CHAPTER -II

REVIEW OF LITERATURE

Crop improvement depends on genetic variability and extent to which traits are heritable. Segregating populations are more suitable for improving the plant type by way of selection than non-segregating ones. A thorough understanding of the genetic diversity, extent of variation, genetic architecture of the plant and heritability of the character among the genotypes would help to carryout effective selection for improving yield.

Limited genetic variability in the population hinders the selection process. When genetic variability is exhausted in any crop, induced mutation using physical and chemical mutagens is applied as potent source to create new genetic variability in the population such as plant type, yield and yield component characters, quality and abiotic/biotic resistance etc. and to remove certain demerits/toxic substances in short time.

Gamma radiation is an important tool for inducing the genetic variability, enhancing yield and yield contributing traits. However, there is a need to predict the most beneficial dose of gamma rays for improvement of specific traits of crop plant because gamma radiation can induce useful as well as harmful effects. According to Melki and Sallami (2008) low doses of gamma rays have positive effects on crop species. In wheat, higher dose of radiation raises the frequency of certain rare types of mutants of special nature to a level where they can usefully employed by the plant breeders to achieve the results that would not be possible to be accomplished by other means. For example, in India NP-836 which is an awned mutant from the awnless wheat variety NP-799, Sharbati Sonara is an amber grain colour mutant was developed at IARI New Delhi from the red grain colour wheat variety Sonora-64 by treating the seeds with gamma rays.

With this purpose in mind a brief review of available and pertinent literature has been cited under the following headings.

2.1 Irradiation and Radio-sensitivity

2.2 Macro mutation
2.3 Micro mutation
2.4 Genetic variability
2.5 Correlation coefficient
2.6 Path coefficient analysis
2.7 Storability of wheat
2.8 Mutation in other crops with different mutagens

2.1 Irradiation and Radio-sensitivity

Gamma rays are the most commonly used physical mutagens for mutation studied, especially in plant, because they have shorter wave length ($10^{-3}$ to $10^{-11}$ cm) and consequently, capable of deep penetration in the tissues. Further, unlike other ionizing radiations, facilities for gamma irradiation are also easily available and are used more frequently than others.

2.2 Macro mutation

They involve change in a whole constellation of characters and thus, have a viable phenotypic expression.

Muhammad and Khalid (2001) concluded that wheat cultivars Pirsabak-91 (P-91), Khyber-87 (K-87) and Tarnab-78 (T-78) were irradiated with 10kR, 20kR, 30kR and 40kR doses of gamma irradiation. The cultivars showed significant reduction in plant height, survival percentage and 1000-grain weight under the influence of high gamma rays doses (30kR and 40kR) excepting days to germination. Germination of all the cultivars was significantly delayed in response to all the gamma rays doses and low dose (10kR) increased the plant height in case of Pirsabak-91. Higher gamma rays doses (dry 30 & 40kR) also created abnormalities in plant height.

Melki and Dahmami (2009) studied seeds of wheat irradiated with i.e., 00, 10, 20 and 30 Gy of gamma rays. Although the 20 Gy does caused an increase of the speed and germination capacity (GC) of the seeds as compared to non-irradiated ones. Furthermore, seed irradiation with this dose had a positive effect on the chlorophyll content and maximum quantum yield of the irradiated plants.
Srivastava *et al.*, (2011) studied in wheat crop that reduction in seedling survival due to the hindrance caused by the mutagen on different metabolic pathways of the cells. 

Sheikh *et al.* (2012) studied mutation breeding, it is important to determine a suitable dose/concentration of mutagen for a crop plant which can be employed for inducing maximum variability through point mutations. Seed germination, seedling growth, pollen sterility and chromosomal aberration are the commonly used criteria for studying radio-sensitivity in wheat plants. 

Singh *et al.* (2012) studied three mutagens, i.e., gamma-rays, EMS, HA, separately and in combination, on radiobiological response, mutation frequency, and mutation spectrum was investigated in five cultivars, i.e., K-24, IB-226, K 527/11, DL-3, and Amber of barley, *Hordeum vulgare*. Gamma-rays produced significant reduction in pollen fertility of a number of cultivars, whereas chemical mutagens had little effect in most of the varieties. The EMS was more effective in inducing chlorophyll mutations than either gamma-rays or HA. Combination treatments often were more effective than individual treatments in all the cultivars. 

Ning *et al.* (2013) concluded that the yellow-green leaf mutant has a non-lethal chlorophyll-deficient mutation that can be exploited in photosynthesis and plant development research. A novel yellow-green mutant derived from *Triticum durum* var. Cappelli displays a yellow-green leaf color from the seedling stage to the maturity stage. Examination of the mutant chloroplasts with transmission electron microscopy revealed that the shape of chloroplast changed, grana stacks in the stroma were highly variable in size and disorganized. The pigment content, including chlorophyll a, chlorophyll b, total chlorophyll and carotene, were decreased in the mutant. 

### 2.3 Micro mutation 

Groski *et al.* (1987) conducted research on a variety of spring wheat cv, KOC-1385. The seeds of this variety were irradiated by Co$^{60}$ gamma rays at 0.96, 0.82 and 0.77 kR. The seed sample was grown in plastic tube of 20cm, 30cm and 40cm long (3 plant/tube) and in term of tube were sunk in (a) and (b) lawn and (c) lawn near a dense canopy. In M$_1$ the height of main stem was greater than in (a) and (b) with number significant difference in the number of tillers per plant. But in M$_2$ the number of tillers
per plant was greater in (a) than in (b) and (c). The numbers of spikes were greater in (a) than in (b) and (c) and same was the situation in case of yield per spike.

**Hassan et. al. (1988)** studied the effect of gamma rays (15-35 kR) and sodium azide on the morphological characteristics of “Sonalika” cultivar of wheat. Higher dose decreased germination percentage and plant height with a maximum reduction of 13.69 per cent caused with 35 kR. Higher dose of gamma rays delayed maturity, whereas higher concentration of sodium azide reduced heading. Sodium azide treatment resulted in more reduction in number of tillers per plant, number of spikelet per plant and length of spike.

**Ayubet. al. (1989)** studied the effect of different dose of gamma rays irradiation in six wheat varieties and concluded that the number of tiller plant, number of grain per spike, grain weight per spike, 1000 grain weight and yield per plant responded differently in different varieties. They further concluded the effect of irradiation was depressing with increase in irradiation doses, which is transmitted from generation to generation.

**Song et. al. (1992)** irradiated a wheat verity 
*(Jiangdu 1 x st)* with Co$^{60}$ source. After selection, they obtained a new variety (8165), which was highly resistant to wheat streak mosaic virus. The new variety so obtained was high yielding as much as 48.1 per cent more yield than that of the control in regions of severe infection. Moreover, it had a growth period of 208-210 days and a 1000 grain weight of 38g.

**Lapochkina (1998)** took a bread wheat 
*(Triticum aestivum L)* pollinated with gamma irradiated pollen grains of *Aegilops* at dose of 0.75, 5.0, 10.0, 13.0 and 15.0 kR as well as non irradiated pollen (control). The use of pollen grains irradiated by of 0.75 and 1.5 dose kR increased yield in hybrid plants in comparison with control.

**Saber et. al. (1998)** treated the two local wheat varieties (Sakha-69 and Giza-163) by gamma-ray doses (50, 100 and 150 Grey) to induce mutations for resistance to the causal fungus of yellow rust. The higher was the mutagen dosage; the lower was the germination percentage. Both wheat varieties showed a similar trend in response. The effect was more pronounced in the pot experiment. The highest gamma-ray dose (150 Grey) was the most effective, as it gave about 67 per cent and 69 per cent (pot exp.) and about 71 per cent and 73 per cent (Petridish exp.) seed germination for Sakha-69 and Giza-163, respectively.
Rachovska and Dimova (2000) observed the effect of gamma rays and sodium azide on six quantitative traits (height of the plant productive tillers, length of the main spike, number of spikelets in main spike, no and mass of grains) in wheat cultivars momchil, pobeda and katya in M$_1$ and M$_2$ generations. The treatments generally had a negative effect on the quantitative traits.

Madihan and Khan (2002) exposed seeds of wheat cultivar Bukhtawar-92 to 5, 10,15,20 and 25 kR dose of gamma rays along with untreated check to study its effects on germination percentage, number of leaves per plant, days taken to heading, plant height, number of tillers, spike length, grain per plant, seed per spike and 1000 grain weight. The most effective dose was 10 kR, while other doses showed fluctuation in their effects.

Singh (2001) induced mutations in five wheat (Triticum aestivum L.) varieties and observed decrease in the mean for number of tillers per plants. The mean plant height, 100-kernel weight, 100 seed weight remained unchanged in mutagen treated population. In terms of induced variability for quantitative characters, gamma rays were most effective than hydroxylamine and hydrazine.

Umer and Madiha (2002) reported that induced variation in yield components of wheat cultivar Bakhtawar-92 by gamma radiation during the Rabi season 1997 - 98. Seeds were exposed to 5, 10, 15, 20 and 25 kR doses of gamma radiation along with an untreated check. The analysis of the data revealed significant differences among the treatments. The most beneficial dose was 20 kR. The impact of this dose was promising in germination (96.47%), plant height (82.78cm), number of grains per plant (59.80), and grain yield/plant (39.26gm), while the other doses such as 5, 10, 15 and 25 showed minor fluctuations in their effects.

Din et. al. (2003) concluded that in five wheat genotypes, days taken to ear head initiation were significantly increased due to 25, 35 and 45 kR treatment of gamma rays except 15 kR dose, slightly enhanced that easing but as the doses increased to higher level, a delay on day to earing was observed. Similarly significant delay in earing completion was recorded in all the genotypes with various doses except 15 kR with which a slight decrease was obtained in time taken to earing completion.
Khan *et. al.* (2003) studied that effect of radiation doses 10, 20 and 30 kR on tillers per plant, spike per plant, spike length, spike per grain, 1000 grain weight and grain yield per plant and noted a significant decrease in all the traits under the study with increase in radiation doses except for 1000 grain weight.

Khalid and Muhammad (2003) treated pure dry seeds of three wheat cultivars viz. Pirsabak-91 (P-91), Khyber-87 (K-87) and Tarnab-78 (T-78) with 100, 200,300 and 400 Gy doses of gamma rays at Nuclear Institute for Food and Agriculture (NIFA) Tarnab, Peshawar. The influence of radiation was examined on some morphological characteristics like germination percentage(%), survival percentage (%), number of tillers per plant, days to heading, spike length, number of grains per spike and grain yield (kg/ha). A gradual decrease in the mean values for all the parameters was observed with the increase in the radiation intensity except number of tillers per plant which showed significant increase in case of all the cultivars. In general, adverse effects on most of the parameters were produced as a result of higher doses (300 and 400 Gy) of gamma rays.

Din *et. al.* (2004) concluded that significant decrease in germination percentage of all the wheat genotypes was recorded with an increase in the radiation intensity. The lowest germination percentage (14.60) was recorded with 45 kR dose and the highest germination percentage (74.26%) was recorded in control. The difference in the mean value of control and 15 kR dose of radiation was non-significant, but they differed significantly from 25, 35, and 45 kR doses of radiation. The average plant height was also significantly decreased with various doses of gamma radiation in all the five genotypes. The maximum reduction (23.63%) in plant height was recorded with 45 kR as compared to control. Similarly significant reduction in number of tillers plant-1 was observed by various radiation doses but remarkable decrease (52.53%) was obtained with 45 kR dose.

Majeed *et. al.* (2009) was studied effect of gamma irradiation significantly affected survival percentage, shoot length/plant, fresh of shoot/plant and dry weight of shoot/plant except germination percentage of *Lepidium sativum* L. Days to initiation of germination and days to completion of germination were significantly delayed at higher doses of gamma rays.
Singh and Balyan (2009) reported that mutagenesis with gamma rays, mutants characterized by reduced plant height, square head, own less ear, amber seed colour, bold seed and storage capacities were induced in bread wheat (*Triticum aestivum* L.) cv. Kharchia 65. The amber seed colour, bold and plumb seed producing M3 mutant progenies namely 351, 445-1, 498 and 632 stored in plastic box for seven year but they not showed significantly high storage capacity against to cereal weevil compared to the contest cv. Kharchia 65.

Borzouei *et. al.* (2010) irradiated two wheat genotypes Roshan and T-65-58-8 with gamma rays at 100,200,300 and 400 Gy to determine the effect on germination and physiological characteristics of wheat seedling.

Kusaksiz and Dere (2010) studied the effect of various doses of gamma rays in durum wheat and observed induced genetic variability among the mutated population which enhanced effective selection for desirable traits.

Mongi and Marouani (2010) studied the effects of irradiation with low doses (0, 10, 20 and 30 Gy) of radioactive cobalt (60Co) c rays on seed germination, shoot and epicotyl growth of hard wheat (*Triticum durum* Desf.) were investigated under laboratory and glasshouse conditions. Irradiated wheat seeds kept their germination speed and capacity levels compared to the control. However, improvements of +18 per cent and +32 per cent were, respectively obtained in root number and root length at the 20-Gy dose. Moreover, the 20-Gy-irradiation dose generated an increase of +33 per cent in epicotyl length. The 20-Gy-irradiation dose improved the root length by +32 per cent and root number by 75 per cent in plants grown on liquid medium. A lower root length increase of +23 per cent was obtained with the same treatment under glasshouse growing conditions.

Singh *et. al.* (2013) reported that seed by gamma irradiation at 0, 0.005, 0.025, and 0.05 kGy on the growth and development of five field crops viz., wheat, garden pea, field pea and spinach. Interspecies variation was found in seedling emergence capacity, plant vigor and mass, leaf development and economic yield in response to gamma irradiation.

Magda and Hanan (2014) studied that fast neutrons from a $^{252}$C source in the fluence range $10^5$–$10^8$ n/cm$^2$ on the Egyptian wheat cultivar (Sakha 92). The experiment
was conducted for three successive seasons (2008-2009, 2009-2010, and 2010-2011) to study the effect of the irradiation on the plant growth, grain yield, and physiological changes of three generations of plants produced by irradiated moisturized grains. A low fast-neutron fluence $2 \times 10^6 \text{n/cm}^2$ increased the yield throughout the three mutagenic generations considerably. It also increased concentrations of the total chlorophyll, sugars, and crude protein. These changes improve the quantity and quality of the grain.

2.4 Genetic Variability

Mutation breeding has been perceived as an important tool to foster additional variability in qualitatively and quantitatively inherited traits in a number of crop plants. The variability thus created enhances opportunities for selection of new genotypes with the desired characteristics. Induced mutation can play a momentous role in the restructuring of the plant, leading to yield improvement. It could create additional genetic variability to supplement conventional crop breeding.

Ali et. al. (2002) reported that high heritability accompanied with high genetic advance in case of plant height, number of productive tillers per plant and coleoptile length were most likely the heritability is due to additive gene effects and selection may be effective in early generations for these traits in wheat.

Sachan and Singh (2003) found that heritability were high (86%) for coleoptiles length, (80%) for plant height and (74%) for number of tillers per plant in durum wheat (*Triticum durum* Desf.).

Kashif and Khaliq (2004) were reported that plant height exhibited highest heritability value of 92.08% while fertile tillers per plant showed minimum value of 40.71%. Genotypically plant height, spike length, spikelets per spike, grains per spike and 1000-grain weight were positively and significantly correlated with grain yield while highly significantly association phenotypically.

Nadia and Khalil (2007) studied genetic improvement in yield related traits of wheat under irrigated and rainfed environments. Randomized block design with three replications were used under each environment. Genetic variations among cultivars under the two environments were significant for all the traits studied (grain yield and its components).
Singh and Sharma (2007) evaluated 40 durum wheat genotypes to determine the genetic variability of yield and yield components. Analysis of variance indicated highly significant differences between genotypes for all the characters. Variability estimates revealed that estimates of phenotypic coefficient of variation were higher than the estimated genotypic coefficient of variation for all the characters. The expected genetic advance and its estimated percentage mean for various characters revealed that grains per spike, harvest index and plant height exhibited the highest genetic advance. Although plant height, spikelet’s per spike and biological yield exhibited moderate heritability values, their genotypic coefficient of variation was relatively less, resulting in less genetic advance.

Saktipada et. al. (2008) carried out an experiment on 14 wheat genotypes to study the magnitude of genetic variability for yield its components. The characters, panicle length, 1000 gain weight and days to maturity showed low heritability coupled with low genetic advance whereas number of spikelets per panicle and grain yield per plant showed high heritability coupled with high genetic advance.

Mukherjee et. al. (2008) gave information of variability, heritability and genetic advance derived from data on 8 different characters recorded in 20 genotypes of bread wheat. The genotype showed significant variation for all the characters. High magnitude of phenotypic and genotypic coefficient of variation was observed for tiller per meter. The observed characters showed high heritability. High heritability coupled with high genetic advance was recorded for number of tiller per meter.

Bhoite et. al. (2008) conducted a study on 25 durum wheat genotypes to determine the genetic variability, heritability and genetic advance analysis of variance for 7 yield contributing characters showed highly significant differences among the genotypes. Grain yield showed the maximum variability, followed by plant height, 1000 gain weight and days to maturity. The genotypic and genotypic co-efficient of variations were almost equal for the all characters. High heritability and high expected genetic advance was recorded in spike length, productive tillers per plant and grain yield per plot.
Waqar et al. (2008) was reported that number of grains per spike, 1000 grain weight and grain yield per plant showed high heritability coupled with high genetic advance in wheat that result in prevailing suitable condition for selection.

Ajmal et al., (2009) studied the phenotypic and genotypic coefficients of variation were highest for seed yield per plant, suggesting that these characters are under the influence of genetic control.

Saif et al. (2009) reported that the magnitude of broad sense heritability of plant height, tillers per plant, grains per spike and grain yield was high and low in case of number of spikelets per spike. Fairly high estimates of heritability and genetic advance for plant height, number of tillers and grains per spike suggested that selection for these traits could be practiced more effectively. Plant height had significantly positive correlation with number of tillers both at phenotypic and genotypic levels. Tillers per plant displayed negative relationship with spikelets per spike, 1000 grain weight and number of grains per spike. Grain yield was positively and significantly correlated with number of grains per spike and 1000 grain weight. Hence the traits are given emphasis during selection of wheat genotypes for improving productivity.

Bangshi et al. (2010) reported highly significant differences and adequate genetic variability among 14 wheat genotypes. GCV, heritability and genetic advance were found high for number of tillers per plant and grain yield per plant. Correlation yield revealed importance of number of tillers per plant and number of grains per spike.

Mudasir and Abdul (2010) studied thirty-seven wheat genotypes and three check varieties for correlation and path coefficient analysis of some quantitative traits in wheat. The estimates of genotypic correlation coefficient were higher than the corresponding phenotypic correlation coefficient for all the character combinations. Seed yield was significantly and positively associated with number of spikelets per ear head followed by number of effective tillers and 100 seed weight at both phenotypic and genotypic levels. Seed yield showed a significant negative association with number of seeds per spikelets at genotypic level.

Kusaksiz and Dere (2010) studied the effect of various doses of gamma rays in durum wheat and observed induced genetic variability among the mutant population.
Kahriziet. al. (2010) was reported high correlations among the leaf dry weight, leaf area ratio and stem dry weight. Heritability estimates high for plant height, leaf dry weight and stem dry weight. High genetic gains were observed for grain yield, tiller/plant, yield/plant, plant height and leaf area ratio.

Kumar et. al. (2010) observed that days to maturity, effective tillers per plant, grain weight per spike, grain yield per plant and leaf blight had maximum coefficient of variation. The high heritability was found for days to 75% heading, plant height, tillers per plant, spike length spikelets spike, grain weight per spike, number of seeds per plant and leaf blight. Highly significant positive association of days to 75 per cent heading with grain weight, spike length and plant height with tillers per plant and effective tillers plant. However, the grain weight and spike length were significantly positively correlated with grain yield per plant. Grain weight per spike and number of seeds per plant were observed positive significant correlation with grain yield per plant in wheat.

Ramya et. al. (2013) studied the 2760 mutants wheat lines, which were in M3 and F3M3 generation were evaluated for yield and quality parameters in augmented (RCBD) design at Dharwad during Rabi2008-09. Heritability estimates were high for days to 50 per cent flowering, days to maturity, 1000 grain weight, grain yield, protein, and zeleny sedimentation value. High heritability coupled with high genetic advance as per cent over mean was observed for the character yield per plant.

Said et. al. (2014) evaluated sixty five wheat accessions for yield and related traits during winter 2010-2011. Maximum genotypic differences were observed for all the studied parameters except chlorophyll concentration index and number of spikelet per spike indicating considerable amount of variation among the accessions for each trait.

Waqasa et. al. (2014) studied the eight F2 populations viz., Manthar-2003 × Fareed-2006, Manthar-2003 × 9444, Manthar-2003 × 9317, Manthar-2003× 9242, Fareed-2006 × 9317, Fareed-2006 × 9242, Fareed-2006 × 9444 and Fareed-2006 × Manthar-2003 involving five varieties/lines Manthar-2003, Fareed-2006, 9444, 9317 and 9242 for the estimation of heritability and genetic advance of various yield traits. Broad sense heritability was varied from 51.72 to 80.11 per cent, 40.26 to 77.96%, 50.21 to 84.51% and 54.48 to 80.91 and the range of genetic advance was from 1.59 to 3.36, 3.35
to 6.88, 0.17 to 0.74 and 3.55 to 6.88 for number of tillers per plant, number of grains per spike, grain weight per spike and grain yield per plant respectively.

Bozhidar and Gergana (2015) observed that phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the traits. High PCV and GCV were observed in trait grain weight per spike (PCV=30.36%, GCV=24.93%). High genetic advance combined with high heritability showed characters: spike length, grain weight per spike and thousand grain weight.

2.5 Correlation coefficient

Yield components and plant traits contribution on grain yield may be important for breeding strategies. Simple correlation analysis that relates grain yield to a single variable may not provide a complete understanding of the importance of each component in determining grain yield. Path coefficient analysis allows an effective means of partitioning correlation coefficients into unidirectional pathway and alternate pathway.

This analysis permits a critical examination of specific factors that produce a given correlation and could be successfully employed in formulating an effective selection strategy

Chowdhry et. al., (2000) reported that yield components like grains number per spike and 1000 grain weight were main contributors to grain yield in wheat.

Desalegn et. al. (2000) reported positive correlation of grain yield with days to anthesis and maturity, grain filling period and plant height, but negative correlation of days to anthesis with grain filling period and plant height in become wheat.

Balcha (2002) observed that grain yield was positively correlated with grain filling period, spike length and harvest index, but negatively correlated with days to heading and maturity, plant height, and thousand kernel weights.

Shahid et. al.(2002) observed that spike length, grains per spike and grain weight per spike had significant positive phenotypic correlation with grain yield per plant, while plant height showed that a strong negative genotype and phenotype correlation with tiller per plant. Highly positive genotype correlation of tiller per plant with grain per spike and grain weight per spike was recorded.
Ahmad et. al. (2003) reported that the genotype correlation were higher than phenotypic ones for most of the characters exhibiting high degrees of genetic association among traits under consideration. Grain yield was positively and significantly correlated with all traits except plant height. The direct effects for biological yield and spike length were positive and negative for the rest of traits.

Asif et. al. (2004) was reported that days to heading and plant height showed relative higher heritability. Grain yield showed significance association with plant height and test weight. Direct positive effects of plant height towards grain yield suggest the effectiveness of these traits to select and identify desirable wheat genotype for a target environment.

Okuyamae et. al. (2004) reported that the grain yield showed positive and significant genotypic and phenotypic correlation with number of grain per spike.

Kashif and Khaliq (2004) concluded that positive correlation between grain yield and plant height was probably due to an increase in panicle length, number of grains per panicle and biological yield because the traits have a positive correlation with the bush height.

Asif et. al. (2004) evaluated ten bread wheat elite lines of diverse origin for the study of correlation and path coefficient analysis. Grain yield showed significant association with plant height and test weight. Direct positive effects of plant height towards grain yield suggest the effectiveness of this trait to select and identify desirable wheat genotypes for a target environment.

Bhutta et. al. (2005) determined plant height and spike length had positive significant genotype correlation but positively non-significant correlation with grain whereas, number of spikelets per spike had negatively non-significant correlation with grain yield at both levels. 1000 grain weight has negative but significant association with grain yield.

Qaisar et. al. (2005) conducted an experiment on six commercial cultivars of wheat to analyze correlation and path coefficient analysis. Positive and significant correlation of grain yield was recorded with plant height, spike length and biological yield at genotypic level. Bio-mass had maximum direct contribution to grain yield
followed by plant height and 1000 grain weight while spike length and flag leaf area had negative direct contribution to grain yield followed by plant height and 1000 grain weight while spike length and flag leaf area had negative direct contribution to grain yield.

Mohammad et al. (2005) collected information on correlation and path analysis among yield and yield associated traits of candidate bread wheat lines including two control cultivars. Positive genotypic and phenotypic correlation was estimated between plant height and biological yield. There were significant and positive genotypic correlations between biological yield with harvest index and grain yield.

Eslami et al. (2005) conducted an investigation to evaluate phenotypic and genotypic correlation coefficients as well as relationships between some of the grain quality traits using four durum wheat genotypes. Results of correlation analysis indicated that seed hardiness correlated significantly with protein content.

Arya et al. (2005) observed grain yield was positively correlated with effective tillers per plant, biological yield per plant and grains per ear. The path analysis suggested that biological yield per plant was the main contributor of grain yield per plant from the study on 10 yield and quality traits in 40 wheat genotypes.

Bhutto et al. (2006) carried out a study on phenotypic correlation coefficient between yield and yield contributing parameters in six spring wheat genotypes. Grain yield per plant recorded significantly positive correlation with spike length, number of grains per spike, number of tillers per plant, seed index and days to maturity.

Yadav et al. (2006) gave information on correlation studies in 90 indigenous and exotic wheat genotypes. Tillers number per plant followed by total biomass and hectoliter weight showed the highest positive correlation with grain yield.

Li Huai Di et al. (2008) analyzed the result from correlation study indicated that the number of effective spikes had positive and negative correlations with grain number per spike and 1000-grain weight and significant or very significant positive correlation with the yield per plant. Grains number per spike had significant negative correlation with 1000-grain weight had positive correlation with the yield per plant. The 1000-grain weight had positive correlation with the yield per plant.
Indoo et al. (2004) studied correlation analysis for grain yield and its components in 36 durum wheat genotypes. There was a significant positive correlation between grain yield and number of tillers per meter.

Dogan (2009) concluded that the correlations among plant height, grain number per spike, grain weight per spike, 1000 grain weight, test weight and grain yield as well as direct and indirect effects of those traits on the grain yield were investigated using path analysis. Grain number per spike, 1000-grain weight, plant height and test weight had significant direct effect on grain yield. It was concluded that these characteristics could be important selection criteria in durum wheat breeding studies.

Eid (2009) reported that 1000 seed weight was positively associated with number of spike, number of grains per spike and spike length at genotypic level for bread wheat genotypes grown both under control and drought condition.

Bangshi et al. (2010) reported highly significant differences and adequate genetic variability among 14 wheat genotypes. Correlation studies revealed importance of number of tiller per plant and number of grain per spike.

Mohammed et al. (2011) twelve agronomic traits were included in the investigation. Highly significant differences were revealed among 16 durum wheat genotypes for all traits studies, suggesting the possibility of improving durum wheat for their traits. Plant height and number of kernels per spike showed the highest phenotypic and genotypic coefficient of variations and genetic advance, whereas days to maturity and test weight had the lowest values. The genotypic correlation estimated showed positive association of grain yield with days to heading (r=0.50), harvest index (r=0.69) and kernels number per spike (r = 0.81). Hence, these traits could be considered as suitable selection for the development of high yielding durum wheat varieties.

Cifici (2012) studied that correlations between traits revealed that important characters, influencing grain yield per spike were spike length, spikelet number per spike and grain number per spike. The results of path analysis also indicated that spike length, spikelet number/ spike and grain number per spike had the maximum direct effects on grain yield per spike.
Degewione et. al., (2013) reported positive and negative non-significant correlation of grain yield with days to heading, grain filling period, days to maturity, plant height, spike length and number of spikelet per spike both at genotypic and phenotypic levels.

Gelalcha and Hanchinal (2013) observed positive and highly significant correlation of grain yield with tillers per plant, number of spikes per square meter, number of grains per spike and total biomass at genotypic, but positive and negative non-significant association with days to flowering, days to maturity, plant height, peduncle length and spike length for bread wheat genotypes grown under irrigated condition.

Hokrani et. al. (2013) studied that the character starch content recorded least variability whereas, seed yield per plant (gm) and number of tillers per plant exhibited high variability. High heritability was observed in all the characters studied in 95 advanced generation free threshable mutant lines of derived *dicoccum* lines along with five checks (DDK-1001, DDK-1025, DWR-1006, UAS-415 and UAS-304) of F4M4 progenies of wheat.

Mehrdelan et. al. (2013) studied that number of panicle per square meter had the most indirect positive effect on grain yield through number of grains per panicle, panicle length and biological yield. Correlation coefficients showed that there was a significant negative correlation with the probability of (α= 0.01) between the traits of grain weight with grain number and there was a positive and significant relationship between numbers of panicle per square meter and number of grains per panicle. Furthermore, there was a positive and non-significant correlation between grain weight and yield and there was a positive and significant correlation between number of grains per panicle and numbers of panicle per square meter and yield with the probability of (α= 0.01).

Singh et. al. (2013) concluded significant and positive association with grain yield and with characters days to 75 per cent heading, days to anthesis, days to physiological maturity, biological yield, effective tillers per plant, grains per spike and spike weight.

Singh et al. (2015) studied in advanced lines of wheat and reported positive correlation of the flag leaf with plant height, 100-grain weight, hectoliter weight and
protein content whereas, negative correlation was observed with gluten content. Plant height also exhibited positive correlation with hectoliter weight and tiller per plant showed positive correlation with yield per plant.

Bozhidar and Gergana (2015) growth thirty eight emmer wheat genotypes in IPGR-Sadovo, Bulgaria during 2012-2014 to estimates variability, heritability, genetic advance and associations among characters. The highly significant and positive phenotypic correlation was found between grain yield per plant and following components: plant height, grain weight per spike, number of grains per spike and thousand grain weight.

4.6 Path coefficient analysis

In any crop improvement programmes planned to be conducted, it is necessary to deal with correlated characteristics of traits. Path coefficient is defined as the degree of influence of one variable on the other in quantitative traits. Path analysis is a special type of multivariate analysis which deals with a closed system of variables (each variable in the system is either a linear combination of some other variables in the system or is one of the basic factors in the system) are linearly related (Dabholkar, 1999).

Subhani and Chowdhry (2000) observed highly significant differences among bread wheat genotypes and found that grain yield was positively and significantly correlated with flag leaf area, tillers per plant, spike length, grains per spike and 1000-grain weight while path coefficient analysis showed that tillers per plant and spikelet per spike had positive direct effects on grain yield of bread wheat grown under irrigated conditions.

Khaliq et. al., (2004) suggested that yield components have either a direct or indirect effect on grain yield or both. Therefore, it was essential to determine the effects of yield components on grain yield. Consequently, path coefficient analysis is the most common statistical method used for this purpose. Path coefficient analysis is a reliable statistical technique, which provides means to quantify the interrelationship of different yield components and indicate whether the influence is directly reflected in the yield or take some other pathways to produce an affect.
Okuyama et. al. (2004) conducted a study on path analysis using different genotypes of wheat like durum and triticale under irrigated and non irrigated field conditions. The result indicated positive direct effect of number of grains with grain yield.

Mohammad et. al. (2005) studied the path analysis on days to heading, days to maturity and plant height and observed negative direct effect on grain yield, whereas biological yield and harvest index had high and positive direct effect on grain yield.

Aycicek and Yildirim (2006) reported positive but small direct effects of 1000 grain weight on grain yield of bread wheat.

Yashpal et.al. (2006) evaluated 60 genotypes of bread wheat to study the association and to determined the selection parameters using cause and effect of relationships among the characters. Independent association of protein content with sedimentation value and positive association of 100-grain weight with grain yield suggested that 100-grain weight could be adopted as one of the selection parameters to bread wheat cultivars for high yield coupled with selection for high gluten strength. Path analysis strongly pointed out the role of productive tillers per plant and 100-grain weight in the determination of grain yield, as the magnitude of their direct effects was the largest.

Majumder et. al. (2008) reported the highest negative direct effect of days to maturity on grain yield and its highest indirect effect next to harvest index via grains per spike.

Ali et. al. (2008) reported grains per spike exhibited the highest positive direct effect followed by number of productive tillers per plant and 1000 grain weight on grain yield of bread wheat.

Majumder et. al. (2008) was reported that spikes per plant, grains per spike, spike length, 100-grain weight and harvest index were the most important characters which possessed positive association with grain yield. Path coefficient analysis revealed that among the different yield contributing characters spike per plant, grain per spike, 100-grain weight and harvest index influenced grain yield per plant directly.
Singh et al. (2010) reported that the grain yield per plant showed very strong positive association with biological yield per plant, grain per spike, tiller per plant, ear length and plant height.

Hasna et al. (2011) studied that path coefficient analysis revealed higher direct effect of number of grains per spike, followed by 100-grain weight and plant height on grain yield of spring wheat. But, it was reported that, spike length followed by days to maturity had negative direct effect on grain yield of this crop.

Asadullahzade et al. (2010) conducted experiment on wheat genotypes and found that there was a very good and positive relation between biological yield and grain yield.

Khan and Naqvi (2012) resulted that path coefficient could be used as an important tool to bring about appropriate cause and effects relationship between yield and yield components. According to obtained results the selection on the basis of number of spikes, number of spikelet’s and number of grains in this material would likely to be most useful for increasing grain yield because of their direct positive contribution to grain yield under irrigated condition. However number of spikes, spikelet numbers, spike length and grains number may be used an effective selection criterion for increasing grain yield of wheat under different irrigation levels. Therefore it is concluded that these traits could be selected for the different stress environments and it would be beneficial for the yield.

Singh et al. (2015) resulted that the path coefficient analysis in wheat the cause and effect relationship between the variables which is unique in partitioning the associations into direct and indirect effects through other dependent variables. Among the traits studied, days to 50 per cent flowering showed negative effect on grain yield. Tillers per plant and days to maturity exhibited positive direct effect on yield.

2.7 Storability of wheat

Storage of seed till next sowing season is essential part of seed industry. Seeds have maximum potential viability during maturity and then the viability starts declining during storage. In storage, viability and vigour of the seeds is regulated by many physico-chemical factors like moisture content of seed, atmospheric relative humidity,
temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials (Doijode, 1988). Very little attention has paid in India regarding the storability of wheat seeds under ambient storage conditions.

Karunakaran et. al., (2001) concluded that deterioration rates of high moisture wheat under various storage conditions would help farmers and grain managers to know how quickly to dry the grain or adjust the storage conditions to prevent further quality loss.

Hussain and Uchino (2006) concluded that storability tests were carried out for determining the amount of time that it took for wheat samples to lose 0.5 per cent of their initial dry matter. The procedure for tracking wheat dry matter loss included measuring carbon dioxide produced by samples of wheat held under controlled moisture and temperature conditions and then using carbon dioxide data to calculate dry matter loss. The overall objective of the present study was to determine whether storage time or storage method for wheat samples before and after using infrared irradiation had any effect on wheat storability test results.

Saeidi et. al. (2007) concluded that greater correlation between seed germination, vigor and emergence percentage in farm situation was obtained but the correlation between all germination characteristics in laboratory and farm situations with yield was not significant.

Bojovic (2010) examined that cultivars of wheat, Florida 302 has been found the most dormant (its seeds germinate in great percentage after the ripening period of 90 days), while KG-56 cultivar has been the least dormant (seeds germinate in great percentage in harvest period, without ripening). The seeds of Triticale were not dormant.

Singh et. al. (2011) studies on seed mycoflora of wheat during storage. Germination was decreased during storage period because fresh seeds showed better germination per cent i.e., from 95 to 100 per cent than stored seeds due to infestation of Aspergillus candidus, Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Aspergillus terreus, Curvularia lunata, Fusarium roseum and Fusarium semitectum during storage.
Chattha Shakeel et. al. (2012) estimated significant differences for seed moisture content (%) and seed vigour in storage container during storage periods. Seed moisture content was at par in seed stored in cloth bags (13.14 %) and gunny bags (13.04 %), but it was significantly highest than polyethylene bags. Similarly, significantly highest seed vigour was noted in seed stored in gunny bags (1755.39) as compared to other storage containers, which were at par with each other.

Chaurasia et. al. (2013) concluded that seeds of wheat variety viz., HUW- 234, UP-2338 and PBW-343 dried and stored in cloth bags, polyethylene bags and gunny bags under ambient conditions for 8 months at Seed Technology Laboratory, Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad. The results indicated that there was an effect of storage place, packaging materials, duration of storage and kind of seed on the viability during storage period. The gunny bags stored seeds showed higher values for seed quality traits in comparison to polyethylene and cloths bags. Seed germination and seedling length was high and at par up to four months of storage and it was decreased significantly after 4 months. Seed vigour was noted highest in 2 months of storage and it was decreased significantly as the period of storage increased.

Zareian et. al. (2013) resulted that seed size had significant impact on all measured traits in laboratory and field with the exception of germination percentage and harvest index. Results indicated that germination rate significantly decreased by increasing seed size. The other traits showed significant increase by increasing seed size. Mahdavi cultivar had significant effect on seedling dry weight and dry weight of 100 plants. Other traits were similar among cultivars. Significant interaction was observed for seedling dry weight and dry weight of 100 plants. Assessment of treatments in this study showed that seed size had no significant impact on germination percentage, but it changes seedling emergence and grain yield, in this way the best category of seed size was related to >2.2-2.5 size, whereas emergence percentage and yield of seeds with 2-2.2 size was significantly less than other sizes.

Kandil et. al. (2013) was elucidated seedling characters effects of soybean cultivars i.e. Crawford, Giza-111, Giza-21, Giza- 22 and Giza-35 due to ageing (storage) in different packaging material i.e. seeds or pods in plastic or cloth bags for different periods i.e. 3, 6, 9 and 12 months under ambient and refrigerator conditions. Seedling
parameters i.e. root and shoot length, seedling fresh and dry weight root/shoot ratio and seedling vigor index were decreased with the period of ageing. Soybean cultivars stored in plastic bags were affected due to storage but the effects were more pronounced in the plastic bags as compared to cloth bags.

Sarlasch et al. (2013) revealed that the treatment T₄ (15 m/ml CoCl₂ priming) and T₆ (2 % KNO₃) after 24 hrs of priming were at par in respect to seedling length (238 and 240), seedling fresh weight (172 mg and 168 mg) and seedling vigour index (22610 and 22800) in the laboratory experiment.

Pathak and Zaidi (2014) studied that infection and identification of different fungal genera associated with storage wheat varieties. Maximum fungal incidence was recorded with Fusarium solani and minimum with Drechslera spp. in variety PBW-343 screening test. In all five varieties tested, PBW-343 was found to be most susceptible and infected with 7 fungal genera as compared to other variety.

2.8 Mutation in other crops with different mutagens

Ali Sakin and Yildirim (2004) reported that durum wheat (Triticum durum Desf.) variety Gediz-75 seeds without presoaking treated with 0.1, 0.2, 0.3 and 0.4% EMS for 8 hours at 24°C. Base populations were retained by randomly selecting normal appearing single plants and those with high grain yield. The selected plants were grown as the M₃ generation. Some mutant progenies derived from 0.1% and 0.3% EMS treatment in the M₃ exhibited higher yield means than that of control. High heritability estimates observed for mutant populations demonstrated that induced variation was maintained in the M₂ and M₃ generations. Some mutant progeny populations in M₄ had higher single plant grain yield than the control. As a result, mutations affecting yield and other characters can be used in durum wheat breeding.

Khan and Goyal (2009) recorded that seed germination induced by mutagenic treatments may be the result of damage of cell constituents at molecular level or altered enzyme activity and correlated seed germination with abnormalities in mitotic cycles and in metabolic pathways of the cells.

Dhulgande et al. (2010) studied that effect of gamma rays (5kR, 7kR and 10kR) and ethyl methanesulphonate (0.05%, 0.10% and 0.15%) on frequency and spectrum of
chlorophyll mutations (xantha, chlorina, viridis and albina) in two varieties of pea, namely, DDR-53 and DMR-55 have been observed. Conclusively the various doses or concentrations of mutagenic treatments have independent response towards frequency and spectrum of chlorophyll mutations.

Devi and Mullainathan (2012) studied the effects of gamma rays and ethyl methane sulphonate (EMS) on mutagenesis of blackgram to determine the effects of induced mutation on the species. Seeds of blackgram were treated with various doses/concentrations of gamma rays (40, 60 and 80 kR) and ethyl methanesulphonate (10, 15 and 20 mM). 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 (80 kR and 20 mM) that were particularly decreased had a pronounced effect on the plant growth and yield of blackgram. High values of heritability and genetic advance indicate the possibility of inducing desirable mutations for polygenic traits accompanied by effective selection in M3 and later generations.

Shagufta et al. (2013) reported that gamma rays (100Gy, 200Gy, 300Gy and 400Gy) were more superior to EMS (0.1%, 0.2%, 0.3% and 0.4%) and SA (0.1%, 0.2%, 0.3% and 0.4%) in reducing seed germination, seedling height and plant survival. However, EMS in turn was more effective than gamma rays and SA in inducing pollen sterility. In general, the reduction in seed germination, plant survival and pollen fertility was more at the higher dose/concentration levels, which indicate the greater sensitivity of fenugreek due to occurrence of more genic, chromosomal and physiological disturbances at these concentrations.

Ndou et al. (2013) concluded that Ethyl methane sulphonate (EMS) is the most useful chemical mutagen to induce genetic variation in plant breeding programs. This study was conducted to determine the optimum EMS concentration, treatment temperature and duration for effective mutagenesis in selected wheat varieties. Seeds of four varieties (B-936, B-966, SST-387 and SST-875) were treated with four EMS concentrations (0, 0.3, 0.5 and 0.7%), three temperature regimes (30, 32.5 and 35°C) at four treatment durations (0.5, 1, 1.5 and 2 h) with two replicates The most effective treatment in variety B-936 was 0.7% EMS at 30°C for 1.5 h exposure. B-966 responded
best at 0.5 per cent EMS at 35°C for 1.5 h; SST387 at 0.5% EMS, 32.5°C and 2 h and SST875 at 0.5 per cent EMS, 32.5°C and 1 h. Increased EMS dose, temperature and exposure time were detrimental to seeds of the respective varieties.