Role of mutation breeding to improve Mungbean (*Vigna radiata* L. Wilczek) yield: An overview

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Abstract: Mungbean (*Vigna radiata* L. Wilczek) is one of the famous legume crops. The grain yield of mungbean is affected by various biotic and abiotic factors. The yield can be increased by improving the genetic makeup and incarporating the resistance against the environmental stresses. Common breeding methods are not useful in enhancing production of mungbean because of low genetic variability. The production can be improved by improving the available genotypes through mutation or by using other advanced breeding methods. The present review article will provide information about the use of mutation breeding in improving the grain yield of mungbean.

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Introduction

Agriculture is an important sector, which provides the food for human being and for animals in Pakistan and many other countries of world. It also supports the agriculture based industries. In Pakistan 70% people are living in rural areas and all of them are engaged in agriculture sector directly or indirectly. It is mostly cultivated in the Asian countries and commonly known as green gram. Mungbean is one of the most important legumes in many Asian countries as China, India and Pakistan. It belongs to the family *Fabaceae* and sub-family *Papillionaceae*. It occupies the second position after chickpea among legume crops. Mungbean is the cheap source of proteins (24%) and carbohydrate (38-50%). For animals it is also used as fodder crop. Dehusked and splited seeds are used as dhal. At green stage it is used as vegetable. Among other pulses it is choosen first because it is easily digestible. It is sown in variety of environments because of its drought tolerance ability, so it can be sown in arid as well as in irrigated areas. Production of mungbean is influenced by genetic and environmental factors. The yield can be increased by improving the genetic makeup and incarporating the resistance against the environmental stresses. Common breeding methods are not useful in enhancing production of mungbean because of low genetic variability. The production can be improved by improving the available genotypes through mutation or by using other advanced breeding methods (Wright, 1935). Mutation breeding is one of the oldest breeding methods. It is used in number of fields as biotechnology, cytogentics and molecular biology. It is an effective tool for the improvement of crop production (Acharya *et al.* 2007). Mutation can be induced by Gamm-rays and other physical and chemical mutagens. Gamma rays affect the plant growth by altering the genetical, physiological, biochemical and morphological features of the cells (Gunckel *et al.* 1961). Khatri *et al*. 2005 observed that high yielding new varieties can be produced by the gamma rays and EMS.

Induced mutations is one of the prime method for the development of high genetic variability and successfully used for the development of higher yielding crop genotypes. Mutation breeding depends upon effectiveness and efficiency of the mutagens. Effectiveness is related with mutation per unit dose of mutagens and efficiency is related with the undesirable changes as sterility, injury and lethality (Goud *et al.* 1967). The desirable mutation depends upon the selection of effective and efficient mutagens (Solanki *et al.* 1994). The two mutagens acting in a sequence one after the other may produce more than additive effect, if the sites not affected by the first are exposed to the action of the second. Mutation is the sudden change in the gene sequence. Mutation can be induced in seed as well as in the vegetative portion of the plant. Inoculated mutation leads to the study of function and structure of the genes. Natural genetic source can be enhanced by the induced mutation and have been used in developing improved cultivars of cereals, fruits and other crops (Lee *et al.* 2002). Practical plant breeding purpose is achievable through mutation. Since last seven decades, more than 2252 mutant varieties have been developed (Maluszynski *et al.* 2000). Ahloowalia *et al*. (2004) observed that through gamma rays, majority of mutant varieties were developed. They observed that gamma rays may cause genetic changes in organism, break the gene linkage and produce many new promising traits for the improvement of crop plants (Shah *et al.* 2008). Mutations are the source of variability in the existing varieties and early maturing lines can be developed which are helpful in the summer season. For the development of better crops, mutation breeding is the best method (Awan, 1991). The heritability of the important traits such as production, resistance against pest and diseases and quality can be analyzed through analysis of the induced mutation (Fawad *et al*., 2015a,b; Kanwal *et al*., 2015; Mumtaz *et al*., 2015; Rizwan *et al*., 2015; Naseer *et al*., 2015; Naseem *et al*., 2015; Masood *et al*., 2015a,b). The low productivity of pulses may be attributed to susceptibility to pathogenic microorganisms, asynchronous habit of pod maturity, shedding of flowers, newly formed pods and indeterminate to long duration of growth resulting low seed yield per plant. The plant is also capable of maintaining soil fertility through biological nitrogen fixation. Various researcher have used different statistical approaches to evaluate grain yield of different crops (Ali *et al*., 2012; Ali *et al*., 2014abc; Ahsan *et al*., 2013; Awan *et al*., 2015;Ramzan *et al*., 2015; Waseem *et al*., 2014).

Review of literature

Awan *et al*, (2004) conducted a study and interpreted that variability in the treated population was higher than the control for all the quantitative traits, namely fertile branches per plant, pods per plant, 100-seed weight and seed yield per plant. The increase in the number of pods was due to an increase in the number of flowers. Similar increases in the number of pods of some other varieties of mungbean have been reported by using ethylmethane sulphonate, nitrosomethyl urea, hydroxylamine and gamma rays as mutagens. The 100-seed weight showed no significant increase over control in the M_2 and M_3 generations. Arshad *et al*. (2004) performed a study on twenty four varieties of gram. They observed the correlation, heritability and variability among various yield traits. For 100-seed weight high heritability with low genetic advance was observed. High genetic advance and high heritability of biological yield and secondary branches was observed. A positive and significant correlation was observed between biological yield, 100-seed weight and plant height. They observed a negative relation of grain yield with harvest index. Celal (2004) observed positive and statistically significant relationship between seed yield per plant and days to 50% flowering, pods per plant, seeds per plant, harvest index and 1000 seed weight and also reported strong association among branches per plant and pods per plant leading to increased yield per unit area. Ciftci *et al.* (2004) performed an experiment on 14 chickpea varieties to check the correlation among yield and yield increasing components by using coefficient analysis. The yield parameters as plant height, number of pods, number of seeds per pod and number of branches were positively and significantly correlated. Path coefficients analysis showed that strong and direct effect of biological yield, harvest index and number of seed per plant on seed yield. Hussain *et al.* (2004) conducted an experiment on the inoculation of 6 mungbean cultivars. Among the whole seed lot two third of the seeds were inoculated and remaining were not inoculated. Due to inoculation 100-seed weight, plant height, number of branches and number of pods per plant were significantly increased. Seed yield was positively correlated with 100-seed weight and number of pods per plant. Khan *et al.* (2004) developed two mutant mungbean varieties. Survival at maturity, seed germination and pollen viability were reduced in response to mutagenic treatments. The reduction in all the parameters was due to high dose of the radiation. The entire yield parameters were increased in M_1 and M_2 generations and all genetic parameters were recorded higher in all treatments. They observed that all characters were positively correlated to each other.

Kumar *et al*. (2004) observed the phenotypic and genotypic association in 21 mungbean varieties. All the parameters regarding the vegetative and reproductive growth, number of primary and secondary branches per plant, plant height, number of cluster per plant, number of pods per plant and harvest indices showed positive correlation with the seed yield per plant at both genotypic and phenotypic levels. Kumar *et al*. (2004) studied the correlation among 21 mungbean genotypes. The seed production was correlated with different characters as number of primary and secondary branches, plant height, pods and clusters per plant and harvest index. Qureshi *et al.* (2004) studied the qualitative and quantitative characters of two chickpea genotypes for genetic variability. The results regarding 100-seed weight, plant weight, plant height, number of primary and secondary branches and number of pods per plant were highly significant. Correlation coefficients of primary and secondary branches, pods per plant and total plant weight with grain yield were significant. However, there was negative correlation between days to maturity and grain yield. Sager *et al*. (2004) studied the predictable yield and yield mechanism, correlation among characters and the effect of different characters on seed yield. The result of correlation among vegetative characters showed that the seed yield per plant was associated with number of seeds per plant. Samiuallah *et al*. (2004) treated mungbean cultivars with gamma radiations and recorded the results of treated cultivars in M_1 generation. They observed that seed germination, pollen development and survival at maturity were reduced than control. From the experiment they reported that these parameters except survival at maturity were dose dependent. The mutagen treatments could alter the average values and create extra genetic variation for quantitative characters.

Sanjose *et al*. (2004) conducted an experiment to study the radiation use efficiency on four varieties of cowpea in four consecutive seasons. The results of radiation were interpreted by calculating the dry matter of plants. The dry matter production in leaves was very low. Different seasons and varieties have no significant effect on dry matter production of the plant. Through gamma-radiation from CN36 two mutant lines M5-16 and M5-29 were derived. Substantial inhibition was produced by the small portion of the proteins. On these two mutant lines insect resistance test was also conducted. The weevil was reared on the mutant lines and the total number of eggs laid and total number of adults was calculated. The amounts of egg laid and total number of adults were less in mutant lines as compared to the standards. Singh (2004) studied the variability, heritability, and genetic advance by using biparental fusion in F_2 plants. He observed that genotypic coefficients of variation and phenotypic coefficients of variation were higher for yield and pods per plants. Sreedevi and Sekhar (2004) studied 21 F_4 progenies of chickpea and conducted a correlation analysis between them. The parameters which were taken in the study were pods and cluster per plant, pods per cluster, plant height, pod length and 100-seed weight. The genotypic correlation coefficients were significant than phenotypic correlation coefficients which showed that there was environmental control on appearance of characters. There was a strong positive correlation between clusters per plant and pods per plant. Pods per plant and seeds per pods were also having a strong positive correlation.

Tejber and Gupta (2004) studied the genetic unevenness in 40 genotypes of lentil for seed yield and three other characters for two consecutive years. They observed that a large variation was existing for the biological yield, number of secondary branches, pods per plant and seed yield per plant. Tuba and Akar (2004) conduct an experiment on five cultivars and twenty six lines of lentil to study the variability and heritability for grain yield and six other yield related characters. The data regarding grain yield per plant and biological yield showed maximum variability. 100-seed weight and days to 50% flowering expressed maximum heritability. Venkatesan *et al*. (2004) conducted a correlation analysis on 49 varieties of black chickpea and the results of their experiment showed that the seed yield was positively correlated with pods per plant and clusters per plant. Yazdi *et al.* (2004) sorted out ninety lentil varieties to study the genetic variation and correlation in characters like, 100-seed weight, time taken to 50% flowering and time taken to 90% maturity. They concluded that all these characters were positively correlated and showed high variability. Ambarkar *et al*. (2005) induced mutation in three chickpea varieties as PG-12, Vijay and PG-5 through gamma radiation. 10Kr, 20kr and 30kr of gamma rays were used and experiment was conducted during rabi season in India. The mutation was observed in M_2 generation. They recorded the mutation in seven different types of the characters like chlorophyll mutations, leaf mutations, sterile and semi-sterile plants, dwarf plants, branching pattern and flower color.

Anbumalarmathi *et al* (2005) revealed that genetic improvement of grain yield was possible by selecting characters having positive correlation and positive direct effect. Anjam *et al*. (2005) developed genetic diversity and association for parameters as seed production, pods per plant, pods dehiscence, biomass production of the plant and plant height in different genotypes of lentil. According to their results all the traits were highly variable. Seed production was positively and significantly correlated with pods per plant and plant height. Dhuppe *et al*. (2005) studied thirty five mungbean genotypes. Data was analyzed for height of plant, number of primary and secondary branches per plant, number of pods and seed per plant, 100-seed weight and yield per plant. At genotypic level seed production showed positive and significant correlation with the days taken to maturity. Number of secondary branches per plant, number of pods per plant and 100-seed weight was correlated with genotypic variation, whereas at phenotypic level number of secondary branches and 100-seed weight were correlated with seed production. Kapoor *et al*. (2005) studied variation and genetic diversity in twenty mungbean varieties which differed from each other for seven yield related characters. Number of Pods and seed yield per plant showed high phenotypic coefficient of variance (PCV). High phenotypic coefficient of variance (PCV) indicated the presence of good amount of genetic variation for 100-seed weight, seed production per plant and pod length along with high heritability.

Khan *et al*. (2005) induced mutation in chickpea through gamma rays to calculate the effect of mutation on gibbrelic acid production along with other characters like height of plants, number of primary and secondary branches per plant, number of pods and seed yield per plant in M_2 generation of chickpea. They observed positive results for quantitative characters when the dose level was low to medium. Neha *et al*. (2005) observed correlation, path correlation and genetic variability in 100 lentil lines for the characters time taken to flower initiation, days to maturity, 100-seed weight, seeds per pod, pods per plant and plant height. The variation was observed in all traits. Heritability was observed in the parameters as days to flowering, days to maturity, seed yield per plant and number of pods per plant. The characters as 100-seed weight, pods per plant and seed yield per plant were genetically advanced. Days to flowering, days to maturity and 100-seed weight were negatively correlated while pods per plant, plant height and seeds per pod positively correlated with seed yield per plant. Parimal and Chakraborti (2005) studied the genetic diversity of eight genotypes of green gram and also studied the quantitative traits of the plant. For all the characteristics the phenotypic coefficients were higher as compared to the genotypic coefficients. High heritability was estimated in two traits as height of plant and 100-seed weight. The association of high heritability and high genetic advance was observed for these two characters. The association among the heritability and genetic advance is because of additive genes. They reported that this type of procedure may be helpful in conventional breeding for the improvement and for the creation of desirable genetic variability.

Sadiq *et al*. (2005) derived information on genotypic, phenotypic variance and coefficient of variability, heritability, genetic advance and correlation coefficient from data on seven yield components in twelve exotic accessions of mungbean. High genetic advance combined with high heritability values were observed for plant height, clusters per plant, pods per plant and seed yield. They further reported that plant height; clusters per plant, pods per plant and pods length were positively correlated with seed yield. Svetleva and Crino (2005) studied the effect of two mutagens on callus production of common bean. The mutagens were applied at different times on the explants of mungbean with different concentrations. Application time effected the callus production of plant at the time of 30 minutes. Both mutagens showed the peak weights at the time 30 minutes. Both mutagens at 90 minuts inhibited the callus production. Among both mutagens ENU showed better results as compared to the EMS. The sub cultures effect on callus production was higher than mutagenic treatments. The correlations among these factors were quite low.

Tejbir and Gupta (2005) studied forty lentil genotypes and performed correlation and path correlation analysis of seed production under late and early sowing. Under the both conditions scientists found the positive and significant correlation among primary and secondary branches per plant, pods per plant, plant height and biological yield. Veerasmani *et al*. (2005) examined the segregating population developed by three crosses, involving four parents of black gram to estimate genetic diversity for eight quantitative characteristics. The phenotypic and genotypic coefficient of variance for characters as plant height, number of branches per plant, number of seeds per pods and seed yield per plant were recorded high. High heritability paired with high genetic advance were recorded for height of plant, number of branches and cluster per plant, number of pods per plant and length of pod. Hakim *et al*. (2006) determined the genetic variation, correlation, heritability and genetic advance in thirteen diverse genotypes of lentil for six yield related traits. The characters as time taken to 50% germination, time taken to 50% flowering and time taken to 90% maturity were genetically variable. Height of plant, days to maturity and days to germination showed high heritability while high genetic advance was found for number of pods and seed per plant and grain production. The parameters as grain production per plant showed highly positive correlation with number of pods and seed per plant and 100-seed weight while negative with time taken to 50% germination.

Shah *et al*. (2006) studied the effect of physical and chemical mutagens on chickpea in M_2 generation. They studied the effects of induced mutation on chlorophyll production. Overall frequencies and spectrum of four types of induced chlorophyll mutants were viridis (9.01%), followed by xantha (8.61%), chlorina (5.82%), albina (0.5%) and others (0.26%). EMS treatments were more efficient and effective than gamma rays. Siddique *et al*. (2006) reported highly significant genetic variation for days to flowering, maturity, pods per plant and grain yield among eight mungbean genotypes and also depict that plant height and days to flowering were mostly governed by additive genes effects. Idrees *et al*. (2006) found that seed yield was correlated with the number of clusters per plant, number of pods per plant and length of pod had positive correlation with seed yield. Seed yield was affected by number of primary branches, plant height and number of clusters per plant. Munawar *et al*. (2006) observed genetic variability for three cultivars of lentil for the characters of germination percentage and seed yield. The seeds were treated with the four level of the gamma radiation. The higher doses of radiation decreased the germination percentage. The yield production was significantly affected by the cultivars. Singh *et al.* (2006) examined the heritability and genetic variation in seventy five induced mutants of lentil under the rain fed conditions. All the parameters showed maximum variation. The heritability was high in all the characters except the plant height and high genetic advance was observed in the charter as number of pods per plant. Pods per plant and 100-seed weight were highly correlated with the grain yield per plant. Solanki (2006) sorted out seventy two ecological lines of lentil for correlation and path coefficient analysis for seed production. Grain yield showed positive correlation with number of primary and secondary branches per plant, pods and clusters per plant and biomass per plant. They further reported that all parameters regarding the yield were significantly correlated. Tadele *et al.* (2006) examined induced polygenic variability in the lines of Kabuli chickpea. The variation was observed in the M_2 generation and observed that the gamma radiation effected the seed production, size of seed and number of pods per plant. The M_3 generation was evaluated and fifteen mutant line were isolated that gave maximum seed yield as compared to the control. The Path analysis showed that number of pods per plant significant effect in the control and mutant progenies, while only in the mutant population 100-seed weight showed positive effect for seed production.

Wani and Khan (2006) worked on mungbean mutants and observed the considerable change in mean values for morphological traits like number of branches per plant, number of pods per plant and yield per plant. They reported that genetic parameters such as, heritability, genotypic coefficient of variation and genetic advance for yield and its components were higher than the control. They also reported that increased genetic variability for morphological traits will provide great scope for better selection. Ali and Shaikh (2007) developed genetic diversity in two varieties of lentil treated with gamma radiations. They observed that both mutant lines give better performance and produced maximum grain yield. Gul *et al.* (2007) estimated the genetic variability in different mungbean genotypes. The parameters such as number of leaves per plant, length of pod, number of pods and seed per plant, 100-seed weight and grain production were studied. The variation was observed in all parameters except number of pods per plant. Maximum number of leaves and seeds were produced by the genotype KRK mung-1. Genotype NFM 3-3 contained maximum pod length and maximum hundred seeds weight. Maximum seed yield was produced by the genotypes NM 21 followed by NM-92 and KRK mung-1, while FM 3-3 which produced minimum seed yield per plant.

Kumar and Rai (2007) conducted the study on chemical mutagen and produced chromosomal variations for the understanding the mechanics of EMS in maize. Seeds were pre-soaked in distilled water and then treated with chemical of concentration 0.5% solution of EMS for different time durations. They investigated that through EMS treatment, many chromosomal abnormalities, namely precocious movements, stickiness, univalent, bridges, laggards, multivalent etc, were present in all the inbred lines of maize. Higher chromosomal abnormalities were observed at the maximum dose 7 hours of treatment in all the inbred lines of maize. However, CM-142 was found to be the most suitable inbred line for induced mutagenesis and it showed minimum chromosomal damage with maximum variability. Malik *et al*. (2007) showed that the genotypic correlations were higher than the phenotypic correlation. Correlation coefficient for bean yield was positive with the parameters as days to flowering, days to maturity, height of plant and number of branches per plant. Path coefficient analysis showed that time taken to flowering had maximum contribution to yield followed by number of pods per plant and height of plant. This decisive factor can be used in the selection of the bean varieties. Makeen *et al.* (2007) evaluated twenty mungbean genotypes to estimate genetic variability, heritability and genetic advance for quantitative characters and reported highly significant differences for all traits with greater magnitude of heritability for plant height and test weight.

Sriphadet *et al.* (2005) reported 89.9, 98.9, 93.7 and 93.2% heritability for number of leaves per plant, seed hardness, pod length, and pod width, respectively. Seed yield is reported to be positively correlated with traits like days to flowering, plant height, branches per plant, pods per plant and pod length. Sadiq *et al*. (2007) evaluated the exotic and native genotypes of mungbean for the improvement of seed yield and disease resistance. Genetic variability for large seed size, hybridization between exotic and indigenous germplasm were created. They produced large seeded varieties with high yield potential and disease resistance. Saeed *et al.* (2007) studied forty three genotypes of mungbean to observe the association of yield per plant with other morphological traits. A significant and positive association was observed for seed yield per plant with pod bearing branches per plant, number of clusters per plant and number of clusters on branches. Number of branches per plant and number of clusters on branches showed a negative correlation. It was also observed that indirect effect of number of pods per plant towards total correlation was high and positive. The high direct effect and correlation of pod clusters per plant confirmed its important role in selection for high yielding genotypes. High heritability was observed for seed yield per plant and pod clusters per plant. Sangsiri *et al*. (2007) conducted a study on variegated leaf mutants of mungbean developed from gamma rays. They observed that all the leaves of F_1 plants showed normal green leaves while the leaves of F_2 plants showed 3:1 ratio of green to variegated leaves. The plants of F_3 generation showed green plants: mixed plants: variegated plants in the ratio of 1:2:1

respectively. The thick portion of the mutant plants showed that the number of chloroplasts containing in the structure were lower as compared to the parents. In the mutant tissues, minimum number of chloroplast was present in the upper palisade cell layer while more of them were in the lower spongy mesophyll.

Atta *et al*. (2008) indicated that more number of secondary branches, pods per plant and large seed size were major yield enhancing factors in the selection of high yielding chickpea varieties. Ganapathy *et al*. (2008) conducted an experiment by using different doses of gamma rays on two varieties of millet. They observed different mutation at different frequencies of the radiations. In control treatment there was no mutation in the chlorophyll production. The spectrums of chlorophyll mutations (albina, xantha, chlorina, viridis and striata) were observed and grouped. Mutation spectrum for both the varieties showed that xantha (2.55%) occurred with the highest frequency, followed by chlorina (1.88%), viridis (0.84%) and albino (0.59%). When the mutagen dose was increased the effect of that mutagen was decreased. Gul *et al.* (2008) determined the correlation among different yield contributing traits of mungbean. Their analysis revealed that earliness showed negative correlation with plant height and dry weight per plant while 100-seed weight was positively correlated. Dry weight per plant showed positive correlation with days to maturity, seeds per pod and plant height while negatively correlated with yield per hectare. 100-seed weight showed positive correlation with pods per plant and harvest index while it showed negative correlation with days to maturity, seeds per pods and plant height. Seed yield per plot was found to be non-significantly correlated with 100-grain weight. Similarly, seed yield per plant was positively correlated with pods per plant, yield per ha and harvest index. Hameed *et al.* (2008) conducted an experiment on chickpea by treating the seeds with different doses of gamma rays. Seeds were sown in incubator for 8 days at room temperature. The results regarding the seedling growth showed the sprouting percentage of the seedling was inversely proportion to the irradiation dose. The concentration of the peroxidase and protease were higher in Kabuli as compared to desi chickpea for protein contents. This indicated that these two genotypes were inherently different. Kabuli chickpea bears the 600 Gy dose of the rays while 500 Gy in desi chickpea. At 500 Gy gamma rays dose the results were non-significantly affected the protein contents and lowered the peroxidase activity and lowered MDA contents.

Jagadeesan *et al.* (2008) introduced variability in the sunflower varieties through gamma rays. The LD_{50} value was fixed at 15 kR for both varieties based on germination percentage. In M_1 generation the germination percentage and survival was decreased with the increase in dose of gamma rays. All the quantitative characters showed the stimulatory and inhibitory effect at low and high dose of gamma rays respectively. In M_2 generation the expression and variability was increased. The variance of the traits as for oil contents, seed yield and plant height was observed. Regarding seed yield per plant, heritability and genetic advance maximum at 20 kR and 5 kR in the genotypes Morden and CO_4, respectively. Karim *et al*. (2008) conducted an experiment on the freshly harvested seeds of the chickpea. They treated the seeds of the chickpea with the ten different doses of the rays as a control viz. 0 to 900 Gy by using CO^{60} as a source. After treating the seeds were sown in the pots and yield attributes were studied in M_1 generation. At different doses the effect was significant. The seeds which were treated with the rays produced early flowering than the control. The highest number of branches was recorded at the 700 Gy dose. Due to higher doses of the rays the number of pods/plant and seeds/pod was reduced. But at 300 Gy and 100 Gy the 100-seed weight and seed yield/plant were increased than control. In 400 Gy treated plants the protein percentage was higher.

Makeen *et al.* (2008) observed the genetic divergence for twenty two mutants of Urdbean variety T9 and observed the nine morphological characteristics. Mutants were arranged in four clusters and this classification was based on D_2 values. Clusters II, II and IV were divergent from the cluster, I, which contained the parent variety, T9. Cluster IV having a single mutant culture AAI-UB8 showed higher value for yield per plant, length of pod, seeds/pod and 100-seed weight. Correlation coefficients showed the mutual relationship between various plant traits for yield increment. Path analysis showed that the length of pod, cluster/plant and 100-seed weight had positive relation with seed yield/ plant. Ngampongsai *et al*. (2008) treated the seeds of mungbean with the different doses of the gamma rays and ethyl methane sulphonate. The purpose of the study was to check the seed production and to check the resistance against the powdery mildew. The lines in which the mutation was induced showed the higher seed yield and disease resistance. Rahim *et al*. (2008) studied thirty four diverse mungbean accessions that were isolated for eight agronomic characteristics. Data was recorded for quantitative and qualitative parameters as days to 50% flowering, time taken to 80% maturity, height of plant, number of pods per plant, length of pod, number of seeds per pod, 1000-seed weight and grain yield. Among all the characters, number of seeds per pod showed maximum variation. Shah *et al*. (2008) examined the gamma rays and EMS mutagen treatments on germination and seedling growth of four chickpea genotypes. In response to lower power of gamma radiation shoot and root lengths were increased in all four genotypes but at higher concentration of radiation and EMS all parameters were decreased.

Toker (2008) conducted research on wild and domesticated chickpea lines by treating them with gamma radiations. In M_2 progeny, a mutant line with white color flower was selected while the color of parent flower was pink. The seed coat color of the mutant line was creamy like Kabuli chickpea and the color of seed coat of the parent line was dark brown. Induced mutants of chickpea recommend an additional path for the evolution of 'kabuli' chickpea. In M_3 generation, multi pinnated leaf, arise growth, green seed and double-podded chickpeas were isolated. Ahmad (2009) conducted the experiment with two commonly grown mungbean varieties viz., M-28 and 6601, in open top chambers and ambient field conditions with the aim of ascertaining the effects of air pollution on yield. A considerable reduction of 47.06% and 51.12% in seed yield for M-28 and 6601, respectively were found which were substantially more that might be predicted elsewhere. These reductions in economic yield were due to decrease in both numbers of seed per pod and individual seed weight. Arulbalachandran and Mullainathan (2009) reported that systematic collection of black gram showed inadequate variability for biotic and a biotic desirable genes. In the present investigation, they induced genetic variability to improve quantitative traits of black gram in M_2 generation in which mutation was induced by EMS. The results showed that a significant enhancement in quantitative mean performance achieved at 0.1% EMS concentration. Arulbalachandran *et al.* (2009) studied genetic variation through genetic marker system. The genetic variation was checked in four mutants such as tall, bushy, dwarf and high seed protein mutants along with parent variety as control by twenty random primers which generated two hundred and two fragments ranged with fifty eight polymorphic DNA bands. Average DNA bands were 10.1 per locus ranged from one to nine. Their results revealed that such type of mutants and their genes were useful, when using in cross breeding/transgenic technologies in the development of crop varieties like high seed protein, lodging resistances, semi dwarf with high yield. Autil and Apparo (2009) treated the seeds of mungbean with different concentrations of SA, EMS and different doses of gamma radiations and observed a wide range of viable morphological and physiological mutants in M_2 and M_3 progenies of mungbean cultivars Vaibhav and Kopargaon-1. The true breeding mutant lines of M_3 generation were compared with their parent cultivars to assess significance of genetic variability. They concluded that chemical mutagens were more efficient than physical mutagens. The Kopargaon-1 cultivar showed more resistance towards mutagenic treatment than Vaibhav cultivar.

Azim *et al.* (2009) studied the effect of gamma radiations on physical and chemical properties of groundnut as well as to investigate its impact on quality attributes of groundnut oil. Seeds were treated with gamma rays and results revealed that the effect of gamma radiations on protein, oil, fiber, carbohydrates and minerals content of groundnut seeds was of no consistent pattern. However, for the quality attributes of groundnut oil, gamma irradiation caused significant decrease in iodine value and significant increase in acid and peroxide values with exception of the acid value. On the other hand, foaming stability was affected negatively with gamma irradiation. Girija and Dhanavel (2009) conducted the mutagenic studies on cowpea variety. The efficiency of gamma rays, EMS and their combined treatments were examined. The lethal dose of the mutagens was tested at 50 percent, at which 50 percent of the seed germination was considered as LD values. The M_1 generation was based on seed lethality and seedling injury and M_2 generation was evaluated for various chlorophyll mutations. When the dose and concentration of the mutagens was decreased the effectiveness increased. EMS was more effective and efficient in causing mutations as compared to gamma rays and the combined treatments. Khan and Goyal (2009) conducted an experiment on two mungbean varieties to reduce maturity period. In M_2 generation the 6 early maturing varieties were isolated after treating the seed with gamma rays, EMS and sodium azide. The Stabilized early mutants were scrutinized up to M_5 generation. High heritability paired with high genetic advance evaluated for time taken to maturity. In parental lines the seed yield of mutant lines was the same. Khattak *et al.* (2009) found that the entire segregating population showed flowers shedding under high temperature but 242 recombinants/mutants were advanced to phenotypic uniformity. Out of 242 recombinants/mutants, 163 showed moderately tolerant and 79 appeared to be susceptible, flowers shedding from terminal raceme on the main stem recorded at 90% pods maturity. Humidity fluctuations showed no effect on the flowers shedding in mungbean. Larik *et al.* (2009) conducted an experiment on M_1 population of two varieties of sorghum namely, DS-75 and Giza-3. They observed seedling emergence, days to 50 percent flowering, plants with abnormal leaves and stems, 1000-seed weight and grain yield per plant and concluded that varieties x treatment effects were non-significant for 1000-seed weight, indicating stability of performance for both characters across different irradiation treatments. Mutagenic effectiveness was found to be dependent upon dose and genotype concerned. However, yield components failed to show high genetic advance, probably due to non-additive gene effects.

Manjaya (2009) irradiated the seeds of soybean cultivar VLS -2 with 250Gy Gamma-rays. A large number of mutants with altered morphological characters like plant height, flower color, sterility, leaf shape, number of pods per plant, seed color, early or late maturity were identified and characterized. In M_5 generation, 24 mutant lines were evaluated for various quantitative characters. Analysis of variance showed highly significant variations among mutant lines for yield per plant. Mutant M-17 sowed significantly higher yield per plant than the parent. This mutant also exhibited more branches, more pods and higher harvest index. Sagel *et al. (*2009) conducted a research to improve the chickpea varieties ILC 482, Akcin-91 and AK 71114. They tried to improve the characters like, resistant to cold, suitable to machinery harvest type, exhibit high yield and high protein content, bigger seed size, resistance to anthracnose and other diseases and pests, and improved quality characteristics. They used eight different gamma radiation doses having rates between 50-400Gy and derived a mutant “TAEK Sagel” which gave the average yield 186 kg/ha with 23% seed protein content. In addition, its cooking time was shorter than the others.

Tah (2009) developed the correlation analysis in morphological traits like days taken to flowering and pod maturity in two mungbean genotypes through introduced mutation. The days taken to first flower was controlled by the additive and dominance gene (DDd_1) and indetermination from first pod maturity to 90% pod maturity was also controlled by the same gene (DDd_2). Due to additive gene effect the heritability for days to first flower, days to first pod maturity and 90% pod maturity was proportion to the genetic variation. Tah and Saxena (2009) studied the effect of gamma radiations to induce the synchronization maturity of pods, correlation for time taken to flowering and maturity pod in two mungbean cultivars. The results revealed that there was no correlation in the flowering and pod maturity period. The decreased flowering and late maturity was observed in the genotypes ‘K851’ and ‘Sona’ with an exception of early maturity in 10 Gy in ‘Sona’. Constant genotypic variance and high broad sense heritability for days to first flowering (D1), days to first pod maturity (D2) indicated an opportunity for successful selection of mungbean genotypes for uniform pods maturity.

Thilagavathi and Mullainatha (2009) conducted a research on the Black gram variety (Vamban-1). They studied the frequency and spectrum of macro mutants along with the mutagenic effect as of different dose/concentration of gamma rays and EMS. The seeds were subjected to different concentrations of EMS and different radiation levels. Lethality and biological damage was calculated in M_1 and M_2 generation. The studies showed that these genotypes have the Chlorophyll mutants and viable mutants. Asghar *et al.* (2010) studied genetic diversity in 30 lentil genotypes originated from Pakistan, Argentina and Syria by using Metroglyph analysis. Metroglyph analysis distributed the genotypes into 10 distinct groups. Maximum mean index score was observed for group-V followed by group-VI and group-VII. Mean index score of exotic accessions was found greater than those of hybrids and mutants. Genotypes like TCL 85-1, ILL 6821; Precoz and Masoor 93 were found to be the desirable genotypes. TCL 85-1 appeared as most prominent one with a high desirability index and maximum index score followed by an exotic accession Precoz. They reported that metroglyph technique was useful in identifying groups of genotypes with yield enhancing traits and in the selection of superior genotypes. Hegazi and Hamideldin (2010) studied the effect of gamma rays on two varieties Sabahia and Balady of okra. The seeds of okra were irradiated with different levels of radiations. They observed that the effect of treatments on both varieties was same. Among all gamma rays doses 400 Gy showed better results on the growth. The parameters as chlorophyll contents, seed production and quality of seed were significantly affected. The results regarding 300 Gy were also positive on all growth parameters. The relatively high doses of gamma irradiation 400 and 500 Gy induced more changes in genomic DNA pattern than the low dose 300 Gy. Huda *et al.* (2010) reported high heritability was observed for flower per plant, 1000-seed weight and grain yield per plant. Abscission percentage showed an inverse relationship while number of flowers showed no significant relationship with seed yield. Seed yield showed a significant positive association with pod number and seed size. But seed size and pod number showed a negative association with seed number. Nagwuta *et al.* (2010) worked on mungbean to study the morphological characters. They observed the variation in growth habit, presence of hairs on leaves and color of seed coat. Their results showed that G-6 and G-8 were in resemblance to each other in about all measured attributes. They also observed the variations among the cultivars in respect of pod length, seed weight, seed yield per plant and number of seeds per plant.

Pavadai *et al.* (2010) conducted an experiment to check the effectiveness and efficiency of yield related parameters for M_2, M_3 and M_4 generation of Soybean by using gamma rays. They concluded that the growth of the plants was increased at the low dose of radiations while decreased at the high dose of the radiations. The results regarding the treatment were positive. The genetic variability, heritability and genetic advance for treated plants were high as compared to the untreated plants. The effective gamma rays dose was 50 kR. Rungnoi *et al*. (2010) developed the F_2 generation by crossing the opaque leaf mutant and a local cultivar "Berken" to observe the inheritance characters. They advanced them up to F_5 generations by selfing to study the growth, development, chlorophyll contents and morphology of seed cells. They reported that chlorophyll content of OL was low than the check and plants exhibited to shrinking pods with yellowish color after 15 days of flowering, while other ordinary plants showed extensive growth of pods up to 18 days after flowering. They also reported that OL characters can be controlled by a single recessive gene which has no link with the other genes controlling growth and color of petiole. Samiullah and Goyal (2009) induced mutations in two mungbean varieties, K-851 and PS-16 using EMS and gamma rays as mutagens. Selection studies were conducted to improve the yield and to generate genetic variability in different quantitative traits viz., fertile branches per plant, number of pods per plant and seed yield per plant. Mean values in traits increased significantly over the controls and genetic parameters were recorded higher for the mutants isolated in M_5 generation. High values of heritability and genetic advance for the mutants indicate that further improvement could be made in next generations.

Singh *et al.* (2010) worked on an experiment by using 31 mutant lines and one parent line of mungbean. They conducted the analysis of variance to express the results. They observed a significant difference for all morphological traits under observations. They found the higher magnitude of phenotypic and genotypic coefficient of variation for yield per plant while it was estimated moderate for clusters per plant and plant height. Singh *et al.* (2010) reported higher values of genotypic and phenotypic coefficients of variance for grain yield per plant, cluster per plant and plant height showed moderate genotypic and phenotypic coefficient of variance. Tabasum *et al*. (2010) conducted an experiment and concluded that plant height, cluster per plant, biomass per plant, harvest index and pods per cluster were significantly correlated with each other at genotypic and phenotypic level. Sriphadet *et al.* (2010) conducted a study to observe the genetic variability and inheritance of agronomic traits and their relationship in two mungbean cultivars "Berken and ACC41". They observed that ACC41 contained more number of leaf and number of pods per plant than Berken. While number of days taken to flowering and seed yield per plant was higher in Berken. Test for germination percentage revealed that ACC41 was 100% hard-seeded and did not germinated at all, while the germination percentage of Berken was up to 100%. They estimated that narrow sense heritability for number of leaves per plant, hardiness, length and width of pods was highly heritable. For number of seeds and seed weight per plant heritability remained lower. Suresh *et al.* (2010) found high heritability coupled with high genetic advance as per cent of mean were observed for plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, 100-seed weight, harvest index and single plant yield exhibited the additive gene action. Tabasum *et al*. (2010) conducted a research to evaluate genetic variability in mungbean. They observed that number of secondary and primary branches, pods/cluster and length of pod exhibited lower variability while clusters/plant, 100-seed weight and harvest index showed normal variability. A good range of the genetic variability was assessed for plant height, pods/plant, and plant biomass and seed yield. Negative correlation was present in pods per cluster and seed production. Significant and positive correlation was present in clusters per plant, pods per plant, plant biomass and harvest index with seed production. Tantasawat *et al*. (2010) studied the genetic variability and their relationship in mungbean and black gram accessions by using ISSR and morphological traits as a tool. Mungbean accessions separated into three clusters. Cluster I was consisting of 15 cultivars, while cluster II comprised on 3 cultivars and cluster III contained 4 genotypes. On the bases of pairs, coefficients of genotypic relationship among all accessions ranged from 0.17 to 0.84 with the average of 0.52. They used 18 ISSR primers and amplified 341 ISSR fragments which showed that polymorphism with the ISSR primers were 90.6%.

Bhosale and Hallale (2011) exposed the seeds of black gram variety TPU-4 to different doses gamma rays. In M_2 generation a wide range of chlorophyll and viable morphological mutations were isolated. Mutant characters were grouped as Chlorophyll, leaf, and pod mutants. Chlorophyll mutations included albino, coppery leaf, light green leaf, variegated leaf, waxy leaf, xantha leaf. Leaf mutations were lanceolate, narrowrugose leaf, round cuneate leaf, unifoliate, and tetrafoliate leaf. Pod mutations were lobed and hairy pods. Higher chlorophyll mutation rate was observed with gamma rays dose of 30KR. Kamannavar *et al.* (2011) tested the fourteen genotypes of mungbean to study their yield stability by performing the pooled analysis of variance and stability analysis. The genotypic (G) x environment (E) interaction and both variance due to genotypes and environment were significant. The portioning of G x E interaction into linear and non-linear components indicated that both predictable and unpredictable components shared the interaction. The genotypes BGS-9, BPMR-1 and KGS-83 gave higher yield across the locations but their performance appeared to be unstable due to significant deviation from regression. Khajudparn and Tantasawat (2011) conducted an experiment to observe the variability, heritability and correlations among physical and physiological traits of mungbean. For all characters the genotypic coefficient of variance differed significantly. Pod length and time taken to flowering showed highest value of heritability. There was a positive correlation among pods per plant, clusters per plant, total dry matter, seeds per pod, seeds per plant, biomass, leaf area index and branches per plant and seed yield. Negative correlation was found among days to maturity and seed production. Seed production followed by the 100-seed weight, seeds per pod, total dry matter and pods per plant was significantly affected by the clusters per plant.

Sagade and Apparao (2011) studied the mutagenic treatments on two varieties of urdbean, TAU-1 and TPU-4 by using EMS and gamma rays as a source to observe the effect on different traits i.e. seed germination, seedling injury, pollen sterility, survival of plants at maturity and frequency of morphological changes and chlorophyll deficient sectors. They observed that both varieties demonstrated different varietals responses towards the mutagenic treatments regarding the above parameters. Seed germination and survival of plants at maturity decreased with increasing concentration/dose of the mutagens, while seedling injury, pollen sterility, and frequency of morphological changes and chlorophyll deficient sectors were found increasing with increasing concentration/dose of the mutagens in both the cultivars of urdbean. Shafique *et al.* (2011) evaluated 34 Black gram cultivars through morphological traits, SDS-PAGE analysis and random amplified polymorphic markers. They observed a considerable amount of genetic diversity in these species. Among the morphological traits, dry pod weight, number of branches per plant and biological yield showed highest level of coefficient of variation. Positive significant correlation was observed between numbers of pods per plant and dry pod length, grain yield and number of seeds per plant, and 100 seeds weight and biological yield. A total of 20 cultivars were identified and characterized on the basis of maximum and minimum value for 10 quantitative traits. Srivastava *et al.* (2011) conducted an experiment to estimate the genetic variability and association among 8 black gram varieties which collected from different locations of India. They used random amplified polymorphic deoxyribonucleic acid markers having size range from 50 to 30000 bp to distinguish among the black gram varieties. They observed that similarity coefficients were maximum between PLU-289 and PLU-456 showing less divergence between these two varieties. Maximum divergence was observed between LBG-20 and PLU-268 indicating the lower similarity in them.

Wani (2011) studied the frequency and spectrum of morphological mutants induced by gamma rays and EMS in chickpea. The seeds of 2 varieties of chickpea, Pusa-212 and Pusa-372, were treated with different gamma rays, EMS and combination treatments. A wide spectrum of viable morphological mutations affecting almost all parts of the plant were isolated in the M_2 generation. The most striking mutants isolated included tall, dwarf, broad leaved, white flowered, bold seeded and high yielding mutants. Combination treatments were most effective in inducing a wider spectrum and maximum frequency of macro mutations, followed by EMS. Of all the morphological mutations, the frequency of leaf mutations was maximum, followed by plant height and seed mutants. Chowhury *et al.* (2012) found highest phenotypic and genotypic coefficients of variance were recorded for plant height and number of seeds per plant respectively when the concentration of EMS was 0.4%. The lowest phenotypic and genotypic coefficients of variance were recorded for number of pods per plant in control. At 0.4% EMS concentration highest broad sense heritability was estimated for plant height and high genetic advance for days taken to flowering was also estimated at the same level of EMS. Sridevi and Mullainathan (2012) studied the effects of gamma rays and ethyl methane sulphonate on black gram. From the experiment they concluded that mean performance of different quantitative traits was significantly better in 15 mM of EMS followed by 60 kR of gamma rays when compared with the control and other doses. Generally, higher doses of gamma rays and EMS were particularly decreased and pronounced effect on the plant growth and yield of black gram. High values of heritability and genetic advance indicated the possibility of inducing desirable mutations for polygenic traits accompanied by effective selection in M_3 and later generations. Grains per pod was negative and non significant while it was positive with cluster per plant and 100-seed weight. Ahmad *et al*., (2012) and Ahmad *et al*., (2015) suggested that the selection of higher yielding mungbean genotypes may be helpful on the basis of induced mutations and Germplasm may be used for mutation breeding programme. Javed *et al*., (2014) found high heritability estimates were observed for all traits. Phenotypic correlation of seed yield per plant with germination percentage and seeds per pod was positive and highly significant however positive and significant phenotypic correlation of clusters per plant and 100-seed weight while pods per plant was negative and significant. Higher heritability and significance correlation indicated that germination percentage, 100-seed weight and seeds per pod may be used to select higher yielding mungbean genotypes.

Conclusion

Mutation breeding provides important information about the ways to produce higher grain yield mungbean genotypes and may be used as advance breeding tool in crop breeding.

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