiata* (L.) Wilzek). *Scholarly Journal of Agricultural Science,* **4**:240-243

Malik, I. A., Sarwar, G., and Ali, Y. 1986. Genetic characterization of gamma irradiation induced leaf mutations in mungbean (*Vigna radiata* L. Wilczek). *Pak. J. Bot,* **18**:75-31.

Maluszynski, M., Zanten, L.V., Ashir, A., Brunner, H., Ahloowalia, B., Zapata, FJ and Weck, E. 1995. Mutation techniques in plant breeding. In: Proceedings of Symposium on Induced Mutations and Molecular Techniques for Crop Im- provement, FAO/IAEA, Vienna, Austria, 489-504

Mishra, D., and Singh, B. 2014. Studies on effectiveness and efficiency of gamma rays in green gram (*Vigna radiata* (L.) Wilczek). *SABRAO Journal of Breeding and Genetics*, **46**:34- 43.

Mishra, D., Singh, B., and Sahu, R. 2013. Gamma ray induced macro mutations in green gram (*Vigna radiata* (L.) Wilczek). *International J. Agriculture and Forestry,* **3**:105-109.

Pavadai, P., Girija, M., and Dhanavel, D. 2010. Effect of gamma rays on some yield parameters and protein content of soybean in M2, M3 and M4 generation. *Journal of Experimental Sciences*, **1**

Tah, P. 2009. Induced synchrony in pod maturity in mungbean. *ARPN Journal of Agricultural and Biological Science,* **4**:42-44

Raihan, A., Hasan, M. M., Islam, S., and Rahman, L. 2018. Development of Yellow Mosaic Virus Resistance in Mung Bean through EMS Mutagenesis. *Asian Journal of Advances in Agricultural Research,* 1-6.

Rajput, M. A. 1974. Increased variability in the M2 of gamma-irradiated mung beans (*Phaseolus aureus* Roxb.). *Radiation Botany*, **14**:85-89.

Roslim, D. I., and Fiatin, I. 2015. Lethal dose 50 (LD50) of mungbean (*vigna radiata* L. wilczek) cultivar kampar. *SABRAO Journal of Breeding & Genetics,* **47**.

Rukesh, A. G., Rahuman, M. A., Latitia, S. C., and Packiaraj, D. 2017. Impact of gamma irradiation induced mutation on morphological and yield contributing traits of two genotypes of Green gram (*Vigna radiata* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**:1229-1234.

Sadiq, M. S., Haidar, S., Abbas, G., Shah, T. M., and Atta, B. M. 2007. Exploitation of exotic and indigenous mungbean germplasm for improving seed yield and disease resistance. *Pak. J. Bot*, **39:**2451-2456.

Sangsiri, C., Sorajjapinun, W., and Srinives, P. 2005. Gamma radiation induced mutations in mungbean. *Sci Asia,* **31**:251-255.

Sarkar, M., and Kundagrami, S. 2018. Selection of high yielding, extra short duration lines of mungbean derived through gamma radiation. *Indian J. Genet,* **78**:233-241.

Shakoor, A., Ahsan-Ul-Haq, M., and Sadiq, M. 1978. Induced variation in mung bean (*Vigna radiata* (L.) Wilczek). *Environmental and Experimental Botany*, **18**:169-175.

Siddique Sadiq, M., Sarwar, G., Khattak, G. S. S., and Saleem, M. 1999. Development of mungbean variety 'NIAB MUNG 98'involving induced mutants through conventional breeding. *Mutation Breeding Newsletter*

Singh, A. 2009. Induced genetic variability in M3 generation of mungbean. *Journal of Food Legumes* **22**:162-165

Singh, A. K., and Singh, R. M. 2007. Gamma rays and EMS induced chlorophyll mutations in mungbean (*Vigna radiata* L. Wilczek). *Indian J. Crop Science*, **2:**355-359.

Singh, A. K., Singh, S. S., Prakash, V., Kumar, S. and Dwivedi, S. K. 2015. Pulses Production in India: Present Status, Bottleneck and Way Forward. *Journal of Agrisearch.* **2**:75-83.

Singh, B., and Rao, G. T. 2007. Induced morphological mutations in greengram (*Vigna radiata* (L) Wilczek). *Legume Research-An International Journal*, **30:**137-140.

Singh, D. P., and Sharma, B. L. 1983. A high yielding mungbean variety through mutation breeding. *Mutation breeding newsletter,* 22

Singh, V. P., and Chaturvedi, S. N. 1982. "Comparative mutagenic effets of EMS and NMU in Vigna radiata (L) Wilczek with DMSO." *Indian journal of botany.*

Sparrow, A. H. 1966. Plant growth stimulation by ionizing radiations. IAEA Sci- ence Series Technical Report 64:12

Swain, D., Baisakh, B., Lenka, D., and Tripathy, S. K. 2019[a]. M1 Biological Injuries: Indicators for M2 Macro-and Micro-mutation in Mungbean [*Vigna radiata* (L.) Wilczek]. *Int. J. Curr. Microbiol. App. Sci,* **8**:1685-1696.

Swain, D., Baisakh, B., Tripathy, S. K., and Lenka, D. 2019[b]. Mutagenic effect of gamma rays, EMS, NG and their combinations for induction of Chlorophyll and macro-mutations in mungbean (*Vigna radiata* (L.) Wilczek). *Journal of Pharmacognosy and Phytochemistry,* **8**:2489-2495.

Tah, P. R., and Saxena, S. 2009. Induced synchrony in pod maturity in mungbean (*Vigna radiata*). *International Journal of Agriculture and Biology,* **11**:321-324.

Vairam, N., and Ibrahim, S. M. 2014. Induced Viable Mutations in Mungbean (*Vigna radiata* (L.) Wilczek). *Biosciences*, 22:48.

Vairam, N., Lavanya, S. A., and Vanniarajan, C. 2017. Screening for pod shattering in mutant population of mungbean (*Vigna radiata* (L.) Wilczek). *Journal of Applied and Natural Science*, **9**:1787-1791.

Vairam, N., Lavanya, S. A., Muthamilan, M., and Vanniarajan, C. 2016. Screening of M3 mutants for yellow vein mosaic virus resistance in greengram [*Vigna radiata* (L.) wilczek]. *International Journal of Plant Sciences (Muzaffarnagar)*, **11**:265-269.

Wani, M. R., Dar, A. R., Tak, A., Amin, I., Shah, N. H., Rehman, R. and Khan, S. 2017. Chemo- induced pod and seed mutants in mungbean (*Vigna radiata* L. Wilczek). *SAARC Journal of Agriculture,* **15**:57-67.

Wani, M. R., Khan, S., and Kozgar, M. I. 2011. An assessment of high yielding M 3 mutants of green gram (*Vigna radiata* (L.) Wilczek). *Rom J Biol,* **56**:29-36.

Wani, M. R., Kozgar, M. I., Tomlekova, N. B., and Khan, S. 2014. Selection for polygenic variability in early mutant generations of mungbean (*Vigna radiata* (L.) Wilczek). Mutagenesis: exploring genetic diversity of crops. *Academic Publishers, Wageningen*, 213-232.

Wongpiyasatid, A., Chotechuen, S., Hormchan, P., Ngampongsai, S., Lamseejan, S., and Pichitporn, S. 1998. Mutant mungbean lines from radiation and chemical induction. *Agriculture and Natural Resources,* **32**:203-212.

Wongpiyasatid, A., Chotechuen, S., Hormchan, P., Ngampongsai, S., and Promcham, W. 2000. Induced mutations in mungbean breeding: regional yield trial of mungbean mutant lines. *Agriculture and Natural Resources,* **34**:443-449.