2. REVIEW OF LITERATURE

The available literature on relevant aspects of this study has been reviewed under the following heads:

2.1 Impact of Seed Size on Growth and Yield Characters.
2.2 Genetic Variability
2.3 Character Association Analysis
2.4 Genetic Divergence

2.1 Impact of Seed Size on Growth and Yield Characters:

Seed size is one of the characters that improved significantly during domestication of many crop species. It is not only an important primary component of grain yield but also a valuable seed parameter of seedling establishment and crop growth. For the last four to five decades, the concept of seed size was studied on physiological parameters and yield of several crops including durum wheat, and results are controversial in most of the characters studied.

Kaufman and McFadden (1960) evaluated the competitive interaction between barley plants grown from large and small seeds and observed that the plants from small seeds yielded approximately 77% of those grown from large seeds in the greenhouse and 57% in the field with inter-plant competition.

Kramer (1984) evaluated three cultivars and two grain sizes in monocultures, intra-cultivar mixture, inter-cultivar mixture, and complex mixture
and observed significant yield differences between cultivars with large grains. In all mixtures, grain size had considerable effect on yield. Genetic variance was lowest in intra cultivar mixtures and highest in inter cultivar mixtures, while the heritability were higher in the mixture than the mono culture. It is recommended that grains be graded in lots of uniform size to avoid the competitive effects caused by size differences.

Gupta et al. (1987) studied the effect of seed size on seed yield and seed quality in three wheat cultivars and concluded that the large seeds showed numerically better performance than medium and small seeds for yield performance than medium and small seeds for yield and its components. However, the medium seeds were superior to large and small seeds in germination percentage, seed vigour index and seed storability index determined by accelerated aging test.

Pande et al. (1992) evaluated three genotypes of wheat differing in grain weight for a number of growth, morphological and yield related traits in mature and immature seeds. They observed that in immature wheat seeds, more accumulation of water in the large seeded type leads to greater enlargement of seed coat, increase in grain weight and volume and decrease in density as compared to small seeded genotypes. Grain weight per year was not significantly different between the three genotypes. It is concluded that the enlargement of the grain-sink and the transport mechanism appear to be genetically linked and should be considered for simultaneously improvement.
Agrawal and Mishra (1996) evaluated the direct and indirect impact of seed characters (grain length, grain width and test weight) on seed yield in 25 genotypes of *Triticum aestivum* and observed that test weight had a relatively high genotypic variation and the highest direct effect on grain yield/plant. Seed width also had a negative direct effect on grain yield.

Martincic and Guberac (1996) investigated the effects of seed size (2.8, 2.5 or 2.2 mm diameter, or ungraded seeds) on grain yield of winter wheat, winter barley, winter rye and spring oats during two years and concluded that the largest seeds gave the highest grain yield in all the cereals. Martincic *et al.* (1996) also reported that the seed germination and field emergence were highest in the largest seeds and lowest in the smallest seeds.

Gan and Stobbe (1996) grown plants with small, large and mixed seed sizes to determine the relationship between MLS (mainstem leaf stage) and single plant grain yields within a canopy of spring wheat. They observed that seed size had a significant effect on MLS only during the early seedling stages; plants grown from large seeds had greater MLS and lower plant to plant variation in MLS than those from small or mixed seed sizes.

Gan and Stobbe (1996) studied the seedling vigour and grain yield of Roblin wheat affected by seed size from 1989 to 1991 and observed that the use of uniform large seeds increased shoot DM yield in 1990 and 1991 also grain yield was increased with uniform large seeds only for early sowing (1990). A small proportion of small seeds in a seed lot decreased shoot DM in two of six
cases, if uniform large seeds are available for sowing, the sowing rate can be reduced.

Jha et al. (1985) studied the effects of seed size on yield in wheat and observed that wheat gave the highest grain yields when sown with large seeds (>5.1mm) followed by medium seeds (2.1-5.1mm) and also observed that yields with ungraded and small seeds (<2.1mm) were similar. The large seeds gave the highest 100-seed weight.

Joshi (1997) studied the effect of non-genetic variation in seed size, growth, grain yield and its components in two wheat varieties with four seed grades to compare the agronomic characters and yield. Plants derived from larger seed classes were taller, had heavier seeds, higher grain yields and had more leaves, tillers and spikelets than plants derived from smaller seeds of the same genotypes. Differences between seed classes were also recorded for leaf area, leaf number, number of tillers/plant and plant height at all 5 growth stages, although these differences were much higher in the initial stages of plant growth. The interaction between seed weight and variety was significant for many characters, indicating that non-genetic variation in seed size had a considerable influence on grain yield.

Saharan et al. (1998) studied the genetic association of days to heading, days to anthesis and grain filling duration with seed size and grain yield. All the traits showed a negative and significant association with seed size and grain yield.
Popa (1999) studied the influence of seed size on wheat productivity during 1994-95 and 1997 and reported a direct correlation between seed size and plant productivity in wheat. Crop yield and yield components increasing with increased seed size and were higher with uniform large seeds than with ungraded seeds.

Sachan et al. (2002) studied the effect of seed size on germination, vigour and field emergence in three varieties of wheat with three screen sizes and one bulk. Germination of bold sized seeds and vigour index exhibited better performance over the control and other grades.

Podolska and Sulek (2002) assessed the effect of varying seed size on the yield and yield components of winter triticale during 2000-02 and observed that the grain yield was significantly lower when small seeds and mixtures of small and big seeds were used for planting. Large seeds increased the number of plants and heads per unit area, grain yield per plant and productive tillering in 2002.

Maurya et al. (2002) studied the effect of seed size on yield and seed quality of soybean and observed the significant differences among the seed produced from different seed sizes for all variables. The medium size seed recorded the highest value for plant stand, seed yield and germination index while, bold seed size showed its statistical superiority for test weight, seedling dry weight and vigour index. They further observed that the interaction effects were non-significant in both the years.
Gurumurthy et al. (2002) conducted a study to determined the optimum sieve size for size grading and better seed quality in four pearl millet varieties. Their results revealed that irrespective of the variety with the increase in seed size, the seed recovery percentage decreased while, 1000-seed weight increased and interaction results were non-significant. Lokesh et al. (2002) also observed that germination percent, 1000-seed weight and vigour index increased with an increase in seed size in all the varieties of finger millet.

Dhanelappagol et al. (2002) studied the effect of seed size on seed quality and grain yield in rabi sorghum and observed that processing recovery decreased with increase in seed size and 1000-seed weight was increased with increase in seed size. Seed germination did not differ significantly among the genotypes and sieve sizes. Maximum grain yield was recorded in seeds obtained from the 4 mm sieve followed by 3.50 mm than the unprocessed seed.

Chavan et al. (2002) studied the influence of seed size and mother plant nutrition on seed yield and quality in sesame with bold, medium and small seed size and four fertilizer doses and observed that bold seeds recorded significantly higher values for growth, yield and seed quality parameters followed by medium and small seeds. Seed recovery, seed yield and quality parameters differed significantly among the seed sizes.

Riethmuller et al. (2003) studied the effects of seed size on rape over two years (2001 and 2002) and concluded that in 1st year, large seed (>7.1 mm) produced more plants, matured earlier and produced a higher yield than small
seed (85% or 0.45 t/ha more yield at the deepest sowing depth at 4.5 cm). In 2nd year, large seed (greater than 2.0 mm in diameter) yielded 19% more than small seed (1.6-1.8 mm).

Stougaard and Xue (2004) studied the effects of spring wheat seed size and seeding rate on wheat spike production, biomass and grain yield under a range of wild oat densities. Wheat plant density, spikes, biomass and yield all increased as seed size and seeding rate increased. The use of higher seeding rate and larger seed sizes improved yields by 12 and 18%, respectively. Accordingly, grain yield were more highly correlated with seed size than with seeding rate effects. As such the plants derived from larger seed appeared to have greater vigour and are able to acquire a larger share of plant growth factors relative to plants derived from small seeds.

Ramadevi and Rama Rao (2004) studied the effect of seed size on growth characteristics and pod yield in groundnut and observed that pod yield and harvest index were more in the plants from bold seeds followed by medium sized seeds plants from srivelled seed recorded less pod yield. They concluded that the plants from bold seeds produced higher growth characteristics and pod yield in groundnut.

Khera et al. (2004) studied the seed size variability and its influence on germination and seedling growth of five tree species and inferred that seedlings from small seed class produced small growth features and low dry weight and this confer a competitive disadvantage in the small sized seeds. The seedlings
from smaller seeds would grow and complete less successfully than the seedlings from large and medium seeds.

Drena (2004) investigated the effect of kernel size on the germination energy, germinability and emergence in winter wheat, winter barley, oats rye and triticale and observed that the kernel size had the least influence on germination energy. Further, large and middle seeds were better than unseived seeds for 4-5% or at its level. The total germinability in all experiments was lower in small seeds and higher in large seeds.

Gadzo (2005) investigated the effect of seed size from the biological and productive properties of winter and spring wheat and observed that the different fractions of winter and spring wheat did not show significant effect on plant height, ear length and number of grains per ear. The different sizes of fractions of wheat seeds in most cases has no significant effect on 100-grain weight. The small seeds of spring wheat produced grains with significantly lower test weight than the control. Sowing of large seeds of winter and spring wheat resulted in grain yield significantly higher than the control winter wheat by 25% and spring by 10.5%.

Xue and Stougaard (2006) observed that wheat yield and economic returns were greater for wheat plants derived from large seeds compared to those derived from small seeds. Averaged over all other factors, adjusted gross return of 578, 657, and 703 $/ha were realized for the small, medium, and large seed size classes, respectively.
Royo et al. (2006) studied the effect of seed size on the growth and yield of different cultivars. Large seeds produced greater plot stands, but the plants had fewer tillers, leaves and spikes and less green area and dry weight than plots sown with small seeds. Grain yield was 16% greater in plots sown with large seeds, which resulted in greater biomass, green area index, spikes per m² and heavier kernels than in plots sown with small seeds. Kernel weight was the yield component most related to grain yield in the three seed sizes. Selection for heavy kernel cultivars may help to improve the yield of durum wheat in Mediterranean environments.

Swanson et al. (2007) studied the association between grain characteristics and alcohol yield among soft wheat varieties and indicated that the inclusion of grain size parameters, thousand grain weight and grain length: width ratio, along with nitrogen, in a multiple regression enabled more accurate prediction of alcohol yield for most of the varieties, indicating that grain size would be a useful parameter for selecting the best samples within varieties.

2.2 Genetic Variability

The efficiency of selection for an effective breeding programme is dependent upon the genetic variability present in the present crop species.

Mosaad et al. (1990) studied the genetical studies of some morpho-physiological traits in 8 cultivars and their populations (F₁ and F₂) in durum wheat and concluded that the average number of days to heading and average plant height for the F₁ and F₂ surpassed the mean parental values. Further, the
broad and narrow sense heritability estimates were 79.32 and 78.01% \( (F_1) \), 73.63 and 65.79% \( (F_2) \) for days to heading, 90.23 and 82.25% \( (F_1) \), 77.16 and 78.43% \( (F_2) \) for plant height and 50.27 and 69.94% \( (F_1) \) and 46.56 and 67.42% \( (F_2) \) for spike length.

Nayeem and Garskin (1990) studied the genetic variability, heritability and genetic advance in 80 promising *Triticum aestivum* genotypes, 14 of *T. durum* and 4 each of triticale and barley and revealed a large amount of genetic variability among genotypes, high heritability and moderate genetic advance for all four crops.

Amin *et al.* (1994) studied the variability, heritability and genetic advance in 21 genotypes of durum wheat and observed significant differences for all the characters. Further, the genotypic coefficient of variation was highest for grain yield, followed by harvest index and grains per spike. Heritability estimates in the broad sense were high for days to anthesis, grain yield and harvest index. High heritability and appreciable genetic advance for grain yield and harvest index was taken as indicating the predominance of the additive gene effects in controlling these traits.

Shimpiger *et al.* (1996) evaluated the genetic variability for 11 yield components in durum wheat (*Triticum durum* Desf.) and indicated that biological yield/m and harvest index had moderate variation, heritability and genetic advance. All other characters had low variation and high heritability estimates, except for number of productive tillers and grain yield. Accession 200
had the highest biological yield/m (610 g). Accession 268, 236, 196, 148, 285 and 67 had high average for grain yield/m and accessions 157, 148, 268, 201, 285, 43 and 49 had high average value for harvest index.

El-Moneim and Belal (1997) evaluated 119 durum wheat genotypes from ICARDA for grain yield and its component and revealed significant differences among genotypes for some traits. High values of PCV and GCV were observed for spikelets per spike, biological yield and grain yield. Further, high values of heritability were observed for biological yield, spikes per plant and awn length.

Budak (2000) studied the heritability estimates on some physiological traits in twelve durum wheat and observed that years and genotypes significantly influenced grain yield, protein content and test weight and also broad sense heritability for grain yield, protein content and test weight were high.

Gupta and Verma (2000) studied the variability, heritability and genetic advance in durum wheat (Triticum durum Desf.) and observed that high heritability estimates coupled with high genetic advance for number of grains per ear, grain yield and biological yield under both the normal and rainfed conditions. Also, medium to low heritability estimates were recorded for days to earing, plant height, tiller number per plant, 1000-grain weight and harvest index under both environments.

Prasad and Pandey (2000) evaluated the variability parameters in forty two genetic stock of T. durum for ten characters and concluded that high magnitude of variation was reflected by a wide range for all characters. Six
characters namely, days to heading, plant height, productive tillers per plant, 1000-grain weight, protein content and sedimentation value, showed high heritability values.

Ismail et al. (2001) evaluated eight durum wheat genotypes for their morphological and agronomical traits in F1 and F2 and observed that heritability estimates were high in the broad and narrow sense for days to heading, days to anthesis and spike length for both generations. In the F1 hybrids, heritability was moderate in the narrow sense for days to maturity and plant height.

Shobhna et al. (2001) studied inheritance of some physiological traits in durum wheat and observed high heritability estimates with low genetic advance for all characters except peduncle length. The moderate heritability associated with the low genetic advance for flag leaf area, root weight and shoot weight were also observed.

Palve and Raghavaiah (2002) evaluated ninety seven durum derivatives along with thirteen parents for grain yield and yield related traits and concluded considerable variability for all character among the genotypes. The highest coefficient of variations exhibited by number of productive tiller per plant. GCVs and PCVs were almost of the same magnitude for sedimentation value, thousand grain weight and days to flowering. It was also observed that broad sense heritability values were also high for these characters indicating a possibility of improving such traits through selection.
Budak and Yildirim (2002) observed heritability in the population of Ege 88 and Kunduru durum wheats and concluded that genetic gains computed based on population means for grain yield per plot and protein content were 513g and 2.87% for Kunduru and 872g and 2.55% for Ege 88 population, respectively.

Sachan and Singh (2003) studied the genetics of yield and its components in ten durum wheat for nine characters and observed high estimates of GCV, PCV heritability and GA for grain yield, number of spikelets per ear, number of seeds per ear, plant height, 100-seed weight and number of tillers per plant. They also observed tiller variability for number of days to flowering and maturity.

Joshi and Mahal (2004) studied the heritability estimates in biparental progenies of two T. durum crosses under four sets of environments. The study indicated high heritability estimates for plant height, spikes per plant and days to flowering in all the four sets of environments. Golabady and Arzani (2003) observed that the considerable genetic variation existed for all traits, particularly for grain yield, harvest index, number of spikes per unit area and number of grains per spike. Phadnawlix et al. (2003) observed high genetic variation for grain yield per plots, weight of grains per ear, 1000-grain weight and number of ears.

Shoran et al. (2005) evaluated 62 elite durum wheat genotypes for genetic variability, character association and cluster analysis and observed enough
variability, heritability and genetic advance for days to heading, maturity duration, plant height, grain yield and 100-grain weight.

Farahani and Arzani (2007) conducted an experiment on F$_1$ hybrids of durum wheat during 2003. The results showed significant differences among the genotypes for all the characters. The results also observed higher coefficients of variation for grain yield, spikes m$^{-2}$ and number of grains per spike, whereas low estimates of CV were observed for days to 50% flowering and days to maturity.

Rawashdeh et al. (2007) evaluated for genetic diversity in durum wheat landraces to identify desirable agronomic traits. The results revealed the presence of a wide range of variability among landraces, which possess high levels of variability for biological yield, fertile tiller, number of seeds per spike, seed weight per spike and weight of 1000 seeds.

2.3 Character Association Analysis

Yield is a complex character and it has a number of components most of which are quantitative in nature. The analysis of genetic and environmental variation often involves partitioning of yield into a number of simple morphological components, which can be used as an alternative criterion of selection for yield if they are highly heritable and bear a positive correlation with yield. When more variables are included in the correlation studies indirect association become more complex. So, path analysis is effective method for finding direct and indirect association towards yield.
Gupta et al. (1979) observed that the genotypic correlation were generally higher than phenotypic ones. Grain yield per plant was positively correlated with harvest index, number of grains per ear, grain yield per ear and 100-grain weight, and was negatively correlated with days to maturity.

Bangarwa et al. (1987) studied the correlation and path coefficient and revealed that grain yield per plant was highly and positively correlated with spikes per plant, plant height, spikelets per spike, spike length and biological yield per plant. The components were positively correlated among themselves. Biological yield and spike length made the maximum contribution to grain yield, as revealed by path analysis. Bhullar and Nijjar (1984) observed that the grain yield was positively and significantly correlated with number of spikes per plant, 100-grain weight and height. Srivastava et al. (1980) studied the association analysis in 103 composite entries of T. aestivum and T. durum and observed that grain yield per ear, ear number m⁻¹ length of row and flowering period, in that order, had the highest direct and positive effects on yield.

The positive association of grains per spike and 100-grain weight and grain yield can be exploited for the improvement of yield in durum wheat. Yield increase has been accomplished by changes in yield components (CIMMYT, 1988).

Bakheit et al. (1989) observed that the grain yield per plant was positively correlated with each of 1000-grain weight, spike length and days to heading in both generations under normal field conditions. Correlation was
determined between aphid resistance parameters and grain yield of the control. Further, spikes per plant had the highest direct effect on yield in all generations, followed by 1000-grain weight and spikelets per spike for the parents and F2 generation.

Amin et al. (1994) evaluated the correlation in some quantitative characters in 21 genotypes of durum wheat and observed that grain yield was positively correlated with grains per spike and harvest index. Villareal et al. (1994) observed that the genotypic correlations of grain yield with other traits indicated that number of grains m$^{-2}$ was the most important determinant of grain yield (r = 0.99).

Deswal et al. (1997) studied the association of grain yield and 9 yield related traits in 38 genotypes of wheat (35 genotypes of T. aestivum and 3 genotypes of T. durum) under two sowing environments and concluded that the total biomass/tiller, number of grains/spike and 1000-grain weight under both sowing conditions, and harvest index and attraction index only under the late sown condition, make the greatest contribution towards grain yield in wheat.

El-Moneim and Belal (1997) evaluated 119 durum wheat genotypes from ICARDA for grain yield and its components and observed that the genotypic correlation coefficients were higher than the phenotypic correlation coefficients for most traits. Grain yield was significantly and positively correlated with plant height, awn length, spikelets per spike and biological yield.
Gupta *et al.* (1997) studied the correlation and path analysis in 60 genotypes of durum wheat and observed that the grain yield was positively correlated with plant height, tillers per plant, biological yield and harvest index. Biological yield, plant height and tillers per plant were found to be positively correlated with each other. Further, path analysis revealed the greatest positive direct effect of biological yield on grain yield, followed by harvest index. The indirect effect of the other attributes was also greatest through biological yield, indicating the utility of this trait in selection programmes for durum wheat under normal and rainfed conditions.

Mahal *et al.* (1998) studied the variability for quality traits in sixty durum wheat for eight characters and concluded that inter-character correlation coefficients were found to be significant only for few cases. A positive correlation \( r = 0.326 \) was observed between 1000-grain weigh and sedimentation value, the same positive association of water absorption with protein content \( r = 0.3694 \), grain hardness \( r = 0.333 \) and yellow berry \( r = 0.264 \), while a solitary negative correlation \( r = -0.282 \) was observed between yellow berry and \( \beta \)-carotene.

Budak (2000) studied the correlation of twelve cultivars of durum wheat, that grain had a positive significant correlations with 1000-grain weight \( r = 0.31 \) which had a significant correlation with test weight \( r = 0.27 \). Protein content had negative significant correlations with grain yield \( r = -0.30 \) and
1000-grain weight ($r = -0.26$) while it had a positive significant correlation with vitreousness ($r = 0.48$).

Prasad and Pandey (2000) evaluated the character associations in 42 genetic stock of T. durum and observed low correlation between 1000-grain weight and yield which indicated that the role of 1000-grain weight in enhancing yield to be limited in case of durum wheat. Also, low negative correlation of yield with protein (-0.18) and no correlation with sedimentation value.

Palve and Raghavaiah (2002) studied interrelationships of agronomic traits in inter-specific derivatives of 97 durum wheat and 13 parental cultivars and observed that grain yield was positively correlated with number of tillers per plant, number of grains per spike, 1000-seed weight, biological yield and harvest index, but was negatively correlated with protein content. Path analysis also revealed that biological yield per plant, number of grains per spike and 1000-seed weight were the most important characters affecting grain yield.

Dokuyucu et al. (2002) observed that grain yield was positively and significantly correlated with grain number per head and grain filling period. Further, path coefficient analysis indicated that grain number per head, grain filling period, grain filling rate and flag leaf area duration had positive and high direct effects on grain yield; 100-grain weight had moderate positive direct effect.

Budak and Yildirim (2002) observed correlation and genetic grains obtained in the population of Ege 88 and Kunduru durum wheat, that grain yield
had positive significant correlation with days to heading \( r = 0.66^{**} \) and plant height \( r = 0.67^{**} \) for Kunduru cultivar, where these correlation were found to be negative for Ege 88 \( r = -0.64^{**} \) and \( r = -0.36^{*} \), respectively. Similarly, protein content had negative significant correlations with heading date \( r = -0.67^{**} \), plant height \( r = -0.53^{**} \) and grain yield \( r = -0.63^{**} \).

Kaya et al. (2002) observed that correlation coefficients among most of traits in durum wheat cultivars were statistically significant, the plant height and peduncle length had the highest positive correlation coefficient, while grain yield was positively correlated with plant height, spike length, spike weight, kernels/spike, kernel weight/spike, spikelets/spike, peduncle length and days to heading. However, it was negatively correlated with spike density. Plant height had also significant positive correlation with all traits except spike density. Similarly, spike length, kernels per spike, kernel weight per spike, spikelets per spike, all are inter-positive correlation except negative correlation with spike density. Further, peduncle length with days to heading positively correlated and spike density is positive correlated with peduncle length and negative correlated with days to heading.

Garcia et al. (2003) evaluated the grain yield and its components in durum wheat under mediterranean conditions, and the path coefficient analysis revealed that grain yield under cooler conditions was mostly determined by kernel weight, where as the number of spikes m\(^{-2}\) predominantly influenced grain production in the warmer environments. The number of kernels per spike had a
significant contribution to grain yield, especially under drought stress conditions. Contrarily, under warmer conditions, negative effects of the number of spikes m\(^2\) were registered on both the number of kernels per spike and kernel weight. Path analysis appear to be a useful tool for understanding grain yield formation and provides valuable additional information for improving grain yield via selection for yield components.

Golabady and Arzani (2003) evaluated 300 genotypes of durum wheat and observed that grain yield had a positive and significant correlation with days to heading, days to maturity, number of grains per spike and grain weight per spike.

Nayeem and Baig (2003) studied the correlation between yield and yield components in 76 genotypes of *T. durum* with three controls and observed that yield per plot was positively correlated with number of days to 50% heading test weight and number of grains per ear. On the other hand, protein content, percentage of yellow berry, number of tillers m\(^{-1}\) and sedimentation value were not significantly correlated with yield per plot and also the path analysis revealed that the number of tillers m\(^{-1}\), number of grains per ear, test weight and sedimentation value had positive direct effects, whereas the number of days to 50% heading, protein content and yellow berry percentage had significant negative direct effects on yield per plot. Maximum direct effects on yield per plot were recorded for number of grains per ear and test weight. So, the number
grains per ear, test weight and number of tillers per metre should emphasized or increased yield.

Phadnawis et al. (2003) evaluated 18 durum wheat genotypes for ten agronomic characters and observed that number of seeds per ear and number of earhead showed positive and significant correlation, whereas number of days to 0 % flowering and maturity recorded significant and negative association with grain yield per plot both at genotypic and phenotypic levels.

Sachan and Singh (2003) studied genetics of yield and its components in ten durum (T. durum) genotypes and observed that yield per plant and number of tillers per plant had the highest direct effects on grain yield.

Tyagi et al. (2003) studied the correlation coefficients (genotypic) among five traits in 62 genotypes of durum wheat and observed significant and positive correlations between days to heading and maturity duration, thousand grain weight and grain yield and plant height with grain yield, whereas, days to heading and maturity duration showed significant but negative correlation with grain yield. Similarly, thousand grain weight also had significant but negative correlation with heading and maturity duration.

Bhagat et al. (2004) studied the correlation and path analysis for grain yield and its components in 36 durum wheat genotypes. The results revealed significant and positive correlation between grain yield and number of tillers m⁻¹, whereas plant height was negatively correlated with grain yield. Further, plant height showed a negative correlation with yield, number of...
tillers m\(^{-1}\) and weight of five tillers and showed a positive correlation with 1000-grain weight. Path coefficient analysis showed that the number of tillers had the highest direct effect.

Okuyama et al. (2004) studied the correlation and path coefficient analysis. The study indicated that grain yield showed positive phenotypic correlation with above ground biomass, number of spikes m\(^{-2}\) and number of grains per spike. Further, path coefficient analysis revealed positive direct effects of number of spikes m\(^{-2}\) and number of grains per spike with grain yield. The results indicated that the number of spikes m\(^{-2}\) and the number of grains per spike followed by the above ground biomass were the traits related to higher grain yield.

Joshi and Mahal (2004) observed positive correlation of grain with the yield components i.e. spikes per plant, grain number per spike and 100 grain weight. Further, maximum number of useful correlation were recorded when selection was conducted visually followed by selection for grain number per spike, 100-grain weight and spikes per plant.

Shoran et al. (2005) observed significant and positive correlations between days to heading and maturity duration, 1000-grain weight and grain yield which suggest that yield improvement in durum wheat might be possible by emphasizing these traits.

Sadeghzadeh and Alizadeh (2005) evaluated 150 exotic and indigenous lines of durum wheat and observed a negative significant correlation between
number of days to heading and 1000-kernel weight in facultative types. In the spring types of durum wheat, the number of days to maturity, grain filling period, plant height and number of days to heading were the most important traits for increasing grain yield. Further, path coefficient analysis revealed the strong direct effect of the number of days to maturity on grain yield.

Farahani and Arzani (2007) observed that grain yield showed significant and positive correlation with harvest index, biological yield, grains per spike and grain weight per spike in 42 genotypes of durum wheat.

Sharma and Sharma (2007) studied the correlation analysis of yield and related physiological traits in twelve generations of durum wheat and observed that the grain yield per plant was significantly and positively associated with peduncle area and flag leaf area. Correlation studies revealed that selection for peduncle area would lead to high yield in durum wheat. However, due consideration should also be given to flag leaf area and spike area during the selection of plants for further tangible advance in grain yield in durum owing to their positive association with grain yield.

2.4 Genetic Divergence

Mahalonobis (1936) proposed the $D^2$ technique for multivariate analysis for the first time. It is considered a powerful tool for measuring genetic difference between biological populations.

Raut et al. (1985) studied genetic divergence in 58 varieties of *Triticum turgidum* L. var. *durum* with diverse sources and pedigrees and
concluded that varieties were grouped into eleven clusters in season first 23 varieties have been grouped in cluster II followed by cluster I with 17 varieties and five clusters (VII to XI) included one variety each. Similarly, thirteen clusters formed in second season, 32 varieties have been grouped in cluster I and seven clusters (VII to XII) included one variety each. It was also observed that there is wide range of variation in cluster means for plant height, extrusion length, awn length, number of grains and yield per plant. However, intra-cluster divergence ranges from 3.32 to 21.23 (1st season) and 5.07 to 15.54 (2nd season). Similarly, inter-cluster divergence ranges from 28.19 to 360.83 (1st season) and 15.59 to 88.62 (2nd season).

Sethi et al. (1992) studied the genetic divergence in 40 varieties of *T. aestivum* and *T. durum* with diverse sources and pedigrees, carried out in two environments revealed their grouping into four and seven clusters. Cluster mean of different characters suggested wide range of variations for plant height, number of grains per ear, 1000-grain weight, grain yield per plant and biological yield plant.

Sethi et al. (1992) studied the genetic divergence in 40 wheat genotypes and observed that they were grouped into 8 clusters, 5 of which contained only single genotypes. Number of tillers per plant, number of grains per year and grain yield were the traits that contributed most to genetic divergence.

Singh (1992) studied genetic diversity in rainfed wheat. Based on Mahalanobis $D^2$ statistic, the cultivars were grouped into 4 clusters, of which
cluster I contained 28 of them. Seed number per spike and 1000-seed weight were the most important traits when grouping germplasm on a genetic basis and could be used for selection of parents for breeding.

Singh (1994) studied the genetic divergence in 90 durum wheat genotypes and observed that the genotypes were grouped into 7 clusters and had a high level of genetic divergence that was not related to geographical origin.

Taleei and Salar (1995) studied the geographical and genetic diversity in 500 Iranian durum wheat landraces and observed that the genotypes of different geographical origin were classified into 5 groups by cluster analysis of the data recorded. There were significant differences between all the characters studied.

Patil and Bhavsar (1997) studied the genetic divergence in 25 *T. aestivum* and 11 *T. durum* genotypes and based on D$^2$ values, the genotypes were grouped into 6 clusters using Toccher's method. Cluster I was the largest, containing 21 genotypes, followed by cluster II containing 6. The maximum distance between clusters was between cluster IV and V, followed by between cluster I and IV. The results indicate wide genetic diversity between the genotypes studied.

Deshmukh *et al.* (1999) observed genetic divergence using Mahalanobis D$^2$ statistics, which is derived from data on yield and 9 yield components in 30 genotypes of durum wheat, and observed that genotypes were grouped into 8 clusters, with the greatest inter-cluster distance (6.784) being between cluster IV and cluster V.
Prasad and Pandey (2000) studied the genetic distance in 42 genetic stocks of *T. durum* and concluded that clusters formed revealed that the absence of relationship between geographical distances and genetic divergence. Crossing cultivars belonging to cluster I, V, VI and VII is expected to give maximum extent of heterosis for yield.

Golabady and Arzani (2003) studied the genetic divergence in 300 genotypes of durum wheat and revealed that cluster analysis was similar to factor analysis in grouping the characters. According to cluster analysis, the genotypes were classified into 6 clusters with significant difference among all the groups. The mean comparisons of traits in these groups showed that genotypes of group 5 and 6 were superior in grain yield and harvest index and are beneficial to the local durum breeding objectives.

Singh *et al.* (2003) studied the genetic divergence in 24 durum wheat genotypes using Mahalonobis $D^2$ statistic and the genotypes were grouped into six different clusters. Further, it was suggested that hybridization between parents included in cluster II and III, followed by selection in segregating generations may help in isolating the desirable strains with early seedling vigour.

Tyagi *et al.* (2003) observed genetic divergence for five important agronomic and yield contributing characters in 62 genotypes of durum wheat and revealed that 62 genotypes can be grouped into five clusters. The maximum
number of genotypes were in cluster V (20 genotypes) while cluster IV had only six genotypes.

Sangwan et al. (2004) studied the genetic diversity of 200 genotypes of durum wheat and they observed genotypes of heterogeneous origin were often grouped together in the same cluster, indicating some degree of ancestral relationship among the genotypes. Based on data on genetic divergence and mean performance of yield and other traits, 7 diverse and superior genotypes (CBD-212, IDYN-573, HNP-79, P-5459, P-5460, WC-5 and WH-902) were identified.

Shoran et al. (2005) studied the genetic diversity in 62 elite genotypes of durum wheat. The dendrograms was generated on the basis of Euclidean distances and observed that the presence of all three checks (released varieties for different agro climatic zones) in nearly clusters indicated that geographical distribution has no correspondence to genetic divergence.

Ribadia et al. (2007) studied the genetic divergence in 50 exotic genotypes of macaroni wheat (T. durum Dcsl.) and observed that the genotypes were grouped into six clusters. Cluster I was the largest with 38 genotypes followed by clusters II and III containing 7 and 2 genotypes, respectively. The highest inter-cluster distance was observed between cluster II and V followed by that between cluster I and IV, suggesting more variability in genetic make up of the genotypes included in these clusters. Days to 50% flowering and length of main spike contributed maximum towards the total divergence.