CHAPTER-II

REVIEW OF LITERATURE

A thorough understanding of the extent of variation, genetic architecture of the plant and heritability of characters among the genotypes would help in developing sound plant improvement programmes. Genetic variability is the gift of nature and its fruitful utilization in any crop species calls for systematic collection, evaluation, description and grouping of genotypes based on economic descriptors.

Genetic improvement in wheat gained attention of workers since long time and comparatively more reports are available on influence of different characters on productivity of the crop. The published literature pertaining to genetic variability, correlation coefficient and path coefficient analysis in wheat are reviewed here under the following sub headings.

2.1 Genetic variability
2.2 Correlation coefficient
2.3 Path coefficient analysis

2.1 GENETIC VARIABILITY

Possibility of achieving improvement in any crop plants depends on the magnitude of genetic variability present in the base population. The phenotypic variability expressed by a genotype or a group of genotypes in any species can be partitioned into genotypic and phenotypic components. The genotypic component being the heritable part of the total variability, its magnitude on grain yield and its component characters influences the selection strategies to be adopted by the plant breeders.

The basic requirements of plant breeding are variation and selection. Thus, variability analysis is useful for getting information about the characters that are expected to respond the selection.

Singh et al. (1982) estimated variability parameters for eleven characters from F₂ progenies of bread wheat crosses among 18 lines. They observed the highest genetic variability for spikes per plant followed by plant height and grain yield. All characters were highly heritable except grain yield per plant.
Das and Rahman (1984) studied eight quantitative traits in nine varieties of wheat. Genotypic and phenotypic variability was high for grains per spike, plant height and days to maturity, but less for 100-grain weight, spike length and grain weight per plant. Heritability estimates was high for all the characters.

While analyzing the data on grain yield per plant and seven experimental yield related traits from six land races of *Triticum aestivum* and five of *Triticum durum*, Pathak and Nema (1985) obtained high values of heritability, genotypic coefficient of variation and genetic advance for 100-grain weight. Heritability was considered moderate along with high genotypic coefficient of variation and high genetic advance for grain weight per ear.

Pathak et al. (1986) studied genetic variability and heritability of grain yield per plant and five related characters in 15 genotypes of wheat. The results revealed that grain yield per ear showed high heritability, high genotypic coefficient of variation and genetic advance, whereas grain yield per plant exhibited low heritability, high genotypic coefficient of variation and high genetic advance. They also observed that the high heritability, low genotypic coefficient of variation and genetic advance were apparent for plant height.

Singh et al. (1987) studied 11 agrophysiological traits with 18 bread wheat varieties. Result revealed that high genetic advance coupled with high heritability was recorded for days to heading and plant height. The days to heading, plant height, numbers of grains per ear and 100-grain weight were less influenced by environments than tiller number, total biomass and grain yield.

Amin et al. (1990) studied 18 genotypes of bread wheat to determine the available genetic variability. Considerable variability with moderate to high heritability and sensible genetic advance were found for grain yield, 1000-grain weight, number of spikes per plant, plant height and days to heading.

Baisakh and Nayak (1991) studied 13 wheat cultivars for grain yield and related its traits. Wide genetic variability was observed for grain yield per plant and tillers per plant. High heritability along with strong genetic advance was observed for plant height.

Kheiralla (1993) estimated variability for grain yield and five yield components in 20 lines of F₃ generation. He found high coefficient of genotypic variation for spike length, grains per spike, 1000-grain weight, spikes per plant and grain yield per plant. Broad sense heritability was high for spike length, grains per
spike and 1000 grain weight, but moderate for spikes per plant and grain yield per plant.

Tiwari and Rawat (1993) studied F<sub>3</sub> generation of 70 wheat genotypes for the estimation of variability parameters. They found the highest heritability for days to heading and the highest genetic advance for grain yield and number of ears per plant.

Fantini <i>et al.</i> (1994) studied parental, F<sub>1</sub>, F<sub>2</sub>, BC<sub>1</sub>F<sub>1</sub> and BC<sub>2</sub>F<sub>1</sub> generations in 14 crosses of bread wheat for the estimation of variability parameters in important agronomic characters. They observed considerable genetic variability among the genotypes. The genetic coefficient of variation was recorded higher for plant height, biological yield per plant and harvest index. Heritability along with high genetic gain was recorded for flag leaf area, grain weight per spike, grain yield per plant, biological yield per plant and harvest index.

Kumar and Luthra (1995) estimated variability parameters by using P<sub>1</sub>, P<sub>2</sub>, F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>, BC<sub>1</sub>, BC<sub>2</sub>, BC<sub>1</sub>s and BC<sub>2</sub>s generations of two bread wheat crosses i.e. HD 2329 x Kalyan Sona and HD 2009 x Sonalika. They found the highest genotypic coefficient of variation for grain yield per plant followed by biological yield, spike number and flag leaf area in cross HD 2329 x Kalyan Sona. In case of cross HD 2009 x Sonalika, this value was maximum for flag leaf area followed by biological yield and yield per plant. Peduncle length showed the highest heritability in cross HD 2329 x Kalyan Sona, whereas harvest index exhibited the highest heritability in cross HD 2009 x Sonalika. In this study, high heritability was associated with low genetic advance for yield per plant, spike number, number of grains per spike, days to ear emergence, flag leaf area, grain filling period, peduncle length, biological yield and harvest index in both the crosses.

Raut <i>et al.</i> (1995) studied genetic variability, correlation and path analysis on 32 genotypes of wheat. The results revealed that grain yield, 100-grain weight, number of tillers per meter row and peduncle length exhibited high estimates of heritability accompanied with high genetic advance.

Shukla <i>et al.</i> (2000) investigated 25 cross combinations of bread wheat over F<sub>2</sub> and F<sub>3</sub> generations to estimate variability for yield components. High genotypic coefficients of variation, high heritability and high genetic advance were observed for grain yield per plant, biological yield per plant, 1000-grain weight and harvest index.

Singh <i>et al.</i> (2001) studied nature and extent of genetic variability in population of 40 newly developed strains of wheat. The maximum range of variation
was observed for grains per spike followed by plant height, days to flowering, flag leaf area, days to maturity, tillers per plant and effective tillers per plant. The estimates of genotypic coefficient of variation were lower than phenotypic coefficient of variation. The maximum heritability was recorded for 500-grain weight followed by grains per spike, tillers per plant, yield per plant, effective tillers per plant, days to maturity, days to flowering, spikelets per spike and flag leaf area. Genetic advance as per cent of mean was maximum for grain yield per plant.

Dwivedi et al. (2002) conducted an experiment to study the variability parameters for 12 metric traits in 72 genotypes of bread wheat. The highest genotypic and phenotypic coefficient of variation was observed for total biomass followed by grain yield per plant, grain weight per ear and tiller number per plant. Similarly, high variability and genetic advance were also observed for these traits along with plant height.

Patel and Jain (2002) evaluated 16 wheat genotypes for grain yield and yield components to obtain basic information on the nature and magnitude of variation. High heritability was observed for all the characters except spikelets per spike and number of kernels per spike, while genetic advance as a percent of mean was the lowest for days to maturity.

Pawar et al. (2003) estimated genetic variability and heritability parameters for grain yield and yield components in 50 wheat cultivars. Result revealed that genetic variability was high for number of days to 50% flowering, plant height, number of productive tillers per plant, length of spike, number of spikelets and grains per ear, 1000 grain weight and grain yield. The genotypic and phenotypic coefficients of variation were the highest for plant height. Heritability for all the characters examined ranged from 84.13 to 99.75 per cent. The estimate of genetic advance was the highest for plant height and the lowest for number of productive tillers per plant.

Kumar and Mishra (2004) studied 30 diverse wheat cultivars for genetic variation. The highest genotypic coefficient of variation was observed for number of tillers per plant followed by number of effective tillers and grain yield. High heritability coupled with high genetic advance as percent of mean was observed for number of tillers per plant, 1000-grain weight, plant height and number of spikelets per plant.

Sharma et al. (2006) examined 11 metric traits of 75 genotypes of wheat for variability parameters. The highest values of genotypic coefficient of variation and
phenotypic coefficient of variation were observed for tillers per plant followed by grain yield per plant, number of grains per ear and total biomass. High values of genetic advance were also observed for all these traits.

Singh et al. (2006) studied genetic variability, heritability and genetic advance for 10 attributes in 37 wheat genotypes under waterlogged reclaimed soils. Result revealed that high value of phenotypic coefficient of variability, genotypic coefficient of variability, heritability and genetic advance for biomass, grain yielding tillers, plant height and grains yield per plant.

Yadav et al. (2006) studied 90 indigenous and exotic genotypes for evaluation of variability parameters. The highest estimates of genotypic coefficient of variation and phenotypic coefficient of variation were observed for number of grains per ear followed by tiller number per plant, grain yield per plant, total biomass and 1000-grain weight. High estimates of heritability were observed for days to heading, plant height, number of grains per ear, 1000 grain weight and total biomass. High estimate of heritability coupled with high genetic advance was observed for number of grains per ear.

Ahmed et al. (2007) investigated the inheritance of traits related to drought in wheat under natural drought conditions. Six wheat varieties and six derived F2 hybrids were studied to ascertain heritability and genetic advance for plant height, days to maturity, number of tillers per plant, spike length, number of grains per spike, 1000 grain weight and grain yield per plant. The result revealed that heritability estimates and expected genetic advance for plant height, days to maturity, number of tillers per plant, 1000-grain weight and grain yield per plant were high for the all the cross combinations while the estimates for spike length and number of grains per spike were relatively low.

Genetic variability, heritability and genetic advance were computed among 14 strains of wheat under salinity and drought stress conditions by Kamboj (2007). Result revealed that heritability estimates was low to moderate for plant height, tillers per plant, days to 75% flowering and days to maturity. For grain yield per plant, high heritability was associated with high genetic advance.

Sidharthan and Malik (2007) studied genetic variability, heritability and genetic advance in 27 bread wheat genotypes for yield attributing characters viz., days to heading, days to maturity, height of plant, number of tillers per plant, biological yield, ear length, grains per ear, 100-grain weight and grain yield per plant. Result
revealed that high coefficient of variation was obtained for biological yield, tillers per plant, seed weight per plant, grains per ear and harvest index. All these traits exhibited high heritability coupled with high genetic advance and genetic variability.

Singh and Sharma (2007) estimated genetic variability in forty genotypes of durum wheat. Result revealed that high phenotypic and genotypic coefficients of variation coupled with high heritability and high genetic advance as per cent of mean was observed for spike length, grain yield, harvest index and grains per spike.

Seventy local and exotic wheat genotypes were evaluated by Ali et al. (2008) for variability parameters of eight metric traits i.e. plant height, number of productive tillers per plant, number of spikelets per spike, spike length, number of grains per spike, fertility per cent, 1000-grain weight and yield per plant. Result revealed that the estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for grain yield per plant, number of productive tillers per plant and number of grains per spike. The remaining traits recorded moderate to low PCV and GCV estimates.

Majumder et al. (2008) studied 20 spring wheat varieties to find out genetic variability and its component characters. Result revealed low differences between the phenotypic and genotypic coefficients of variations indicated low environmental influences on the expression of these characters. High heritability coupled with high genetic advance was obtained with plant height, grains per spike, 100-grain weight, harvest index and grain yield.

Kalimullah et al. (2009) determined the genetic and phenotypic coefficient of variation and heritability in a set of 22 wheat lines along with four check cultivars for grain yield and its component traits in irrigated and unirrigated environments. Genetic variances were greater than environmental variances for most of traits. Heritability estimates was of higher in magnitude for plant height, medium for physiological maturity, spikelets per spike and 1000-grain weight and low for spikes per meter square.

Kumar et al. (2009) evaluated thirty genotypes of bread wheat for grain yield and other related characters. They observed six characters i.e. plant height, effective tillers per plant, grain yield per plant, spike length, grains per spike and 1000-grain weight exhibited high variability. The remaining traits shows moderate to low variability.
Monpara (2009) evaluated a set of 21 elite genotypes of durum wheat selected based on maturity time for grain yield and some agronomical and physiological growth parameters. Result revealed that the genotypic coefficient of variation was moderate for all the characters, except days to maturity, vegetative period and grain filling period, for which, the low magnitude was noted. High heritability coupled with high genetic advance was observed for days to ear emergence, plant height, flag leaf area, spike length, spikelets per spike, grains per spike and 100-grain weight. However, low heritability along with moderate genetic advance was observed for grain yield per plant.

Subhashchandra et al. (2009) studied genetic variability and relationship between genetic diversity and transgressive segregation in tetraploid wheat for nine metric traits in the F₂ populations of 28 crosses derived through Diallel Mating System. Significant genotypic differences were observed for all the traits studied indicating considerable amount of variation generated in the segregating population for each character. The highest genotypic and phenotypic coefficient of variation was observed for yield per plant followed by productive tillers per plant. Similarly, high heritability and genetic advance were also observed for these traits along with spike length and days to 50% flowering. Positive and significant correlation of yield per plant with spike length and productive tillers per plant was observed, while days to 80% maturity showed negative and significant association with spike length, plant height and protein content. Spike length showed the highest positive direct effect on yield per plant followed by productive tillers per plant. Spike length via productive tillers per plant had the highest indirect positive effect on yield per plant.

Yadav et al. (2009) studied genetic variability and identification of important metric traits associated with grain yield in 51 genotypes comprising both under normal and salt affected condition. Result revealed that high magnitude of heritability coupled with high genetic advance as per cent of mean was recorded for plant height and specific leaf area in normal soil and only specific leaf area in salt affected soil.

Zecevic et al. (2010) studied variability, heritability and components of variance for number of grains per spike and grain weight per spike in 10 winter wheat varieties. Result revealed for average estimated values of number of grains per spike and grain weight per spike differed significantly among years and among varieties. The average variation coefficient for number of grains per spike was 17.4 per cent and for grain weight per spike was 21.4 per cent. Heritability value in broad sense for
number of grains per spike was about 60 per cent and for grain weight per spike about 40 per cent.

Abinasa et al. (2011) observed highly significant differences among durum wheat genotypes for all traits studied, suggesting the possibility of improving durum wheat for these traits. Results revealed that plant height and number of kernels per spike showed the highest phenotypic and genotypic coefficients of variations and genetic advance, whereas, days to maturity and test weight had the lowest values. Plant height exhibited highest heritability value of 98.3 per cent while number of spikelets per spike showed minimum value of 36.4 per cent. The genotypic correlations estimated showed positive association of grain yield with days for heading, harvest index and kernel number per spike. Harvest index and biomass exhibited the highest positive and significant direct effect on grain yield.

Ahmadizadeh et al. (2011) studied genetic diversity in 37 durum wheat land races, an experiment based on randomized complete block design with three replications was carried out in normal irrigation and drought stress conditions. Result of variance revealed that there were highly significant differences among the genotypes in all of the traits. Environment mean squares were significant for all the traits studied showing the drought stress has significant effect on all the traits. The heritability estimates were high for plant height in both conditions. In well-watered condition biological yield, awn length and harvest index showed more direct positive effects on yield. In drought stress condition, biological yield, spike length, number of grains per spike and harvest index showed more direct positive effects on yield.

Thanna et al. (2011) investigated variability of eight wheat genotypes in two environmental conditions. The value of phenotypic coefficient of variability (PCV) was higher than genotypic coefficient of variability (GCV) for growth, yield and its components characters under both conditions. Under water stress, high heritability was observed for plant height, number of kernels per spike, 1000-kernel weight and grain yield.

Ali and Shakor (2012) studied heritability, variability, genetic correlation and path analysis for quantitative traits in durum and bread wheat under dry farming conditions. The first experiment included 25 strains of durum wheat and the second included 20 strains of bread wheat. The result showed that high genetic variation, heritability and genetic advance for plant height, number of spikes, 1000-grain weight, biological yield and grain yield in durum wheat.
Baranwal et al. (2012) analyzed genetic variability in 24 genotypes of wheat. Result revealed that high genotypic coefficient of variation (GCV) was observed for grains per spike, peduncle length, plant height, whereas low GCV was observed for days to heading, chlorophyll content and tillers per meter square. In all cases, phenotypic variances were higher than the genotypic variances. High heritability with low genetic advance in per cent of mean was observed for days to heading. High heritability with high genetic advance as per cent of mean was observed for peduncle length and grains per spike.

Singh et al. (2012) studied genetic variability using 16 genotypes of wheat under rainfed condition. High phenotypic and genotypic coefficient of variation coupled with high heritability and genetic advance as per cent of mean were reported for grain yield, biological yield, days to 50% flowering, spikelets per spike, effective tillers per plant and days to maturity.

Talebi and Fayyaz (2012) carried out field investigation to estimate genetic parameters on 24 Iranian bread wheat cultivars under two constructing water regimes. Result showed that the highest environmental variances were found for plant height, number of seeds per meter square and yield in both environments. The GCV values were the lowest for harvest index and highest for plant height, number of seeds per spike and plant grain yield. 1000 seeds weight and plant biomass as well as number of seeds per meter square also showed relatively low GCV values. Broad sense heritability estimates were very high under both control and water stress conditions for plant height and number of seeds per spike, while broad sense heritability significantly decreased under water stress condition for harvest index, 1000-grain weight and number of seeds per plant.

Tsegaye et al. (2012) studied genotypic, phenotypic and environmental coefficient of variation, heritability, genetic advance, correlation coefficients and path coefficients analysis for yield and its contributing parameters in 23 durum wheat genotypes. Result revealed that analysis of variance for traits studied showed significant differences among the genotypes. Phenotypic coefficient variation values for most characters were closer than the corresponding genotypic coefficient variation values showing little environmental effect on the expression of these characters. The estimated values of broad-sense heritability were found between 11 per cent (biological yield) and 90 per cent (days to heading). Biological yield, number of tillers per plant and 1000-grain weight had high degree of positive association with grain
yield. Phenotypic path analysis described that biological yield and harvest index have direct contribution towards grain yield.

Zarkti et al. (2012) studied agro-morphological variability in a set of Moroccan durum wheat germplasm collection. Result indicated that 1000-kernel weight and plant height presented the highest coefficient of variation.

Alam et al. (2013) studied genetic variability and diversity in 13 advanced durum wheat genotypes along with the two local checks namely WRF-7 and Prodip. Statistical analysis revealed significant differences for all the characters studied, indicating presence of considerable amount of variations among genotypes for each character. The high genotypic and phenotypic coefficient of variation was obtained for grains per spike and spikes per meter square. Moderate to high heritability with moderate genetic advance in per cent of means were estimated for plant height, spikes per meter square and 1000-grain weight.

Bhushan et al. (2013) studied 40 wheat cultivars for variability parameters. Result revealed that the higher magnitudes of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for grain yield, biological yield, productive tillers per plant and plant height. The high heritability in broad sense was estimated for all the characters except for grain filling period and test weight. High heritability coupled with high genetic advance as per cent of means were recorded for plant height, harvest index, biological yield and grain yield.

Degewione et al. (2013) estimated extent of genetic variability in 26 bread wheat genotypes using 10 agronomic traits such as days to heading, grain filling period, days to maturity, plant height, number of tillers per plant, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield per plot. Result revealed that bread wheat genotypes differed significantly for all characters studied. High phenotypic coefficient of variation and genotypic coefficient of variation were recorded for grain filling period, number of tillers per plant and grain yield per plot. High genetic coefficient of variation along with high heritability and genetic advance were recorded in grain yield per plot and days to heading.

Demelash et al. (2013) evaluated 12 bread wheat varieties under rainfed condition to study the genetic variation present in wheat varieties. The highest genotypic coefficient of variation was observed for grain yield, thousand grain weight and harvest index.
Mousavi et al. (2013) studied drought stress effects on wheat morphological traits of 20 bread wheat cultivars in two separate experiments in field conditions. The results showed that there is a considerable variation between the genotypes for height of the plant, length of the spike, length of the awn, the weight of the 100 kernel, length of the seed, length of the peduncle and the diameter of the seed.

Singh et al. (2013) estimated 90 wheat cultivars grown under moisture stress condition. They studied characters such as days to heading, days to anthesis, days to maturity, grain filling duration, plant height, spike length, effective tillers per plant, grains per spike, grain weight per spike, 1000-grain weight, harvest index, canopy temperature-anthesis, canopy temperature-grain filling, biological yield and grain yield. The analysis of variance revealed highly significant differences among varieties for all the traits. The GCV and PCV were high for effective tillers, grain filling duration, grain weight per spike, grains per spike, grain yield, spike length, plant height and days to heading. The genotypic coefficient of variation for most of the characters was almost equal to its phenotypic coefficient of variation. High heritability estimates was observed for days to heading, days to anthesis, days to physiological maturity, grain filling duration, plant height, spike length and effective tillers. High heritability coupled with high genetic advance was also registered for days to heading, grain filling duration, plant height, spike length, effective tillers and grain yield.

Tambe et al. (2013) studied genetic variability, correlation and path coefficient analysis for grain yield and its components in 28 diverse genotypes of durum wheat. The analysis of variance revealed the significant differences among the genotypes for all the traits. The high GCV and PCV were observed for grain yield per plant, number of effective tillers per plant, spike length and 1000-grain weight. The high heritability combined with high genetic advance as per cent of mean was observed for grain yield per plant.

Kumar et al. (2014) estimated of genotypic coefficient variation (GCV) and phenotypic coefficient of variation (PCV) and revealed that PCV was slightly higher than GCV. The experimental material consists of 50 wheat genotypes in F5 generation and 4 checks. Highest estimates of GCV and PCV were observed for grain yield per plant followed by biological yield and harvest index. Heritability estimates revealed that characters like biological yield per plant exhibited highest heritability followed by test weight and flag leaf length. Genetic advance revealed that it was high for plant
height and biological yield per plant, moderate for harvest index and test weight and low for flag leaf width, days to 50% flowering, spike length and flag leaf length. Characters like plant height, 1000-grain weight and harvest index showed high heritability coupled with high genetic advance.

Rahman et al. (2014) studied genetic variability, correlation and path coefficient for four physiological traits and grain yield per plant in 24 diverge genotypes of wheat. It was observed that phenotypic variances were slightly higher than their corresponding genotypic variances. Genotypic variance was much higher than their corresponding environmental variances which indicated that the traits were less influenced by the growing environments. It was observed that days to booting, days to heading and days to anthesis showed almost equal phenotypic and genotypic coefficient of variation. On the other hand, days to maturity showed low phenotypic coefficient of variation and genotypic coefficient of variation values as compared to days to booting, days to heading and days to anthesis. Comparatively high genotypic coefficients of variation were found in days to booting and days to heading. These traits also exhibited high heritability accompanied by high genetic advance. Genotypic correlation coefficients were found to be higher than their corresponding phenotypic correlation coefficients in most cases. Grain yield per plant had positive significant association with days to maturity. Path coefficient analysis revealed that days to booting and days to maturity had direct positive effect towards grain yield.

Zeeshan et al. (2014) evaluated variability, heritability, genetic advance in ten wheat genotypes. Result revealed high phenotypic and genotypic coefficient of variability for most of the traits. The PCV values were close to the GCV values. High heritability coupled with high genetic advance was exhibited by number of tillers per plant, biological yield per plant, harvest index, 1000-grain weight and grain yield per plant.

Shah et al. (2015) studied genetic variability and diversity in 52 genotypes for 14 quantitative characters in bread wheat. Result revealed that high genotypic coefficient of variation coupled with high heritability and high genetic advance as per cent of mean were observed for days to 50% flowering, days to maturity, plant height, number of grains per main spike, grain yield per plant and biological yield per plant.

Wolde et al. (2016) studied genetic variability, heritability and genetic advance for yield and yield related traits in durum wheat. Result of variance analysis revealed highly significant differences among accessions for all traits. High
phenotypic coefficient of variation and genotypic coefficient of variation values were recorded for productive tillers per plant, number of grains per spike, 1000-grain weight, grain yield and harvest index. The heritability values were high for all the characters studied.

Arya *et al.* (2017) studied 49 genotypes of wheat for generating scientific information on nature and magnitude of genetic variability and diversity for designing breeding programme. Analysis of variance revealed significant differences among the genotypes for all the characters under study. The highest estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for grain yield per plant. High heritability coupled with high genetic advance was observed for grain yield per plant.

Chimdesa *et al.* (2017) studied genetic variability among bread wheat genotypes for growth, yield and yield components. Results of the analysis of variance revealed that genotypes were differed significantly for all characters studied. Grain yield per hectare was positively correlated with biological yield per plot and harvest index, but was negatively correlated with peduncle length both at genotypic and phenotypic level.

Kabir *et al.* (2017) evaluated ten wheat genotypes were for genetic variability for yield and association between different plant characters. Analysis of variance revealed highly significant variation among different wheat genotypes for all traits studied. PCV values are higher than GCV for all traits and narrow difference was found between GCV and PCV for most of traits. High heritability coupled with high genetic advance was estimated for traits like yield per hectare, total grain yield per plot, straw weight per plot and harvest index.

Khan and Hassan (2017) evaluated 27 genotypes for heritability, genetic advance and association of yield and yield related traits in wheat. For all the studied traits, mean squares showed the presence of significant variation among the genotypes. The highest heritability was noticed in plant height followed by flag leaf area. Grain yield was observed to have positive significant association with most of the important yield related traits such as fertile tillers, spike length, 1000-grain weight and grains per spike.

Kumar *et al.* (2017) computed variability, heritability and genetic advance for yield and yield related trait in 30 wheat genotypes. The result showed that the genotypic coefficient of variation were high for grain yield, biological yield, flag leaf
area, number of productive tillers and number of grains per spike, while the estimates of phenotypic coefficient of variation were high for grain yield, biological yield, flag leaf area, number of productive tillers and number of grains per spike. Heritability estimates were highest for days to 50% flowering, number of productive tillers, flag leaf area, chlorophyll content, grain yield and biological yield. Genetic advance estimates were highest for flag leaf area, number of grains per spike and Plant height.

Lone et al. (2017) studied genetic variability and correlation in winter wheat germplasm for morphological and biochemical characters. Significant genotypic differences were observed for all the traits studied indicating considerable amount of variation among genotypes for each character. The result revealed high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for number of grains per earhead, moderate for earhead length, peduncle length, number of effective tillers per plant and plant height. Plant height exhibited highly significant and positive genotypic and phenotypic correlation with peduncle length and number of effective tillers per plant.

Sabit et al. (2017) studied genetic variability, correlation and path analysis for yield and its components in F₅ generation of bread wheat. The result of mean sum of squares showed significant differences among all the characters. The maximum genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for biological yield per plant. High heritability was recorded for number of grains per spike. High genetic advance was recorded for plant height. Seed yield exhibited positive significant correlation with biological yield, main spike weight, spikelets per spike at genotypic level, while biological yield per plant showed positive significant association at both genotypic and phenotypic level.

Shah et al. (2017) evaluated F₄ wheat lines for genetic variability, heritability, genetic advance and correlation studies. Result revealed significant difference for all the traits. High magnitude of heritability was noted for all parameters except spike length which was moderate. High expected genetic advance was noted for flag leaf area, grain yield per plant, biological yield per plant and harvest index. Grain yield per plant exhibited positively genotypic and phenotypic correlation with days to heading, plant height, flag leaf area, spike length, grain weight per spike, 1000-grain weight, grain yield per plant, biological yield per plant and harvest index.

Bhanu et al. (2018) studied 20 genotypes of wheat for assessment of direct selection parameters (variability, heritability, and genetic advance), indirect selection
parameter (correlation) and their relation with heat tolerance. Result revealed that the traits viz., days to heading, days to anthesis, days to maturity and 1000-grain weight exhibited high heritability, which was coupled with high genetic advance as per cent of mean was recorded for 1000 grain weight and yield per plot. Days to heading had positive and significant correlation with days to anthesis and days to maturity.

Rathwa et al. (2018) carried out experiment to assess genetic variability with respect to grain yield and its components for heat tolerance in durum wheat. Result revealed that values of phenotypic coefficient of variation were slightly higher than that of genotypic coefficient of variation for all the traits studied. High heritability coupled with high genetic advance expressed as percentage of mean was observed for all characters for days to maturity, plant height and length of main spike.

2.2 CORRELATION COEFFICIENT

It is often observed that certain quantitative characters of economic importance are associated with one another. It is well known that different components of grain yield very often exhibit considerable degree of association among themselves and with grain yield. Therefore, to accumulate optimum combination of yield contributing characters in a single genotype, it is essential to know the implication of the interrelationship of various characters. In such cases, the knowledge on association between such characters is quite helpful to the plant breeders to formulate their selection strategies. The concept of correlation was given by Galton (1889) and later it was elaborated by Fisher (1918). Correlation coefficient is useful as a basis for selecting desirable parents. The interrelationship of grain yield and its components worked out by various workers in wheat has been reviewed here under.

Kumar (1979) computed correlation coefficient for yield components in 50 varieties of common wheat. The results indicated significant and positive association of effective tiller per plant and spike length with grain yield per plant.

Nanda et al. (1980) evaluated F₂, biparental and F₃ generations of bread wheat cross WG 357 x Tobari 66 and reported that grain yield was positively correlated with tiller number, grain size, grain number per ear, spikelets per spike and ear length but neither with heading date in F₂ and biparentals nor with plant height in F₂ generation. The magnitude of the correlation coefficient varied over generations and the magnitude of genotypic and phenotypic correlation was not comparable.
Singh et al. (1982) computed correlation coefficients among 11 characters from F2 progenies of crosses among 18 lines and reported that ear length, grains per spike and plant height were positively and significantly associated with grain yield, while days to flowering and maturity were negatively correlated with grain yield.

Borghi et al. (1983) determined correlation coefficients in F2 and F3 generations of seven bread wheat crosses and found higher values of correlation coefficient between yield and harvest index in the F2 generation, but these values were much lower in the F3 generation.

Falcinelli et al. (1983) investigated association among five characters in F2, F3 and F4 generations of five bread wheat crosses. They found significant and positive relationship for 1000 grain weight, days to heading and plant height in all the three generations. Plant height was significantly and positively correlated with 1000-grain weight, while days to heading was significantly and negatively associated with 1000-grain weight and plant height in all the three generations.

In F2 generations of a seven parental diallel (excluding reciprocals) of bread wheat, Singh et al. (1985) observed positive and significant relationship of grain yield with spikes per plant, plant height, spikelets per spike, grains per spike and 1000-grain weight. They also found significant and positive correlation between spike length and 1000-grain weight, spikelets per spike and grains per spike, spikelets per spike and spikes per plant and 1000 grain weight and grains per spike.

Adary and Al-Fhady (1987) studied 24 genotypes grown over two years and revealed the marked genetic variability for grain yield and its components. Grain yield was positively correlated with numbers of ears per unit area, grains per ear and number of days to heading.

Genotypic correlation of six yield component with grain yield per plant was tabulated for a group of 30 genotypes by Shamsuddin (1987). Flag leaf area, glume weight per plant, biological yield and spikes per plant showed high, significant and positive correlation with grain yield per plant.

Srivastava et al. (1988) estimated correlation in 19 cultivars and 48 hybrids. They observed that grain yield per plant was positively and significantly correlated with harvest index, biological yield, grain weight per spike, spikes per plant and flag leaf area.

Bhowmik et al. (1989) studied correlation for eight parents and 56 hybrids for six characters in wheat. Result revealed in most of the cases that genotypic
correlations were higher than the phenotypic correlations. Numbers of spikes per plant and spike length showed highly significant and positive correlation with grain yield at genotypic and phenotypic levels.

Amin et al. (1990) studied 18 genotypes of wheat to determine the association among grain yield and its components. They found that grain yield was positively and significantly correlated with plant height and number of spikes per meter.

Baisakh and Nayak (1991) evaluated 13 wheat cultivars for 10 yield related traits for several genetic parameters. They observed that grain yield was positively correlated with tillers per plant and internode length.

Raut et al. (1995) estimated correlations derived from data on nine yield components in 32 genotypes of bread wheat. They found that grain yield was positively and significantly associated with harvest index, number of grains per ear and number of spikelets per ear.

Correlation analysis of 38 genotypes of wheat was carried out by Deswal et al. (1996). They observed that grain yield showed significant and positive association with total biomass per spike, number of grains per spike and 1000-grain weight.

Genotypic and phenotypic correlation coefficients were worked out by Mondal et al. (1997) on seven yield components in 99 diverse genotypes of bread wheat. They observed that grain yield was significantly and positively associated with ear length, 100 grain weight and tillers per plant.

Narwal et al. (1999) studied correlation of grain yield with seven related traits in 204 advanced wheat lines grown under normal and late sown conditions. The results showed grain yield per plant was significantly and positively correlated with tillers per plant, grains per spike and 1000-grain weight under normal sown condition and tillers per plant and spike length under late sown condition. However, days to 75% flowering was negatively correlated with grain yield at both conditions.

Subhani and Chowdhry (2000) estimated character association of morphological traits under stress and irrigated conditions. Significant mean squares among crosses were obtained for all characters under irrigation as well as drought stress. Positive and significant correlations of grain yield per plant was observed with flag leaf area, specific flag leaf weight, tillers per plant, peduncle length, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot, biomass per plant and harvest index. Negative and significant correlation was also noted between days to heading and grain yield per plant. In case of drought stress conditions, grain yield
was positively and significantly correlated with flag leaf area, specific flag leaf weight, plant height, peduncle length, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot, biomass per plant and harvest index.

Mishra et al. (2001) worked out association analysis in 28 genotypes of wheat planted under three dates of sowing for representing major growing conditions of wheat. The correlation studies indicated that grain yield per plant had positive correlation with grain yield per spike and number of grains per spike; grain yield per spike with harvest index and number of grains per spike in all the three dates of sowings. Thousand grain weight was an important yield contributing trait in rainfed situation and it exhibited positive correlation with harvest index in all the sowing dates.

One hundred and eighty wheat genotypes and three varieties were used for studying the genotypic correlation among grain yield and its related characters by Singh and Singh (2001). The results showed that number of seeds per spike had positive correlation with grain yield followed by 1000-grain weight and spike length. Days to 50% flowering showed highly significant and negative correlation with seed yield.

The characteristics of 50 bread wheat genotypes, collected from India and Mexico were studied for correlation by Bergale et al. (2002). They observed that the number of spikes per plant, grains per spike, plant height and harvest index showed a significant and positive correlation with grain yield.

Dwivedi et al. (2002) studied correlation coefficients for 12 metric traits in 72 genotypes of bread wheat. Positive and significant correlation of grain yield with total biomass, tiller number per plant, grain weight per ear and 1000-grain weight was observed, while days to heading showed negative and significant association with 1000-grain weight.

Singh et al. (2003) carried out correlation analysis using 50 genotypes of bread wheat. The results revealed positive and significant correlation of effective tillers per plant, biological yield per plant and harvest index was observed with grain yield per plant. However, days to heading had negative and significant correlation with 1000-grain weight.

Ihsan et al. (2004) computed correlation on ten metric traits in five wheat cultivars and their twenty hybrids. Grain yield had significant and positive phenotypic correlation with plant height, number of tillers per plant, spike length, number of
spikelets per spike and 1000-grain weight, whereas it had significant and positive genotypic correlation with all the characters.

Sharma et al. (2004) studied character association in grain yield and nine other characters in 300 wheat genotypes. They observed that the grain yield had significant and positive correlation with biological yield per plant, number of productive tillers per plant, plant height and harvest index.

Mohammad et al. (2005) studied grain yield and yield contributing traits eight in bread wheat lines in order to find out the genetic contribution of different characters towards grain yield. Result for days to heading showed negative and significant correlation with harvest index. Days to maturity was negatively correlated at both genotypic and phenotypic levels with biological yield, harvest index and grain yield. The level of negative genotypic correlation was significant with harvest index and grain yield. Plant height showed negative genotypic and phenotypic correlation with harvest index and grain yield. Biological yield had positive and significant genotypic and phenotypic correlation with harvest index and grain yield. Harvest index had positive and significant genotypic and phenotypic correlation with grain yield. Genotypic and phenotypic correlation coefficients revealed that important characters that influencing grain yield are harvest index and biological yield.

Mehmet and Telat (2006) calculated correlation coefficients between grain yield and yield components of 20 bread wheat genotypes. Positive and significant correlation of grain yield was observed plant density, plant height, grain number per spike, grain weight per spike and 1000-grain weight. Grain yield was negatively and significantly correlated with time to heading.

Sharma et al. (2006) studied 11 metric traits of 75 genotypes of wheat. They observed that the grain yield was positively and significantly correlated with tillers per plant, total biomass, grains per ear, days to maturity and ear length.

Sidharthan and Malik (2006) studied 27 genotypes of wheat for correlation. They observed high value of phenotypic correlation of grain yield per plant with biological yield and days to heading. Correlation was moderate with ear length, number of tillers per plant and grains per ear, while 100-seed weight exhibited negative correlation with days to heading, days to maturity and grains per ear.

Yadav et al. (2006) studied correlation in ninety indigenous and exotic genotypes of wheat. They observed that tiller number per plant followed by total biomass showed positive and high correlation with grain yield. Significant and
positive correlation was observed between days to heading and number of grains per ear and plant height with 1000-grain weight and total biomass. However, days to heading was negatively correlated with 1000-grain weight.

Munir et al. (2007) studied correlation for ten yield related traits in two bread wheat crosses derived from crossing Kohistan-97 (high yielding) with Inqlab-91 (medium yielding) and Chakwal-86 (low yielding) under drought conditions. Result revealed that the genetic correlation coefficients were greater than the corresponding phenotypic correlations. Grain yield per plant showed a positive and significant correlation with flag leaf area, tillers per plant, spike length, grains per spike, grain weight per spike and 1000-grain weight in both the crosses.

Sen and Toms (2007) estimated correlation coefficient for grain yield components in 87 genotypes of wheat including two checks. The results indicated that grains per spike and 1000-grain weight showed positive and significant correlation with grain yield both at genotypic and phenotypic levels.

Subhra et al. (2008) computed correlation coefficient among 21 diverse genotypes of bread wheat under late sown condition. The phenotypic correlation study revealed that 1000-grain weight had significant and positive correlation with grain yield per plant. The genotypic correlation revealed the same trend with slight variation with in magnitude of correlation value.

Kumar et al. (2009) estimated correlation coefficient among 179 genotypes including four check varieties and revealed that nine characters namely, biological yield per plant, tiller number per plant, grain weight per ear, grains per ear, harvest index, spikelets per spike, plant height, flag leaf area and flag leaf sheath length showed significant and positive correlation with grain yield.

Monpara (2009) estimated correlation coefficient in a set of 21 elite genotypes of durum wheat selected based on maturity time. He observed that grain yield per plant correlated in desired direction only with effective tillers per plant.

Yadav et al. (2009) identified the important metric traits associated with grain yield in 51 genotypes comprising both under normal and salt affected condition. Significant and positive association of grain yield was observed with biological yield and tiller per plant under both the conditions.

Khan and Dar (2010) computed correlation using 37 wheat genotypes and 3 check varieties and found that grain yield was significantly and positively associated with number of spikelets per plant, followed by number of effective tillers and 100-
seed weight at both phenotypic and genotypic levels. Grain yield showed a significant and negative association with number of seeds per spikelet at genotypic level. Among the significant inter-relationships, the association of days to 75% spike emergence with days to maturity and 100-grain weight were significant and positive, but were negative and significantly associated with number of seeds per spikelet and number of grains per spike. Similarly, the associations of spike length with number of seeds per spikelet and number of spikelets per plant and number of effective tillers were negative and significant. The association of number of spikelets per plant with number of effective tillers was also positive and highly significant.

Khan et al. (2010) studied correlation among yield and different yield related traits in 16 wheat genotypes under moisture stress conditions. Result revealed that grain yield was positively correlated with days to maturity, tillers per meter square and number of grains per spike. Negative correlation of grain yield was observed with plant height, spike length, peduncle length, peduncle extrusion, sheath length and 1000-grain weight.

Talebi et al. (2010) studied genetic variation and interrelationships of agronomic characteristics in durum wheat. Results showed that there was strong positive association of grain yield with the number of seed per spike, biomass and harvest index. Grain yield was negatively associated with spike length and plant height in different moisture conditions.

Bilgin et al. (2011) studied genetic variation and inter-relationship of some morpho-physiological traits in durum wheat lines. Result revealed that grain yield was positively and significantly correlated with grain weight per spike, test weight, plant height, grains per spike, spikelets per spike, 1000-grain weight and spike length whereas it showed negative and important correlation coefficient with days to 50% flowering. The highest direct positive effect on yield was computed for grain weight per spike. On the other hand, days to 50% flowering and spike length had negative direct effect on yield.

Subhani et al. (2011) evaluated 19 wheat genotypes received from CIMMYT, Mexico and one local variety of Faisalabad planted in two separate field experiments under water stress and irrigated conditions. The results revealed that plant height and 1000-grain weight were positively correlated with grain yield. Negative correlation of grain yield was observed with days to heading and tillers per meter square in irrigated
conditions. Under drought stress conditions, tillers per meter square and 1000-grain weight expressed positive correlation with grain yield.

Ali and Shakor (2012) studied heritability, variability, genetic correlation and path analysis for quantitative traits in durum and bread wheat under dry farming conditions. The result showed that grain yield was correlated genetically positive and significantly with 1000-grain weight, biological yield and harvest index in durum wheat, while showed genetically positive and significant correlation with all traits in bread wheat.

Baranwal et al. (2012) estimated correlation of yield and yield contributing traits in twenty four genotypes of wheat. They observed that yield per plot had high positive and significant correlation with tillers per meter square and 1000-grain weight.

Iftikhar et al. (2012) investigated association of some agronomic traits on grain yield using 15 wheat genotypes. The results revealed that flag leaf area, spikelets per spike, grains per spike and 1000-grain weight had positive and significant correlation with grain yield at both genotypic and phenotypic levels, whereas spike length was correlated positively and significantly with grain yield at genotypic level but non-significantly at phenotypic level. Tillers per plant showed negative and significant association with grain yield at both levels.

Karimizadeh et al. (2012) studied traits affecting grain yield in 18 durum wheat genotypes by simple correlation, coefficient and path analysis under two irrigated regimes. Result indicated that grain yield positively and significantly correlated with test weight and 1000-kernel weight in irrigated condition, and with plant height in rainfed condition. The correlation coefficient between test weight and kernel number per spike and grain yield is nearly equal to its direct effect in irrigated condition.

Singh et al. (2012) studied characters association between grain yield and its contributing characters using sixteen genotypes of wheat under rainfed condition. Grain yield had significant and positive correlation with days to maturity, plant height, effective tillers per plant, 100-grain weight and biological yield.

Talebi and Fayyaz (2012) carried out field investigation to estimate relationship among morpho-agronomic traits studied on 24 Iranian bread wheat cultivars under two constructing water regimes. Result showed positive and significant correlation between harvest index, number of grains per spike and number
of seeds per meter square with yield at both genotypic and phenotypic level in both environments.

Fellahi et al. (2013) studied 29 bread wheat genotypes to determine character association between grain yield and yield components. The results indicated that grain yield was positively correlated with biological yield, straw yield and number of spike per plant. Biological yield was correlated positively and significantly with straw yield, number of spike and thousand seed weight, but negatively with grain number per spike.

Ghafoor et al. (2013) estimated correlation coefficients for various parameters of 20 wheat genotypes. The genotypes included six parents and their fourteen F2 crosses. Grain yield per pant had positive and highly significantly correlation with plant height, spike weight and grains per spike, while grain yield negative and highly significant correlation with days to maturity.

Nukasani et al. (2013) evaluated 114 pre-breeding lines of wheat for correlation and path analysis. Result showed that three characters viz., tiller number per meter, grain weight per spike and number of grains per spike exhibited positive and significant association and maximum positive direct effects on grain yield.

Rashidi et al. (2013) studied genotypic variation of spike related traits using a sample of durum wheat lines. Plant height, peduncle length, number of node per stem, number of spikes per plant, spike length, number of grain per spike, 1000-grain weight and grain yield were measured. Estimate of correlation between traits indicates that there was significant and positive correlation between grain yield and traits such as number of spikes per plant, spike length and grain per spike. Regression and path analysis showed that the traits such as number of grain per spike, spikes per plant and spike length had positive and direct effect on yield.

Tambe et al. (2013) studied genetic variability, correlation and path coefficient analysis for grain yield and its components in 28 diverse genotypes of durum wheat. The analysis of variance revealed the significant differences among the genotypes for all the traits. The results of correlation studies indicated that genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients for most of the traits. Grain yield per plant had significant and positive correlation with grain filling period, effective tillers per plant and 1000-grain weight at both genotypic and phenotypic levels.
Afridi et al. (2014) studied genetic potential and variability for morpho-yield traits in durum wheat lines. Result revealed that high significant differences were observed among the selected durum wheat lines for all the studied traits viz., days to heading, days to maturity, plant height, spike length, spikelets per spike, 1000-kernel weight and grain yield. Estimates of correlations between traits indicated that days to heading showed positive correlation with days to maturity and plant height. Positive correlation of spike length with spikelets per spike and of 1000-kernel weight with grain yield was observed.

Zeeshan et al. (2014) studied character association and their causal effects on grain yield per plant in ten wheat genotypes. Grain yield per plant had positive and significant correlation at both genotypic and phenotypic levels with 1000-grain weight and harvest index, number of tillers per plant and spike length, but non-significant with number of spikelet per spike and flag leaf area.

Dutamo et al. (2015) studied path coefficient and correlation of yield and yield associated traits in bread wheat germplasm. Result revealed that among the characters, grain yield showed positive and significant correlation with grain filling, productive tiller, spike length, spikelet per spike, kernel per spike, 1000-grain weight, biomass yield and harvest index.

Bhutto et al. (2016) studied correlation and regression analysis for yield traits in wheat genotypes. The phenotypic correlations revealed that tillers per plant and grains per spike were highly positively associated.

Dabi et al. (2016) tested 30 bread wheat genotypes to assess the association among yield and yield contributing traits and determining the direct and indirect effect of the traits on the grain yield. Result for grain yield showed significant positive phenotypic correlations with 1000-kernels weight, above ground biomass, harvest Index and plant height. As per the path analysis above ground biomass and harvest index showed high positive phenotypic direct effect on grain yield. Similarly, at genotypic level above ground biomass and harvest index showed highly significant direct effect on the grain yield.

Desheva (2016) carried out experiment to investigate the correlation and path coefficient analysis in 35 genotypes of winter bread wheat varieties. The result revealed highly significant and positive genotypic and phenotypic correlation between grain yield per plant and number of productive tillers per plant, number of grains per spike, grain weight per spike and 1000-grain weight. The number of spikelets per
spike correlated positively and significantly with number of grains per spike and grain weight per spike. Number of grains per spike had positive and significant phenotypic and genotypic correlations with grain weight per spike. Grain weight per spike positively correlated with thousand grains weight.

Singh (2016) computed correlation and path coefficient analysis to identify the important characters for selection under different environmental conditions. Result revealed that estimates of genotypic correlation coefficients were higher in magnitude than the estimates of phenotypic correlation coefficients for almost all the character combinations in all the environments. The grain yield showed significant and positive association with tiller number, biological yield and harvest index in all the environments.

Singh et al. (2016) studied interrelationship between grain yield and its component characters in F_2 generation of bread wheat. The result of correlation estimates showed positive and significant correlation of grain yield with number of tillers per plant, ear weight and 100-grain weight. However, it showed negative and significant correlation with plant height.

Al-salim et al. (2017) studied correlation and path analysis between grain yield and yield related traits in wheat. Results showed that grain yield had a positive significant correlation with number of spikes per meter square and grain number per spike. Results of path coefficient analysis showed that the direct effect of number of spikes per meter square on grain yield was high and positive. Results also showed that number of spikes per meter square had the highest contribution in yield as a direct effect, followed by the corporate effect of number of spikes per meter square and number of grains per spike.

Ayer et al. (2017) computed correlation and path coefficient analysis in advanced wheat genotypes to determine the association between yield and yield attributing traits. Simple correlation coefficients revealed that the association of grain yield with biological yield followed by harvest index, plant height and 1000 grain weight were positive and highly significant. The positive and significant association of grains per spike followed by flag leaf area with grain yield was also found. Path analysis showed that biological yield and harvest index had the highest positive direct effect on grain yield. While other traits contribute to the grain yield significantly indirectly via biological yield and harvest index.
Lone et al. (2017) studied genetic variability and correlation in winter wheat germplasm for morphological and biochemical characters. Significant genotypic differences were observed for all the traits studied indicating considerable amount of variation among genotypes for each character. Plant height exhibited highly significant and positive genotypic and phenotypic correlation with peduncle length and number of effective tillers per plant.

Mecha et al. (2017) studied correlation of yield and yield associated traits in bread wheat genotypes. Analysis of variance revealed that there was a significant difference among the sixty four genotypes for all the characters studied. Grain yield had positive correlation with grain filling period, number of productive tillers per plant, spike length, number of spikelets per spike, number of kernels per spike, 1000-kernel weight, biomass yield per plot and harvest index at both phenotypic and genotypic level.

Meles et al. (2017) studied genetic variability, correlation and path analysis of yield and grain quality traits in bread wheat. Data were subjected to analysis of variance which revealed significant differences among the genotypes for all the characters. Grain yield was positively and significantly correlated with biological yield, harvest index, plant height and 1000 kernel weight of which biomass yield and harvest index had the highest positive direct effect on grain yield.

Nikkahkouchaksaraei and Martirosyan (2017) assessed heritability and genetic advance for agronomic traits in durum wheat. The result for grain yield showed the highest positive correlation with number of grains per spike.

Shah et al. (2017) evaluated F₄ wheat lines for genetic variability, heritability, genetic advance and correlation studies. Grain yield per plant exhibited positively genotypic and phenotypic correlation with days to heading, plant height, flag leaf area, spike length, grain weight per spike, 1000-grain weight, grain yield per plant, biological yield per plant and harvest index.

### 2.3 PATH COEFFICIENT ANALYSIS

Grain yield is the ultimate result of interactions involving a number of component factors, which are interrelated. The knowledge of such interrelationship is useful in knowing the magnitude and direction of association. However, study of correlation alone for ascertaining the importance of characters may be misleading when several characters are associated with grain yield. Path analysis is simply standardized partial regression coefficient, which splits the correlation coefficients
into the measures of direct and indirect effects of a set of independent variables on the dependent variable. The concept of path coefficient analysis was originally developed by Wright (1921), but the technique was first used by Dewey and Lu (1959). A brief review of work related to path analysis in wheat is presented as under.

Pathak et al. (1986) carried out path analysis for a group of 15 cultivars of wheat. They observed that grain weight per ear has highest direct effect on yield.

Shamsuddin (1987) reported path analysis from 30 varieties of bread wheat. The results revealed that spikes per plant, grains per spike, 1000-grain weight, glume weight per plant, biological yield and harvest index were directly related to grain yield per plant. The flag leaf area was indirectly correlated with grain yield through biological yield and glume weight per plant.

Srivastava et al. (1988) studied path analysis in 19 cultivars and 48 hybrids and observed that biological yield, harvest index, grain filling period and days to anthesis had high direct effects on grain yield.

Amin et al. (1990) evaluated 18 genotypes of wheat to calculate direct and indirect effect among grain yield and its components. They observed that plant height, number of spikes per square meter and 1000-grain weight registered maximum positive direct effect on grain yield.

The nature and extent of direct and indirect effects on grain yield in twenty two varieties of bread wheat were estimated by Barma et al. (1991) through path analysis. Ear length had the highest direct contribution to grain yield per plant followed by days to heading, 1000-grain weight and number of grains per ear. The direct influence of plant height and days to maturity was also high and negative. The number of ears per plant also showed negative effect. Plant height, number of ears per plant and grains per ear had high indirect contribution to yield through ear length. The indirect contribution of number of ears per plant, plant height, ear length and days to maturity and that of days to maturity via days to heading was also high.

Information on path analysis was derived from data on 10 yield components in eight bread wheat genotypes and their 15 F₁ hybrids by Ibrahim (1994). The results indicated that number of grains per spike and 100-grain weight had the highest effect on grain yield at both the phenotypic and genotypic levels.

Mondal et al. (1997) carried out path analysis on seven yield components in 99 diverse genotypes of bread wheat. The results indicated that grains per ear, 100-
grain weight and tillers per plant had positive direct effect on grain yield, while plant height and days to maturity had negative direct effect on yield.

Narwal et al. (1999) studied 204 advanced wheat lines grown at two locations and worked out path analysis. The results revealed that the tillers per plant, grains per spike and spike length had positive and large direct effect on grain yield at both locations.

Tammam et al. (2000) performed path analysis for grain yield and some other characters in F1 and F2 generations of half-diallel cross involving five bread wheat genotypes. They found that grain yield was affected directly by spikes per plant, seeds per spike and 1000-kernel weight. Grain yield was also affected indirectly by biological yield via effects on number of spikes per plant, number of seeds per spike, 1000-seed weight and days to heading.

Mondal and Khajuria (2001) carried out path analysis in ten wheat cultivars and observed that the direct effect of the characters under study varied from positive to negative and low to high. The number of effective tillers and 1000-grain weight had significant association and positive direct effect on grain yield.

Bergale et al. (2002) studied 50 bread wheat genotypes for path analysis. The results of path analysis revealed that spikes per plant and grains per spike showed high positive direct effect on grain yield.

Dwivedi et al. (2002) studied path analysis for 12 metric traits in 72 genotypes of bread wheat. The results indicated that total biomass showed the highest direct effect on grain yield which was followed by tillers per plant and grain weight per ear. Total biomass and 1000-grain weight had the highest indirect effect via tillers and total biomass to grain yield, respectively.

Singh et al. (2003) carried out path analysis in 50 genotypes of bread wheat and revealed that biological yield per plant, grains per ear, 1000-grain weight and effective tillers per plant had positive and high direct effect on grain yield per plant.

Ihsan et al. (2004) computed path analysis for 10 metric traits in five wheat cultivars and their twenty hybrids. The results indicated that the direct contribution of spike length to grain yield was highest and positive whereas, the number of spikelets per spike had the maximum negative direct effect on grain yield. Plant height, spike length, spike density, number of tillers per plant, peduncle length and number of grains per spike also showed direct positive effect on grain yield.
Mohammad et al. (2005) studied grain yield and yield contributing traits in bread wheat lines in order to find out the genetic contribution of different characters towards grain yield. Positive direct effect of days to heading, days to maturity and biological yield with grain yield were observed. Harvest index showed positive and highest direct effect on grain yield.

Mehmet and Telat (2006) calculated path analysis between grain yield and yield components of 20 bread wheat genotypes. They observed positive direct effect of plant height and grain weight per spike and negative direct effect of time to heading associated with grain yield.

Ravikant et al. (2006) studied 495 germplasm lines and carried out path analysis. The results showed that number of productive tillers per plant, number of grains per ear and 1000-grain weight had high and positive direct effect on grain yield per plant. However, days to 75% flowering had maximum negative direct effect on grain yield per plant.

Sharma et al. (2006) studied 11 metric traits of 75 genotypes for path analysis. Path analysis showed that total biomass and number of tillers per plant were main contributors towards grain yield per plant.

Sidharthan and Malik (2006) studied 27 genotypes of wheat for path analysis. They observed maximum positive direct contribution of biological yield, days to heading and grains per ear towards grain yield per plant.

Gupta et al. (2007) conducted path coefficient analysis with 22 triticale x bread wheat derivatives along with six checks to select true breeding derivatives for tolerance to drought and cold stress conditions. Path coefficient analysis revealed that biological yield had the highest positive direct effect on grain yield followed by harvest index, specific leaf weight, stomatal number, 1000-grain weight, stomatal size, spikelets per spike and days to heading.

Sen and Toms (2007) studied 87 genotypes of wheat including two checks for path analysis. The results of path analysis revealed that 1000-grain weight, grains per spike, tillers per meter and days to maturity showed positive direct effect on grain yield.

Nofouzi et al. (2008) studied path analysis of grain yield with its components in durum wheat under potential and drought stress condition. In one experiment, the plants were commonly irrigated until physiological maturity but in another experiment drought stress imposed in four different stages including; tillering, stem
elongation, anthesis and grain filling. Results revealed that harvest index, plant height and number of tillers had high correlation with grain yield. Number of seeds per spike, length of spike and 1000-seed weight had the highest direct positive effects on grain yield. Path analysis for 1000-seed weight, number of tillers per plant and number of seeds per spike showed that plant height, length of spike, days to flowering were the most effective components of traits, respectively.

Mamta et al. (2009) studied 40 genotypes in two environments for path analysis. The results of path coefficient analysis showed that biological yield was the main contributor to grain yield.

Dogan (2009) studied 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. Results revealed that grain number per spike, 1000-grain weight, plant height and test weight had significant direct effect on grain yield.

Gulmezoglu et al. (2010) studied comparative performance of triticale and wheat grains by using path analysis with an objective to compare released triticale cultivars in terms of grain yield, plant height, protein and spike characters with bread and durum wheat and to evaluate the usefulness of path coefficient analysis for interrelationship among characters determining grain yield in triticale, bread and durum wheat in two locations. Path coefficient analysis revealed that grain yield of bread and durum wheat depended on the effect of plant height, length of spike, protein, in addition to these, spike weight for durum wheat. Even though the effect of spike weight was positive, plant height and protein had a negative effect on the grain yield of durum wheat.

Khan and Dar (2010) studied 37 wheat genotypes and 3 check varieties for path coefficient analysis of some quantitative traits in wheat. Path coefficient analysis revealed that the magnitude of positive direct effect on grain yield was highest through number of spikelets per plant, followed by number of grains per spike and 100 grain weight, whereas protein content followed by number of grains per spikelet and number of effective tillers exhibited high, but negative direct effect on grain yield per plant.

Khan et al. (2010) studied path analysis among yield and different yield related traits in 16 wheat genotypes under moisture stress conditions. Path analysis indicated that peduncle length had the highest direct effect on grain yield followed by
tillers per meter square, grains per spike, spike length and days to maturity, whereas peduncle extrusion, sheath length, 1000-grain weight and plant height had negative direct effect on the same parameter.

Rangare et al. (2010) studied bread wheat germplasm for path analysis. The results indicated positive direct effect of effective tillers per plant, plant height, 100-grain weight and days to maturity towards grain yield per plant.

Mollasadeghi et al. (2011) studied cause and effect relations among some morphological traits of nine advanced wheat genotypes. Path analysis results showed that the grain yield has a direct and positive effect over harvest index, while the straw yield has a direct and negative effect over it. Of effective traits to grain yield, four traits including number of grains per spike, grain weight, 1000-grain weight and biological yield had the most direct and positive effect on grain yield. Three traits including spike length, spike weight and biological yield had the most direct effect to straw yield.

Cifci (2012) studied grain yield per spike and some agronomic traits of durum wheat for correlations and path analysis. The result revealed that correlations between traits showing important characters influencing grain yield per spike were spike length, spikelet number per spike and grain number per spike. Path analysis also indicated that spike length, spikelet number per spike and grain number per spike had the maximum direct effects on grain yield per spike.

Iftikhar et al. (2012) investigated path coefficient analysis of some agronomic traits on grain yield using 15 wheat genotypes. The results revealed that plant height, spike length, grains per spike and 1000-grain weight had positive direct effect on grain yield.

Khan and Naqvi (2012) conducted research with 13 wheat genotypes and carried out path analysis. According to obtained results of path coefficient, number of spikes, number of spikelets and number of grains has positive direct contribution to grain yield under irrigated condition.

Singh et al. (2012) studied path analysis using 16 genotypes of wheat under rainfed condition. Path coefficient analysis revealed positive direct effect of days to 50% flowering, plant height, spike length, number of grains per spike, biological yield and harvest index on grain yield.
Fellahi et al. (2013) studied 29 bread wheat genotypes to determine direct and indirect effects between grain yield and yield components. Results revealed that biological yield and harvest index showed positive direct effect towards grain yield.

Hannachi et al. (2013) investigated path analysis for 15 hybrids of durum wheat. Path coefficient technique exhibited that above ground biomass and harvest index exerted positive direct effect on grain yield, whereas straw yield had a negative direct effect on grain yield. The highest indirect effects on grain yield were observed with straw yield, spikes number per plant, plant height, and 1000-grain weight through above ground biomass and also with harvest index via straw yield.

Khan et al. (2013) studied relationship between important traits of durum wheat and their direct and indirect effects on grain yield. Result revealed that positive and significant correlation was found for plant height, spikes per meter square and 1000-grain weight with grain yield. Maturity days, spikes per meter square and thousand grain weight has significant positive direct effects on grain yield. Grains per spike had direct positive effect but in low magnitude. The indirect effect of head days and plant height on grain yield was found mainly through maturity days and 1000-grain weight.

Zeeshan et al. (2014) estimated variability parameters, character association and their causal effects on grain yield per plant in 10 wheat genotypes. 1000-grain weight showed maximum direct effect towards grain yield per plant, followed by number of tillers per plant, harvest index and spike length, while lowest direct effect was contribute by flag leaf area.

Dutamo et al. (2015) studied path coefficient and correlation of yield and yield associated traits in bread wheat germplasm. Result revealed that among the characters, grain yield showed positive and significant correlation with grain filling, productive tiller, spike length, spikelet per spike, kernel per spike, 1000-grain weight, biomass yield and harvest index. In path coefficient analysis harvest index showed direct effect on yield.

Dabi et al. (2016) tested thirty bread wheat genotypes to assess the association among yield and yield contributing traits and determining the direct and indirect effect of the traits on the grain yield. Result of path analysis revealed that above ground biomass and harvest index showed high positive phenotypic direct effect on grain yield. Similarly, at genotypic level above ground biomass and harvest index showed highly significant direct effect on the grain yield.
Desheva (2016) carried out experiment to investigate the correlation and path coefficient analysis in 35 genotypes of winter bread wheat varieties. The result revealed highly significant and positive genotypic and phenotypic correlation between grain yield per plant and number of productive tillers per plant, number of grains per spike, grain weight per spike and 1000-grain weight. The grain weight per spike and number of productive tillers per plant had strongest direct effect on grain yield per plant. The number of grains per spike via grain weight per spike and 1000-grains weight via grain weight per spike had the highest positive indirect effect on the grain yield per plant.

Singh (2016) computed correlation and path coefficient analysis to identify the important characters for selection under different environmental conditions. Path coefficient analysis identified biological yield and harvest index as most important characters which not only showed highest direct effect towards grain yield but almost all other character also showed indirect contribution towards grain yield.

Singh et al. (2016) studied interrelationship between grain yield and its component characters in F2 generation of bread wheat. The Path coefficient analysis revealed that high positive direct effect of 100-grain weight followed by harvest index and biological yield and traits viz., plant height and number of spikelets per ear had negative direct effect on grain yield per plant.

Al-salim et al. (2017) studied correlation and path analysis between grain yield and yield related traits in wheat. Results of path coefficient analysis showed that the direct effect of number of spikes per meter square on grain yield was high and positive. Results also showed that number of spikes per meter square had the highest contribution in yield as a direct effect, followed by the corporate effect of number of spikes per meter square and number of grains per spike.

Ayer et al. (2017) computed correlation and path coefficient analysis in advanced wheat genotypes to determine the association between yield and yield attributing traits. Path analysis showed that biological yield and harvest index had the highest positive direct effect on grain yield. While other traits contribute to the grain yield significantly indirectly via biological yield and harvest index.

Chimdesa et al. (2017) studied genetic variability among bread wheat genotypes for growth, yield and yield components. The computed path coefficient for yield showed that days to maturity, number of productive tillers, and biological yield per plot, harvest index and spike length had positive direct effect, while days to
heading and grain filling period had high negative direct effect at both genotypic and phenotypic level.

Mecha et al. (2017) carried out path coefficient studies of yield and yield associated traits in bread wheat genotypes. Path coefficient analysis showed that biological yield, thousand kernel weight, harvest index and number of kernels per spike showed positive direct effect. Among these characters biological yield, 1000-kernel weight, harvest index and number of kernels per spike had positive correlation with grain yield.

Sabit et al. (2017) studied correlation and path analysis for yield and its components in F₅ generation of bread wheat. The result showed that plant height, days to 50% flowering, spike length, peduncle length, biological yield, harvest index and main spike weight displayed positive direct effects on grain yield per plant at both genotypic and phenotypic level.