Use of Radiations to Study Useful Mutations in *Zea mays* for Grain Yield: A Review

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Abstract: Mutations have served as vehicle of progress in evolution as well as in improvement of living organisms in terms of their utility in breeding. Variation is pre-requisite for maize breeding. The present review will describe about the use of radiations for the induction of mutation in maize genome. Various studies have been carried out to evaluate maize under the use of different radiation doses. It was concluded that higher heritability, genetic advance, general and specific combining ability, strong genotypic and phenotypic correlation, additive and dominance gene action for grain yield per plant, 100-grain weight, cob girth, cob length and cob weight may be used for the development of synthetic as well as hybrids to improve grain yield of maize through mutation breeding program.
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Introduction

Maize (*Zea mays* L.) is the most widely grown cereal in the world. In terms of productivity, it is also a leading cereal of the world (Abuzar *et al*., 2011). Maize is a diploid species having 20 chromosomes. It is monoecious plant having staminate flowers in the tassel and pistillate flowers located midway on the stalk. Ovules are 95% cross pollinated and 5% self-pollinated where principal pollinating agent in cross-pollination is wind. Maize is indigenous to Americas and for the Native Americans; it has been principal food grain. About 8000 years ago, maize was domesticated and in its wild form, it is no more available (Sleper and Poehlman, 2006). Maize is used as food for humans and feed for livestock and poultry. It is used as raw material in food, medicine and textile industries for the manufacturing of corn oil, corn flakes, dextrose and textile dyes (Ali *et al*., 2011a; Ali *et al*., 2014abc). Maize is an important cereal crop that is grown as food for human and feed for livestock. Its grain constitutes about 9.7396 % grain protein, 4.85% grain oil, 9.4392% grain crude fibre, 71.966% grain starch, 11.77% embryo while fodder contains 22.988% acid detergent fibre, 51.696% neutral detergent fibre, 28.797% fodder cellulose, 40.178% fodder dry matter, 26.845% fodder crude fibre, 10.353% fodder crude protein and 9.095% fodder moisture (Aalyia *et al*., 2016; Ali *et al*., 2016; Saif-ul-Malook *et al.,* 2014ab; Ali *et al*., 2013). Primary purpose of corn production is to meet industrial needs and to fulfill animal feed requirements. Out of total corn production, 65% is used to feed animals and 35% to fulfill nutrient requirement of humans (Banziger *et al.,* 2000; Fawad *et al*., 2015ab). In Pakistan, maize contributes 2.2% to value addition in agriculture and 0.5% to GDP. During 2012-13, maize was cultivated on an area of 1.085 million hectares with production of 4.631 million tons. Yield per hectare in 2012-13 stood at 4268 kg per hectare (Pakistan Economic Survey, 2012-13). Major biotic and abiotic factors which cause economic loss to the maize crop are drought and nitrogen stress (Banziger *et al.,* 2000; Filipovic *et al*., 2014), seedling and leaf blights, seed, root, stalk, ear and kernel rots, smuts, stalk borer, armyworm, cutworm and shoot fly (Chaudhry, 1994). Genetic variation of useful traits is required for crop improvement. When a certain variation is lacking, mutagenic agents such as radiations and certain chemicals can be used to induce mutations and generate genetic variation from which desired mutants can be selected. When genes for resistance to a particular disease or tolerance or stress cannot be found in the available gene pool then mutation induction is the best alternative (Novak and Brunner, 1992 and Saif-ul-Malook *et al*., 2014cd). The useful mutations for a certain trait can be used as such or genes of that trait can be transferred to the commercial varieties in which a particular trait is absent (Irfaq and Nawab, 2001). Ionizing radiation is the basic tool of nuclear technology for crop improvement. Gamma rays have been utilized in different crops for the creation of various positive mutations (Majeed *et al*., 2010).

Gene action for various traits under the use of radiations: Sharif *et al*. (2000) evaluated two varieties of cotton under the 0, 25, 30 and 35 kR levels of gamma rays. Seedling height, germination percentage and plant height were reduced as a result of mutagenic effects of gamma rays. Effects of treatments on seedling and plant height were significant while on germination were non-significant. Irfaq and Nwab (2001) studied effect of different levels of gamma rays on three wheat cultivars, Pirsabak-91 (P-91), Khyber-87 (K-87) and Tarnab-78 (T-78). The irradiation levels were 10, 20, 30 and 40 kR. There was a remarkable reduction in 1000-seed weight, plant height and survival percentage at higher irradiation levels of 30 and 40 kR. For all cultivars, there was delay in germination at all levels of gamma rays. There was an increase in plant height in case of Pirsabak-91 at 10 kR. Abnormality in plant height occurred at levels 30 and 40 kR. For some other characters, there was a different response of all cultivars at different levels of gamma rays. Amjad and Anjum (2002) conducted study to investigated effects of various levels of various levels of gamma rays on seeds of onion. The various levels of irradiation were 10, 20, 40, 80 and 100 kR. There was no notable effect of irradiation on seed viability except for 100 kR where there was reduction in viability. Germination percentage was stimulated at lower irradiation levels without being affected at higher levels. Effect of irradiation was more pronounced on root growth as compared to shoot growth. Up to 40 kR, severe reduction in seedling growth occurred with an increase in dose. Gao *et al*. (2004) evaluated effect of enhanced UV-B radiation on growth, yield and seed qualities of maize under field conditions. Maize yield, dry matter accumulation, chlorophyll a and b, protein content, sugar and starch were reduced. Jacks and Thapa (2004) studied effects of various levels of gamma rays on seeds of *Pinus kesiya* and *Pinus wallichiana*. The gamma rays levels used were 1, 2.5, 5, 10, 15, 20 and 30 kR. Seeds treated at 30 kR germinated in case of *P. kesiya* while the seeds of *P. wallichiana* were not germinated at this level. Root length of both species decreased with the increase in radiation level. There was stimulatory effect shown by lower levels of irradiation. Abdel-Hady and Ali (2006) evaluated wheat seeds under different levels of gamma rays. The radiation levels used were 150, 250, 350 and 450 Gy and the characters studied were callus induction percentage, plant regeneration and agronomic traits. All the traits were stimulated at gamma rays level of 150 Gy. All the traits were reduced significantly at higher levels of irradiation. Hernandez *et al*. (2006) studied effects of different levels of laser irradiation on low germinating corn hybrid. Three levels were used and each level was used for six different time periods. There was a remarkable increase in emergence and dry weight of seedlings of laser irradiated seeds as compared to control. Sadek *et al*. (2006) studied correlation and path analysis in five parent inbred lines and their six single crosses. Positive and highly significant correlation of grain yield was found with plant height, ears dry weight per plant, ears height, ear length, 100-kernels weight, kernels per row, ear diameter, blades area per plant, fourth leaf blade area and leaf area index. There was positive but not significant correlation of kernels yield per plant with ears per plant, days to 50% plant polling and grain rows per ear while there was negative and highly significant correlation of grain yield with days per plant to 50% silking. Order of parameters causing variation in plant yield was LAI, blades area, ears dry weight per plant, kernels per row, days to 50% silking, ear length, ear diameter, plant height, fourth leaf area, 100-kernels weight, ear height. Adamu and Aliyu (2007) evaluated three varieties of tomato for morphological parameters under the different levels of sodium azide. The seeds of these varieties were treated with doses of 1, 2 and 4 mM. The characters studied were fruits per plant, root length, seedling length, seed germination, seedling survival and plant height. With the exception of plant height, variety and treatments were highly correlated with reference to the studied traits. Chicea and Racuciu (2008) evaluated maize seeds under different levels of beta irradiation in laboratory. The irradiation source used was ^{90}Sr and dose range was 0 to 5 Gy. Under different irradiation levels, there was an increase in germination percentage. Stimulating effect of low levels of beta rays was observed on growth of plantlets. The highest stimulating effect on plantlets growth was shown at 0.615 Gy. Hameed *et al.* (2008) evaluated effect of gamma rays on desi and kabuli chickpea seeds for traits such as germination, growth, seedling fresh weight, root and shoot length and their ratio. Irradiation doses were inversely related with germination percentage and growth rate of sprouts. Karim *et al*. (2008) studied effect of different levels of gamma rays on two large seeded chickpea varieties, Binasola-2 and CPM-834. The irradiation doses were 0, 100, 200, 300, 400, 500, 600, 700, 800 and 900 Gy while the irradiation source was ^{60}Co. Treated generations showed early flowering and maturity than untreated generations. Highest numbers of branches were recorded at 700 Gy while there was a reduction in pods per plant and seeds per pod at higher levels of irradiation. There was increase in 100-seed weight and yield per plant in treated generations at 100 and 300 Gy as compared to control. Majeed *et al.* (2010) studied effect of different levels of gamma irradiation on dry seeds of *Lepidum sativum* L. The seeds were treated at levels of 20, 30, 40, 50, 60, 70 and 80 kR using ^{60}Co as radiation source. The effect of different doses was studied on days to germination, days to completion of germination, germination percentage, survival percentage, shoot length per plant, root length per plant, number of branches per plant, number of leaves per plant, fresh shoot weight per plant and dry weight of shoot per plant. There was a significant effect of gamma rays on all characters. At higher irradiation levels, there was delay in germination initiation days and germination completion days. With the increase in dose level, all other characters were declined. There was no significant effect of higher irradiation level on germination percentage. Khawar *et al*. (2010) studied effect of different levels of gamma rays on seeds of maize, wheat, chick pea and black eye beans. With the increase in dose level, shoot and root lengths were decreased in all samples. Seeds with doses of more than 2 kGy were not germinated. Nastasic *et al*. (2010) evaluated S_1 and HS progenies of synthetic maize for association between grain yield and its related components. All yield components showed strong, medium strong and highly significant relationship with grain yield in both progenies. Grain yield and 1000-kernal weight showed highest association. For the other traits, 1000-kernel weight and kernel depth in S_1 generation and 1000-kernel weight and ear length in HS generation had highest genotypic correlation. In both progenies, S_1 and HS, 1000-kernel weight and number of kernel rows had highest, significant and desirable effect on grain yield. In both progenies, there was a undesirable direct of kernel depth on kernel yield. Singh and Datta (2010) studied effects of different levels of gamma rays on wheat seed. The radiation levels ranged from 0.01 to 0.10 kGy. There was an increase in ear bearing tillers and number of grains due to gamma rays which resulted in an increase of grain yield. There was a negative effect of gamma rays on 1000-kernel weight. The response of wheat towards low doses was uniform. Wannows *et al*. (2010) carried out correlation and path analysis studies in fifteen maize hybrids in order to investigate nature of association between different traits and direct and in direct effects of different yield related components on yield. Significant and positive association of grain yield and leaf area index, grains per row and ear length was revealed through coefficients of correlation. Through path coefficient analysis, direct and positive effects of physiological maturity, leaf area index and ear diameter on kernel yield were detected. Ali *et al*. (2011b) studied correlation and path analysis in 40 maize genotypes at 40% soil moisture in green house. The effects of different characters on fresh shoot length were investigated through path analysis. Highest direct effect on fresh shoot length was shown by fresh root length. Following fresh root length, highest direct effects on fresh shoot length were shown by dry root weight, root density, leaf temperature and dry shoot weight. Major contribution towards fresh shoot length was of fresh root length, leaf temperature, dry root weight, dry shoot weight and root density. Ilker (2011) carried out correlation and path analysis studies in eight varieties of sweet corn. Direct effects of fresh ear weight on fresh kernel yield were highly positive while its effects on all other traits were indirect. Ear length and kernel rows per ear were characters of consideration in the breeding of sweet corn. Iqbal *et al*. (2011) reported genotypic and phenotypic interrelationship among various traits in maize. The association of leaf area and plant height with total produce was significant and positive. These traits were of major importance for selection of genotypes. Moradi and Azarpour (2011) studied direct and indirect effects of yield components on yield of a single cross cultivar 704 through path analysis. Ear length, seed rows per ear, plant height and ear per plant had a significant correlation with maize yield. Highest positive effect on yield was shown by ear length. Indirect effect of ear length on yield was shown through rows per ear and 1000- grain weight. Oancea *et al*. (2011) studied effect of UV-irradiation on maize and wheat seeds. With the increase in irradiation exposure time, seed germination was delayed. There was a negative correlation between shoot and root length and time of exposure. Pavan *et al*. (2011) reported correlation and path analysis studies in 87 maize hybrids for the determination of association between yield and its related parameters. The genetic interrelation of kernel yield with plant height, ear diameter, 100-grain weight, yield per plant, grains per ear, grain rows per cob and cob length was positive and significant. Highest direct influence of grain rows per cob, grains per cob, 100-grain weight, plant height and yield per plant on kernel yield was revealed through path analysis. Rahimi and Bahrani (2011) evaluated two varieties of wheat under different levels of gamma rays. Different levels of gamma rays were 0, 25, 50, 75, 100 and 125 Gy. There was an effect of different irradiation levels on 1000- seed weight, grain yield and leaf area index. As compared to control, there was 5% more yield from plants of irradiated seeds. There was a decrease in leaf area index with increase in level of gamma rays. Rahimi and Bahrani (2011) studied effect of gamma irradiation on agronomic characteristics and quality of fatty acids of two brassica cultivar. Measured traits were decreased with increasing irradiation level up to 300 Gy. At 100 Gy level, highest seed yield, plant height and 1000-seed weight were obtained. Minimum amounts of measured traits were obtained at 500 Gy. Songsri *et al*. (2011) evaluated seeds of five physic nut (*Jatropha curcas L.)* genotypes under six levels of gamma rays. The irradiation doses were 0, 200, 400, 600, 800 and 1000 Gy while the characters studied were germination percentage, survival percentage and growth genotypes. At the irradiation levels of 600, 800 and 1000 Gy, there was no survival of seedlings. Plant height, germination percentage and survival percentage were significantly reduced at higher levels of gamma irradiation. Irradiation level higher than 600 Gy resulted in complete death. Sreckov *et al*. (2011) studied path analysis and correlation among yield and yield related traits in two test cross populations of maize. In first studied population, there was a highest genotypic correlation of grain yield with rows of kernels. There were highest but negative correlation coefficient values of grain yield with rows of kernels in the second population. Influence of ear height on grain yield in both populations was significant and desired one. Undesired but highly significant effect of plant height was found on kernel yield. Alaei (2012) reported correlation studies in ten genotypes of maize for different morphological characters. The association of kernel yield with all characters studied was considerable and positive except plant height. Kernel rows per ear and kernels per ear were the highest correlated parameters. Albokari *et al*. (2012) evaluated four varieties (Hinta, Khaliji, Lokaimy and Qasime) of wheat under various levels (50-500 Gy) of gamma rays. There was reduction in height of seedlings of all cultivars with the increase in gamma rays level. Al-Enezi *et al*. (2012) studied effects of low levels of X-rays on seeds of date palm. Germination of irradiated seeds was decreased as compared to control. Remarkable increase in root length was observed with the increase in X-rays level. Leaf length increased at lower levels but was reduced at higher levels. Aminu and Izge (2012) carried out heritability and correlation studies in maize under drought conditions. Phenotypic and genotypic correlations of kernel yield were found to be significant and positive with ears per plant, ears per plot and 100-kernel weight. For kernel yield, genotypic correlation magnitude was higher than coefficients of phenotypic correlation. Aynehband and Afsharinafar (2012) evaluated three lines (D-136, K-432 and K-433) of amaranth under different levels of gamma rays. The irradiation levels used were 0, 100, 150, 200 and 250 Gy. With the increase in irradiation level, shoot length, root length and germination percentage was decreased. Sensitivity of seeds of amaranth lines with respect to germination characters increased with increase in irradiation level. Germination characters were sensitive even to low levels of gamma rays. Emrani *et al*. (2012) evaluated two canola cultivars (RGS003 and Sarigol) for various agronomic traits under different levels of gamma rays. Characters studied were seed yield per plant, 1000-seed weight, pods per plant, seeds per pod and days to flowering. Through analysis of variance, highly significant effects for doses levels, genotypes and genotype × dose were recorded. For all characters greater variation was recorded as compared to control. Highest genotypic coefficient of variation, genotypic coefficient of variation and genetic advance of mean was recorded for yield per plant. Yield components were the main determinants of yield. The yield components were influenced positively by mutagens.

Gnanamurthy *et al*. (2012) reported effects of different chemical mutagens on quantitative characters of corn. The mutagens used were sodium azide, ethyl methane sulphonate and diethyl sulphate. The doses levels of these mutagens were 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 mM. There was a remarkable reduction in parameters related to morphology and yield such as dry weight per plant, fresh weight per plant, seed germination, days to first tassel and silking, 100-kernel weight, yield per plant, plant height, ears per plant, leaves per plant, ear diameter, ear length and grains per ear. With the increase in level of mutagens, there was more reduction in parameters related to phenotype and yield. Haddadi *et al*. (2012) evaluated 28 F_1 progenies of eight inbred lines of maize for yield and yield related parameters combining ability. The interrelations of kernel weight and kernels per ear row were significant and positive with kernel yield. These parameters can be the basis for selection of genotypes. Hedimbi *et al*. (2012) reported effect of ultraviolet-A and ultraviolet-B radiations on maize seedling under controlled conditions. There was reduction in concentration of chlorophyll a and b with the increase in exposure duration. By increasing time of exposure to ultraviolet-A and ultraviolet-B, number of leaves, stem diameter, plant height and seedling height were also reduced. In plants exposed to ultraviolet-B, there was more reduction in chlorophyll a and b. Mudibu *et al*. (2012) evaluated effect of different doses of gamma rays on different morphological and agronomic characters of three soybeans (*Glycine max* L.) varieties. The effect of different levels of gamma rays (0, 0.2, 0.4, 0.6 and 0.8 kGy) was studied on characters like grain yield, pods per plant, seeds per plant, 100-seed weight, days to 50% flowering, plant height, stem diameter, leaves per plant, leaflet length and width and pod length and width at three lodge stage. Many of these characters were decreased remarkably in M_1 generations at 0.2 and 0.4 kGy gamma rays level. Grain yield and yield components were increased remarkably in M_2 generations of all varieties at doses of 0.2 and 0.4 kGy. For morphological characters, there was remarkable decrease or no change at 0.2 and 0.4 kGy in M_2 generations. In treated generations of mutated seeds, mutants with high yield potential were found.

Perveen *et al*. (2012) studied mutagenic effects of different levels of ethyl methane sulphonate on two varieties of *Vicia faba* L. The various parameters studied were plant height, pod length, pods per plant, seeds per pod, seed yield and 100-seed weight. Distinct morphology of mutants was observed as compared to the control. Significant mean values of plant height and pods per plant were obtained. The difference of seeds per pod from control was non-significant. Sri Devi and Mullainathan (2012) studied effects of different doses of gamma rays and ethyl methane sulphonate on black gram. The levels of gamma rays were 40, 60 and 80 kR while dose levels of ethyl methane sulphonate (EMS) were 10, 15 and 20 mM. Performance for differen traits at EMS level of 15 mM and gamma rays level of 60 kR was better than control. The different traits were decreased at higher doses. Yield and growth were the most affected traits at higher doses of both EMS and gamma rays. Zarei *et al.* (2012) evaluated interrelationship among grain yield and related characters in 11 corn hybrids. Plant height, ear length, days to maturity, kernel length, number of kernels per ear and 100-grain weight had positive correlation with yield. Plant height and ear length showed highest correlation followed by 100-grain weight and kernels per row. Positive direct effect on grain yield was shown by ear length, kernel length, 100-grain weight and total number of kernels per ear. Number of total kernels had highest direct effect while 100-grain weight had highest indirect effect. Amini *et al*. (2013) reported correlation and path analysis of grain yield related traits in six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of maize. Genotypic correlation values among traits were greater than phenotypic correlation values. There was high positive genotypic association of plant height with grain yield. Yield components had high positive direct effects on grain yield. There was high positive and direct effect of ear seed on grain yield. Significant negative correlation was shown by ear seed weight with grain yield by means of large indirect and negative effects on rest of the yield related traits. Aney (2013) studied effect of different levels of gamma irradiation on two pea varieties *Pisum sativum* var. *hortense* and *Pisum sativum* var. *arvense*. The effect of radiation levels was studied for percent germination, plant height, maturation period, branches and flowers per plant, pods per plant, pod size, seeds per pod and per plant, 100-seed weight and seeds per 100 gram. In treated plants, reduction in germination percentage and number of flowers was dose dependent. Stimulatory effect was shown by lower doses on yield contributing characters like pods per plant, seeds per plant and pod size in both varieties.

Aparna *et al*. (2013) studied effects of different gamma irradiation levels on germination and growth parameters of groundnut. Ground nut seeds were treated at levels of 0.70 to 2.30 kGy using ^{60}Co as a radiation source. With the increase in dose level, there was a decreasing trend in germination percentage. Root length, shoot length, vigour index and root to shoot length ratio were also decreased at higher levels of gamma rays as compared to untreated seeds. Emrani *et al.* (2013) evaluated two cultivars of maize for different levels of gamma radiations. The traits studied were germination percentage, germination rate, root length, shoot length and shoot diameter. Root and shoot growth of both cultivars was highest on third and fourth day at 400 and 600 cGy level of irradiation. At 800 cGy, traits showed significant reduction. Fellahi *et al*. (2013) reported correlation and path analysis studies in 29 bread wheat genotypes to determine different traits affecting grain yield and their direct and indirect effects on yield. Spike per plant, biological yield and straw yield showed positive correlation with grain yield. For increasing yield, positive direct effects were shown by harvest index and biological yield. For genetic improvement of wheat genotypes for yield, harvest index and biological yield can be important selection criterion. Girija and Dhanavel (2013) studied effect of different levels of gamma rays on different quantitative traits of cowpea such as plant height, leaves per plant, branches per plant, days to first flower, clusters per plant, pods per plant, seeds per plant, hundred seed weight and yield per plant. There was more reduction for all characters at higher doses as compared to lower doses in M_1 generation. The results revealed that different doses of gamma rays can be used effectively for creating variability for various quantitative traits. Huang *et al*. (2013) studied correlation, regression and path analysis of grain yield related traits in *Crambe abyssinica*. Significant association of plant height with height of branches and number of first branches was revealed through partial correlation. There was a significant correlation of height of branches with primary inflorescence pod number and secondary branches number while branches height had negative association with first branches number. 1000-grain weight, secondary branches number and pods per plant had significant association with first branches number. There was a significant association between secondary branches number and yield per plant. Correlation of pods per plant with seed yield was significant while with 1000-grain weight was negative. There was a significant correlation between 1000-grain weight and yield per plant. It was revealed through regression and path analysis that only contribution of 1000-seed weight and pods per plant was significant towards yield per plant. Lukanda *et al*. (2013) reported effect of different levels of gamma rays on morphological and agronomic characters of three varieties (JL12, JL24 and kimpese) of groundnut. The irradiation levels were 100, 200, 400 and 600 Gy while irradiation source was cesium 137. The effect of different irradiation doses was studied on grain yield, pods per plant, seeds per plant, 100-seed weight, days to 50% flowering, plant height, leaflet width, leaves per plant, stem diameter, leaflet length and ramifications per plant. Grain yield and other agronomic and morphological characters were increased significantly at 100 Gy level. This increase was more prominent in JL24 variety. At gamma rays levels of 400 and 600 Gy, there was a remarkable reduction in plant growth and grain yield. Marcu *et al.* (2013) studied effect of gamma radiation on dry maize seeds. With the increase in irradiation dose, germination percentage germination index, root length and shoot length were decreased. Plants obtained from seeds exposed to higher doses , survived for less than 10 days. Minisi *et al.* (2013) reported effect of gamma irradiation on wet and dry seeds of *Moluccella laeyis* L. at 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20 kR. For wet treatment, seeds were soaked in water 12 hours before treatment and the characters studied were germination percentage, survival percentage, growth traits and morphological variation. During both seasons, highest germination percentage of dry seeds was obtained at 2.5 and 5 kR while of wet seeds at 2.5 kR. For wet seeds, plant height was increased at low levels and decreased at higher levels. Number of branches and dry biomass were increased at higher irradiation levels. Numbers of flower per branch were increased for dry seeds at 2.5 kR. Some morphological changes were found in wet seeds at irradiation level of 12.5 to 17.5. Munawar *et al.* (2013) reported correlation and path analysis studies for yield and its related parameters in maize hybrids. The genotypic and phenotypic association of kernel yield with kernel rows per cob and kernels per row was significant and positive. For improvement of yield, kernels per ear row and kernel rows per ear were found to be important characters.

Mustafa *et al.* (2013) studied interrelationship of various character in 40 corn genotypes. After root density and dry root weight, effect of fresh root weight was highest and direct on fresh shoot weight. The main contribution towards fresh shoot length was of dry shoot weight, dry root weight and fresh root length. These parameters were of prime importance in selection of genotypes. Sikandry *et al.* (2013) reported effects of different levels of gamma rays on yield related parameters of two sunflower cultivars. All normal parameters of both cultivars were stimulated under the influence of gamma rays. Plant height was increased as compared to normal height of both cultivars. There was a positive enhancement in character like leaf length, leaf width and leaves per plant. There was a remarkable increase in the diameter of stem and flower head. Jinpeng *et al*. (2014) evaluated maize variety, Zheng 58 under different levels of radiations from ^{7}Li source. The radiation levels used were 0, 10, 20, 30,40 and 50 Gy. There was a inhibitory effect of irradiation on germination and survival rate. With the increase in irradiation level, there was a decreasing trend in plant height, cob length and germination rate in M_1 generation. Kumar *et al*. (2014) reported correlation and path analysis studies in 60 F_1 generations of maize for 12 different characters. The association between kernel yield was positive with shelling percentage, 100-kernel weight, kernels per row, plant height, ear girth, kernel rows per ear, ear height and ear length. The association of kernel yield with days to 50% silking and 50% tasseling was negative. The direct effect of 100-kernel weight on kernel yield was highest. After 100-kernel weight, highest direct effect was of ear girth and grains per row.

. Kwaga (2014) studied direct and indirect effects of various yield related parameters on the kernel yield of two maize varieties, OBA-98 and OBA-SUPER. Highest contribution towards the yield was of cob length while 100-grain weight was the second major contributor. In terms of combined contribution, contribution of 100-kernel weight and pod length was the highest one. Nataraj *et al*. (2014) carried out correlation and path analysis studies in 39 inbred lines of maize in order to investigate association of different yield and yield related characters. The association of kernel yield at phenotypic and genotypic level with ear diameter, kernel rows per ear, kernels per ear row, ear weight with husk, ear weight without husk, ear height, ear length and 100-kernel weight was positive and significant. Highest direct effect on kernel yield was shown by kernel rows per ear, kernels per ear row, ear weight with husk and 100- grain weight. Effects shown by ear diameter, plant height and ear height on kernel yield were direct and considerable. The effects shown by remaining traits on kernel yield were direct and negative. Ramya *et al.* (2014) reported effects of different doses of gamma rays and ethyl methane sulphonate on black gram variety TNAUC (Bg)[6]. The dose level of gamma rays was 150, 200, 250, 300 and 350 Gy while of ethyl methane suphonate was 10, 15, 20, 25 and 30 mM. The characters studied were seed germination and survival, pollen and seed fertility, plant height, number of primary branches, clusters per plant, pods per plant, pod length, seeds per plant, 100-seed weight and yield per plant in M_1 generation. There was a decreasing trend in germination and survival percentage, pollen and seed fertility and yield related traits with increase in doses of mutagens. Ethyl methane sulphonate was more efficient than gamma rays and produced greater physical injuries. Rigon *et al*. (2014) studied direct and indirect effects of different parameters on yield of 25 maize hybrids. Different parameters studied were ear length and diameter, kernel rows, stem diameter, 100-kernel weight and grains per ear. Significant association of ear length was found with kernel yield.

It was concluded from above discussion that the use of radiations may be helpful to improve grain yield in maize through mutation breeding program.

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