CHAPTER - V
DISCUSSION

The green revolution that enabled the doubling of cereal production of India in a decade was largely due to the introduction of high yielding wheat varieties, adoption of better production technologies and easier access to irrigation. Success of plant breeding programme depends on the choice of appropriate parents. It is expected that the utilization of divergent parents in hybridization results in promising recombinants. The improvement of grain yield largely depends on magnitude of genetic variability present and the extent to which grain yield determining characters are heritable. It is also important to understand the character association with grain yield for effective selection in the segregating population. A thorough knowledge of the nature and magnitude of genetic variability and the extent of association between grain yield and its components are essential before launching a breeding programme. Similarly, heritability and genetic advance estimates are helpful in selecting superior individuals.

The grain yield has complex gene action and hence, it requires proper study, different factors affecting the grain yield are to be considered and evaluated with regards to their contribution to yield. For a particular crop, information on the nature and magnitude of variability present in the available material due to genetic and non-genetic causes is an important pre-requisite for starting any systematic breeding programme.

To step up wheat yield per unit area and per unit time, there is a need to develop high yielding varieties with resistance to biotic and abiotic stresses. Information on the phenotypic and genotypic relationships of grain yield in the wheat with its component characters and also among the characters themselves would be very useful to the breeders in developing an appropriate breeding strategy. Grain yield is a complex character and is influenced by number of traits as well as the effect of environment and hence, the selection of genotypes with desirable characters would be greatly enhanced if; significant correlation between grain yield and its component characters are established. In order to improve grain yield by accumulating optimum combination of yield contributing characters in a single genotype, it is essential to know the implication of the interrelationship of various characters. The information
Discussion

on correlation and path coefficients provides an opportunity to know the magnitude and direction of association of yield with its direct and indirect components.

During the last decade, there is increase in the temperature due to climate change. The high temperature at the stage of grain filling period in wheat crop affect the grain yield of crop. There is need to develop high temperature tolerance in wheat genotypes with the help of different breeding procedure to prevent yield loss. For this purpose different screening tools used to identify heat tolerance genotype. Fischer and Maurer (1978) has given the screening method to estimate heat sensitivity index (S) for yield related traits in wheat genotypes sown under normal and late sown conditions.

5.1 ANALYSIS OF VARIANCE

In the present study, analysis of variance revealed that mean square due to genotypes were significant for all the traits in both normal and late sowing conditions that indicating the presence of sufficient amount of genetic variability among the genotypes for grain yield per plant and other yield contributing traits. These findings of mean sum of squares are in accordance with the findings of Abinasa et al. (2011), Tambe et al. (2013) and Wolde et al. (2016) who also observed significant variability in bread wheat germplasm. Hence, it can be noted that systematic crossing among selected genotypes in self-pollinated like wheat generates variability in subsequent generation.

5.2 GENETIC VARIABILITY

Genetic variability is pre-requisite for genetic improvement in a systematic breeding programme. There is more genetic potentiality in the genetically variable populations and thus, the chances to obtain the desired types are increased. The estimates of genetic parameters are helpful for plant breeders to predict the performance of genotypes in the subsequent generations. So, it is necessary to split the phenotypic variability into heritable and non-heritable components. The present experimental material showed a wide range of variation for plant height followed by number of grain per main spike, grain yield per plant, number of effective tillers per plant, days to maturity and grain filling period. The harvest index, number of spikelets per main spike, days to heading expressed a moderate range of variation.
5.2.1 Genotypic and phenotypic coefficient of variation

The better index for measuring the genetic variation is genetic co-efficient of variation (GCV) as described by Burton and De Vane (1953) for comparing the genetic variability present in different traits. The estimates of genotypic and phenotypic coefficient of variability in both sowing conditions indicated that the values of phenotypic coefficient of variation were slightly higher than that of genotypic coefficient of variation for all the traits studied, indicating less effect of environment on the expression of characters studied. Similar results have been reported by Majumder et al. (2008), Thanna et al. (2011), Tsegay et al. (2012), Desheva and Cholakov (2014), Malav (2015) and Wolde et al. (2016).

The high values of GCV were observed under normal sowing condition for canopy temperature depression at grain filling stage followed by grain yield per plant, biological yield per plant, length of main spike, number of grain per main spike, harvest index, number of effective tillers per plant, 100-grain weight and plant height. The high values of GCV were observed under late sowing condition for canopy temperature depression at grain filling stage followed by grain yield per plant, biological yield per plant, harvest index, length of main spike, 100-grain weight, number of effective tillers per plant, chlorophyll content and grain filling period.

The characters which observed for high magnitude of GCV in both normal and late sowing condition are also reported by researchers. High GCV estimates in wheat have been reported for canopy temperature depression at grain filling stage (Talebi 2011), grain yield per plant (Hirachand et al. 1978; Kheiralla et al. 1993; Kumar and Luthra 1995; Shukla 2000; Dwivedi et al. 2002; Sharma et al. 2006; Yadav et al. 2006; Subhashchandra et al. 2009; Singh et al. 2010; Singh et al. 2012; Ashwini et al. 2013; Bhushan et al. 2013 and Kumar et al. 2014). For Biological yield per plant Fantini et al. 1994; Kumar and Luthra 1995; Shukla 2000; Sidharthan and Malik 2007; Bhusan et al. 2013; Kumar et al. 2014 and Malav 2015. For length of main spike, (Kheiralla et al. 1993; Singh et al. 2013; Ashwini et al. 2013). For number of grain per main spike, (Das and Rahman. 1984; Kheiralla et al. 1993; Sharma et al. 2006; Singh and Sharma. 2007; Singh et al. 2010; Baranwal et al. 2012; Kalariya and Monpara. 2014, for harvest index (Shukla et al. 2000; Sidharthan and Malik 2007; Singh and Sharma 2007; Kumar et al. 2013a; Kumar et al. 2014; Malav 2015 and Wolde et al. 2016), for number of effective tillers per plant (Singh et al. 2001; Pawar et al. 2002; Sidharthan and Malik 2007; Ali et al. 2008; Dhakar et al. 2012; Singh et
Discussion


The moderate values of GCV were observed under normal sowing condition for number of effective tillers per plant, length of main spike, number of grain per main spike and harvest index. The moderate values of GCV were observed under late sowing condition for number of effective tillers per plant, length of main spike, and 100-grain weight.

The low value of GCV was observed under normal sowing condition for days to heading, days to maturity, grain filling period, plant height, number of spikelets per main spike, number of grains per main spike, chlorophyll content at anthesis and chlorophyll content at 21 days after anthesis. The low value of GCV was observed under late sowing condition for plant height and days to maturity. The finding of these characters are supported by earlier reports of Abinasa et al. 2011 and Baranwal et al. 2012.

High phenotypic coefficient of variation was observed under normal sowing condition for canopy temperature depression at grain filling stage followed by grain yield per plant, number of effective tillers per plant, length of main spike, biological yield per plant, harvest index and 100-grain weight exhibited moderate value of phenotypic coefficient of variation, whereas days to heading, plant height, number of spikelets per main spike and number of grain per main spike noted low values of phenotypic coefficient of variation. High phenotypic coefficient of variation was observed under late sowing condition for grain yield per plant, biological yield per plant, harvest index and length of main spike. Grain filling period, number of effective tillers per plant, 100-grain weight and chlorophyll content at anthesis exhibited moderate value of phenotypic coefficient of variation, whereas plant height and days to maturity noted low values of phenotypic coefficient of variation.

5.2.2 Heritability

The genotypic coefficient of variation measures the amount of variation present in a particular character. However, it does not determine the proportion of heritable variation present in the total variation. Therefore, heritability which represents the heritable variation existing in the character was calculated. High values of heritability in broad sense are helpful in identifying the appropriate character for selection and in enabling the breeders to select superior genotypes on the basis of phenotypic expression of quantitative traits (Johnson et al. 1955).

In the present study, high heritability (broad sense) values were observed under normal sowing condition for canopy temperature depression at grain filling stage, canopy temperature depression at vegetative stage days to heading, days to maturity, plant height, number of effective tillers per plant, length of main spike, number of grains per main spike, grain yield per plant, biological yield per plant, harvest index and chlorophyll content at 21 days after anthesis, while moderate estimates for grain filling period, 100-grain weight and chlorophyll content at anthesis. High heritability (broad sense) values were observed under late sowing condition for canopy temperature depression at grain filling stage, days to heading, grain filling period, plant height, number of effective tillers per plant, length of main spike, grain yield per plant, biological yield per plant, harvest index, 100-grain weight, chlorophyll content, canopy temperature depression, while moderate estimates for days to maturity and number of spikelets per main spike. The high heritability values for different traits indicated that heritability may be due to higher contribution of genotypic component in these traits.

Above characters which observed for high magnitude of heritability in both normal and late sowing conditions are also reported by researchers. High magnitude of heritability have been reported for biological yield per plant (Patel and Jain 2002 and Wolde et al. 2016), for harvest index (Patel and Jain 2002; Majumder et al. 2008 and Wolde et al. 2016), for grain yield per plant (Narwal et al. 1999; Khumkar et al. 2001; Patel and Jain 2002; Chavada and Monpara 2007; Kamboj 2007; Majumder et al. 2008; Gashaw et al. 2010; Bilgin et al. 2011; Thanna et al. 2011; Said et al. 2014 and Wolde et al. 2016), for number of grains per main spike (Ansari et al. 1999; Narwal et al. 1999; Majumder et al. 2008; Mohammadi et al. 2011a; Thanna et al. 2011; Said et al. 2014 and Wolde et al. 2016), for number of productive tillers per plant (Ansari et al. 1999; Narwal et al. 1999; Patel and Jain 2002; Kamboj 2007; Said...

The moderate heritability was reported in wheat for length of main spike (Ansari et al. 1999; Narwal et al. 1999; Patel and Jain 2002; Gashaw et al. 2010; Mohammadi et al. 2011a; Tsegay et al. 2012; Said et al. 2014 and Wolde et al. 2016).

5.2.3 Genetic advance

The genetic advance under normal sowing condition at 5% selection intensity (k=2.06) was found high for number of grains per main spike, plant height and days to maturity. In that normal sowing condition moderate genetic advance was observed for harvest index, biological yield per plant, days to heading, grain filling period, chlorophyll content and grain yield per plant, while it was low for all the remaining traits studied. The genetic advance under late sowing condition at 5% selection intensity (k=2.06) was found high for harvest index, chlorophyll content, biological yield per plant canopy temperature depression at grain filling stage and canopy temperature depression at vegetative stage. In that late sowing condition moderate genetic advance was observed for days to heading, plant height, grain filling period and days to maturity, while it was low for all the remaining traits studied including number of spikelets per main spike.

High magnitude of genetic advance have been reported for number of grains per main spike (Pathak and Nema 1985; Amin et al. 1990; Ansari et al. 1999;

The moderate results of genetic advance have been supported for days to maturity (Kamboj 2007), plant height (Kamboj 2007), grain filling period (Kummar et al. 2014), and grain yield per plant (Monpara 2009; Bilgin et al. 2011).

The low results of genetic advance have been supported by Desheva and Cholakov (2014) for number of spikelets per spike; Pawar et al. (2002) for number of effective tillers per plant; Abinasa et al. (2011) for days to maturity; Bilgin et al. (2011) for grain yield; Talebi (2011) for chlorophyll content at anthesis and chlorophyll content at 21 days after anthesis;

5.2.4 Genetic advance expressed as percentage of mean

The genetic advance expressed as percentage of mean under normal sowing condition was found high for length of main spike, number of grains per main spike, grain yield per plant and biological yield per plant, while, moderate values of genetic advance expressed as percentage of mean was recorded for canopy temperature depression at grain filling stage, canopy temperature depression at vegetative stage, days to heading, grain filling period, plant height, number of effective tillers per plant, harvest index and 100-grain weight. The genetic advance expressed as percentage of mean under late sowing condition was found high for canopy temperature depression at grain filling stage, canopy temperature depression at vegetative stage length of main spike, grain yield per plant, biological yield per plant, harvest index, while moderate values of genetic advance expressed as percentage of mean was recorded for days to heading, grain filling period, plant height, number of effective tillers per plant, 100-grain weight, chlorophyll content and canopy temperature depression.

Recent used researchers also reported for characters that observed in both normal and late sowing conditions. High values of have been reported in wheat for length of main spike by Patel and Jain (2002), Singh and Sharma (2007), Dhakar et al. (2012), Tsegay et al. (2012) and Wolde et al. (2016). Grain yield per plant by Singh et al. (2001), Patel and Jain (2002), Singh and Sharma (2007), Dhakar et al. (2012),
Singh et al. (2012), Bhushan et al. (2013), Tambe et al. (2013) and Wolde et al. (2016). Biological yield per plant by Patel and Jain (2002), Singh et al. (2012) and Bhushan et al. (2013). In case of normal sowing condition the number of grains per main spike by Patel and Jain (2002), Singh and Sharma (2007), Baranwal et al. (2012), Dhakar et al. (2012), Maurya et al. (2014) and Wolde et al. (2016). In late sowing condition the harvest index by Patel and Jain (2002), Singh and Sharma (2007), Bhushan et al. (2013) and Wolde et al. (2016).

Moderate values of genetic advance expressed as percentage of mean was recorded for plant height by Maurya et al. (2014) and days to heading by Patel and Jain 2002.

Johnson et al. (1955) suggested that the heritability and genetic advance when considered together would be more useful in predicting the resultant effects of selection. Rapid progress in selection can be achieved when high heritability is accompanied with high genetic advance, which forms the most reliable index of selection (Burton and De Vane, 1953). In the present study, moderate to high heritability coupled with high genetic advance expressed as percentage of mean were observed under normal sowing condition for days to heading, grain filling period, number of effective tillers per plant, number of grains per main spike, grain weight per main spike, grain yield per plant, biological yield per plant, harvest index, 100-grain weight, chlorophyll content, and canopy temperature depression, while under late sowing condition for days to heading, grain filling period, plant height, number of productive tillers per plant, number of grains per main spike, grain weight per main spike, grain yield per plant, biological yield per plant, harvest index, 100-grain weight, chlorophyll content and canopy temperature depression, which may be attributed to the preponderance of additive gene action and possessed high selective value and thus, selection pressure could profitably be applied on these characters for their rationale improvement (Panse, 1957). Moderate heritability with moderate genetic advance expressed as percentage of mean was manifested under normal sowing condition by plant height, while under late sowing condition days to maturity, which indicated non-additive type of gene action controlling these characters, so selection might be useful.

High heritability with high genetic advance expressed as percentage of mean was also reported by Singh et al. (2001) for grain yield per plant; Patel and Jain (2002) for biological yield per plant, harvest index, grain yield per plant, number of
Discussion

effective tillers per plant, chlorophyll content at anthesis, chlorophyll content at 21
days after anthesis 100-grain weight, grain filling period, grain weight per main spike
length of main spike and plant height; Kumar and Mishra (2004) for number of tillers
per plant, 1000 grain weight and plant height; Singh and Sharma (2007) for spike
length, grain yield, harvest index and grains per spike; Talebi (2011) for canopy
temperature at grain filling stage (CT_{gr}), canopy temperature at vegetative stage
(CT_{vg}), canopy temperature depression at vegetative stage (CTD_{vg}) and canopy
temperature depression at grain filling stage (CTD_{gr}); Baranwal et al. (2012) for
grains per spike; Dhakar et al. (2012) for plant height, weight of 100 seeds, seeds per
spike, number of productive tillers per plant, length of spike, grain yield per plot,
grain yield per plant and days to maturity; Singh et al. (2012) for grain yield,
biological yield, days to 50 per cent flowering, effective tillers per plant and days to
maturity; Tsegay et al. (2012) 1000 grain weight and spike length; Bhushan et al.
(2013) for plant height, harvest index, biological yield and grain yield; Tambe et al.
(2013) for grain yield per plant; Wolde et al. (2016) for productive tillers per plant,
spike length, number of grains per spike, 1000 grain weight, grain yield and harvest
index.

5.3 CORRELATION COEFFICIENTS

In plant breeding programmes, several yield attributing characters are often to
be handled together by the plant breeders as most of the characters especially of
fitness are correlated. Thus, the different components of grain yield very often exhibit
considerable degree of association among themselves and with grain yield. Grain
yield is a complex character and the multiplicative end product of many quantitative
traits. Therefore, selection for yield per se will not be desirable. Searle (1965)
suggested that the average merit of a character in a population could be changed by
means of selection programme based on the phenotype of the main trait concerned.
However, such an improvement would be more reliable if indirect selection based on
another trait correlated with it is made. Therefore, for rationale improvement of grain
yield and its components, the understanding of correlations has been observed very
useful. The real association could be known only through genotypic correlation which
eliminates the effect of environments.
Correlation among traits may result from pleiotropy, linkage or physiological associations among characters. The linkage is a cause of transit correlations particularly in a population derived from crosses between divergent strains. The correlation is the overall or net effect of the segregating genes; some of the genes may increase both the characters causing the positive correlation, while, the others may increase the one and decrease the other causing the negative correlation (Falconer, 1989). Thus, 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.

The study of genotypic correlation gives an idea of the extent of relationship between different variables. This relationship among yield contributing characters as well as their association with yield provides information for exercising selection pressure for bringing genetic improvement in grain yield. In general, the values of genotypic correlation were higher than their corresponding phenotypic correlations in the present study. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. Munir et al. (2007), Majumder et al. (2008), Malav (2015) and Singh (2016) also reported that genotypic correlations were higher than the phenotypic correlations.

The characters, grain yield per plant under normal sowing condition exhibited highly significant and positive genotypic and phenotypic correlation with harvest index, biological yield per plant and number of grain per main spike. It also manifested the significant positive correlation with days to heading at phenotypic level. Grain yield per plant also manifested positive, but non-significant genotypic and phenotypic correlation with 100-grain weight, number of spikelets per main spike, length of main spike, grain filling period and days to maturity.

The significant and positive correlation of grain yield per plant with harvest index also reported by Subhani and Chowdhry (2000), Mishra et al. (2001), Bergale et al. (2002), Singh et al. (2003), Majumder et al. (2008), Kumar et al. (2009b), Ahamed et al. (2010) and Zeeshan et al. (2014), biological yield per plant by Singh et al. (2003), Sharma et al. (2004), Mohammad et al. (2005), Sidharthan and Malik (2006), Singh et al. (2008), Kumar et al. (2009b), Yadav et al. (2009), Ahamed et al. (2010), Singh et al. (2012), Bhushan et al. (2013), Fellahi et al. (2013); number of grain per main spike by Hirachand et al. (1978), Nanda et al. (1980), Singh et al.

The days to heading exhibited significant and positive correlation at genotypic level with number of spikelets per main spike, number of grain per main spike and biological yield per plant (Nanda et al. 1980, Singh et al. 1982, Falcinelli et al. 1983, Singh et al. 1985, Adary and Al Fhady 1987, Subhani and Chowdhary 2000, Ihsan et al. 2004 and Yadav et al. 2006).

The days to maturity exhibited significant and positive correlation at genotypic level with number of spikelets per main spike and number of grain per main spike (Singh et al. 1982, Subhani and Chowdhary 2000, Ihsan et al. 2004, Joshi 2005 and Sharma et al. 2006).

The grain filling period exhibited significant and positive correlation at genotypic level with harvest index (Bhushan et al. 2013).

The plant height exhibited positive and non-significant correlation at both phenotypic and genotypic levels with harvest index and chlorophyll content at 21 days after anthesis (Sharma et al. 2006, Yadav et al. 2006 and Khan et al. 2013). Number of effective tillers per plant exhibited positive and significant correlation at genotypic level with length of main spike, number of spikelets per main spike, number of grain per main spike and biological yield per plant (Suryakant et al. 2011, Baranwal et al. 2012, Singh et al. 2012, Ashwini et al. 2013 and Zeeshan et al. 2014). Length of main spike exhibited significant and positive correlation with number of spikelets per main spike, number of grain per main spike, biological yield per plant and chlorophyll content at 21 days after anthesis at both phenotypic and genotypic levels (Samrat et al. 2011 and Karimizadeh et al. 2012). The number of grain per main spike exhibited significant and positive correlation with biological yield per plant and 100-grain weight at both the genotypic and phenotypic levels (Hirachand et al. 1978, Sidharthan and Malik 2006, Suryakant et al. 2011 and Talebi and Fayyaz 2012). Biological yield per plant showed significant and positive correlation with 100 grain weight at both genotypic and phenotypic levels (Fellahi et al. 2013). Harvest index showed significant and positive correlation with 100 grain weight at genotypic level (Karimizadeh et al. 2012).
The characters, grain yield per plant under late sowing condition exhibited significant and positive genotypic and phenotypic correlation with biological yield per plant.

The significant and positive correlation of grain yield per plant with harvest index also reported by Subhani and Chowdhry (2000), Mishra et al. (2001), Bergale et al. (2002), Singh et al. (2003), Saxena et al. (2007), Majumder et al. (2008), Kumar et al. (2009b), Ahamed et al. (2010), Gashaw et al. (2010), Talebi et al. (2010), Abinasa et al. (2011), Siahbidi et al. (2012), Gelalcha and Hanchinal (2013) and Zeeshan et al. (2014) Singh (2016) and Mecha et al. (2017); biological yield per plant by Singh et al. (2003), Sharma et al. (2004), Mohammad et al. (2005), Sidharthan and Malik (2006), Saxena et al. (2007), Singh et al. (2008), Kumar et al. (2009b), Yadav et al. (2009), Ahamed et al. (2010), Kant et al. (2011), Siahbidi et al. (2012), Singh et al. (2012), Tsegay et al. (2012), Bhushan et al. (2013), Fellahi et al. (2013), Chhibber and Jain (2014), Malav (2015) and Singh (2016); plant height by; Subhani and Chowdhry (2000), Bergale et al. (2002), Khaliq et al. (2004), Sharma et al. (2004), Mehmet and Telat (2006), Singh et al. (2008), Dogan (2009), Kumar et al. (2009b), Gashaw et al. (2010), Bilgin et al. (2011), Subhani et al. (2011), Siahbidi et al. (2012), Singh et al. (2012), Ghafoor et al. (2013), Khan et al. (2013) and Kumar et al. (2013b); length of main spike by Subhani and Chowdhry (2000), Khaliq et al. (2004), Munir et al. (2007), Ali et al. (2008), Singh et al. (2008), Ahamed et al. (2010), Bilgin et al. (2011), Iftekhar et al. (2012), Sharma et al. (2013), Zeeshan et al. (2014) and Mecha et al. (2017) and number of grains per main spike by Subhani and Chowdhry (2000), Mishra et al. (2001), Bergale et al. (2002), Mehmet and Telat (2006), Munir et al. (2007), Sen and Toms (2007), Ali et al. (2008), Majumder et al. (2008), Singh et al. (2008), Dogan (2009), Kumar et al. (2009b), Ahamed et al. (2010), Gashaw et al. (2010), Khan et al. (2010), Abinasa et al. (2011), Bilgin et al. (2011), Kant et al. (2011), Iftikhar et al. (2012), Siahbidi et al. (2012), Ghafoor et al. (2013), Gelalcha and Hanchinal (2013), Khan et al. (2013), Ali et al. (2015), Kaleemullah et al. (2015), Malav (2015) and Mecha et al. (2017).

Days to heading possessed positive correlation with grain filling period, plant height, number of effective tillers per plant, length of main spike and chlorophyll content at 21 days after anthesis at both genotypic and phenotypic levels (Nanda et al. 1980, Singh et al. 1982, Falcinelli et al. 1983, Singh et al. 1985, Adary and Al Fhady 1987, Subhani and Chowdhary 2000, Ihsan et al. 2004 and Yadav et al. 2006).
Discussion

Days to maturity possessed positive correlation with number of spikelets per main spike, chlorophyll content at anthesis and chlorophyll content at 21 days after anthesis at both genotypic and phenotypic levels (Singh et al. 1982, Subhani and Chowdhary 2000, Patel and Jain (2002), Ihsan et al. 2004, Joshi 2005 and Sharma et al. (2006), Talebi (2011).

The grain filling period possessed significant and positive correlation with plant height at genotypic level and chlorophyll content at 21 days after anthesis levels. It was also had positive correlation with number of spikelets per main spike, number of grains per main spike, biological yield per plant, 100-grain weight and chlorophyll content at 21 days after anthesis at both genotypic and phenotypic levels (Bhushan et al. 2013, Patel and Jain (2002) and Talebi (2011).

The plant height possessed highly significant and positive correlation both at genotypic and phenotypic levels with harvest index. It was also had positive correlation with number of spikelets per main spike, number of grain per main spike, chlorophyll content at anthesis and chlorophyll content at 21 days after anthesis at both genotypic and phenotypic levels (Hirachand et al. 1978, Amin et al. 1990, Kumar et al. 2009, Talebi (2011) and Bhushan et al. 2013). Number of effective tillers per plant exhibited positive correlation both at genotypic and phenotypic levels with chlorophyll content at anthesis, 100-grain weight and length of main spike plant (Suryakant et al. 2011, Baranwal et al. 2012, Singh et al. 2012, Ashwini et al. 2013 and Zeeshan et al. 2014, ). Length of main spike exhibited significant and positive correlation with number of spikelets per main spike at genotypic level. It is also had positive correlation with number of grain per main spike, biological yield per plant and chlorophyll content at anthesis (Samrat et al. 2011, Talebi (2011) and Karimizadeh et al. 2012 ). Number of spikelets per main spike possessed exhibited positive correlation with harvest index at both levels and negative correlation with number of grain per main spike and biological yield per plant at both levels (Singh et al. 1985, Monpara et al. 2009 and Singh et al. 2012). The number of grains per main spike showed significant and positive correlation with harvest index at genotypic level (Srivastava et al. 1988, Dwivedi et al. 2002). It was also had negative and significant correlation with biological yield per plant and 100-grain weight at genotypic level (Singh et al. 2012). Biological yield per plant showed significant and positive correlation with 100 grain weight at both genotypic and phenotypic levels (Singh et al. 2003, Yadav et al. 2006 and Fellahi et al. 2013,).
The present results on correlation coefficients, thus, revealed that under normal sowing condition harvest index, biological yield per plant, 100-grain, length of main spike and plant height, while under late sowing condition harvest index, biological yield per plant, plant height length of main spike and number of grains per main spike were the most important traits and may contribute considerably towards higher grain yield. The interrelationship among yield components would help in increasing the yield levels and, therefore, more emphasis should be given to these components, while selecting better types in wheat.

5.4 PATH COEFFICIENT ANALYSIS

Grain yield, a polygenic trait, is influenced by its various components directly as well as indirectly via other traits, which create a complex situation before a breeder going for making selection. Path coefficient analysis provides a more realistic picture of the interrelationship, as it considers direct as well as indirect effects of the variables by partitioning the correlation coefficient.

In the present study, path coefficient analysis under normal sowing condition revealed that harvest index and biological yield per plant exhibited high and positive direct effects on grain yield per plant. Thus, these characters turned-out to be the major components of grain yield. Similar results obtained by Shamsuddin (1987), Srivadtava et al. (1988a), Subhani and Chowdhry (2000), Dwivedi et al. (2002), Singh et al. (2003), Sharma et al. (2006), Mohammad et al. (2005), Sidhartha and Malik (2006), Gupta et al. (2007), Majumder et al. (2008), Mollasadeghi et al. (2011), Singh et al. (2012), Tsegay et al. (2012), Bhushan et al. (2013), Fellahi et al. (2013), Hannachi et al. (2013) and Zeeshan et al. (2014). Days to heading exhibited low and positive direct effects on grain yield per plant. Thus, these characters turned-out to be the minor components of grain yield. Similar results obtained by (Singh et al. 2012), The characters like days to maturity, length of main spike, number of spikelets per main spike and chlorophyll content at 21 days after anthesis exerted low and negative direct effects on grain yield per plant. Similar results obtained by (Mondal et al. 1997, Khan and Dar 2010, Talebi (2011) and Ata et al. (2014)).

Under normal sowing condition harvest index exhibited low and positive indirect effects via days to heading, plant height, length of main spike and chlorophyll content at 21 days after anthesis (Talebi (2011) and Ata et al. (2014)). Biological
Discussion

yield per plant showed low and positive indirect effects via days to heading and grain filling period. Same results were finding out by (Shamsuddin 1987). 100-grain weight exerted low and positive indirect effects on days to heading, grain filling period, length of main spike, number of spikelets per main spike and biological yield per plant. Similar results was observed by (, Tammam et al. 2000, Gupta et al. 2007 and Hannachi et al. 2013). Plant height exerted low and positive indirect effects on grain yield per plant via days to heading, days to maturity, number of spikelets per main spike and harvest index. Same results was observed by (Khan et al. 2013). Length of main spike exhibited low and positive indirect effects on days to heading, grain filling period, plant height and biological yield per plant. Similar results were recorded by (Farzanch and Maragheh 2013). Days to heading showed low and positive indirect effects via grain filling period, harvest index and canopy temperature depression, but it was observed high and positive indirect effects on biological yield per plant.

In the present study, path coefficient analysis under late sowing condition revealed that biological yield per plant, number of grains per main spike, number of spikelets per main spike, chlorophyll content at 21 days after anthesis, days to maturity and grain feeling period exhibited high and positive direct effects on grain yield per plant. Thus, these characters turned-out to be the major components of grain yield. Same results obtained by Shamsuddin (1987), Srivatava et al. (1988a), Dwivedi et al. (2002), Singh et al. (2003), Sharma et al. (2006), Sidhartha and Malik (2006), , Mohammad et al. (2005), Gupta et al. (2007), Majumder et al. (2008), Mollasadeghi et al. (2011), Singh et al. (2012), Tsegay et al. (2012), Bhushan et al. (2013), Fellahi et al. (2013), Hannachi et al. (2013) and Zeeshan et al. (2014). Number of effective tillers per plant and length of main spike exhibited low and positive direct effects on grain yield per plant. Thus, these characters turned-out to be the minor components of grain yield. ), Mondal and Khajuria (2001), Singh et al. (2003), Ihsan et al (2004), Sen and Toms (2007), Rangare et al. (2010) and Zeeshan et al. (2014), . The characters like chlorophyll content at anthesis, days to heading and harvest index exerted low and negative direct effects on grain yield per plant. Similar results obtained by Mondal et al. (1997), Khan and Dar (2010), Ata et al. (2014),. The characters days to maturity exerted high but negative direct effects on grain yield per plant same results were also reported by Mondal et al. (1997), Khan and Dar (2010) and Iftikhar et al. (2012).
Under late sowing condition harvest index exhibited low and positive indirect effects via grain filling period, number of spikelets per main spike, number of grains per main spike, harvest index, 100-grain weight and chlorophyll content at 21 days after anthesis. Biological yield per plant showed low and positive indirect effects via days to heading, grain filling period, length of main spike, harvest index and chlorophyll content at 21 days after anthesis. Length of main spike exerted low and positive indirect effects on number of effective tillers, number of spikelets per main spike, number of grains per main spike, biological yield per plant and harvest index. Plant height exerted low and positive indirect effects on grain yield per plant via grain filling period, number of spikelets per main spike, number of grain per main spike, harvest index length, 100-grain weight and chlorophyll content at 21 days after anthesis. Number of grain per main spike exhibited low and positive indirect effects on grain filling period, length of main spike and 100-grain weight. 100-grain weight exhibited low and positive indirect effects via days to heading, grain filling period, number of effective tillers per plant, length of main spike and harvest index, while it was high and positive correlation with biological yield per plant.

The residual effect of the present study under normal sowing condition was 0.0971 indicating that the characters studied contributed 93 per cent of the yield. It is suggested that maximum emphasis should be given to all the characters studied in selecting wheat with higher yield. The residual effect under late sowing condition was 0.0971 indicating that the characters studied contributed 93 per cent of the yield. It is suggested that maximum emphasis should be given to all the characters studied in selecting wheat with higher yield.

In the present study under normal sowing condition, the characters like harvest index, biological yield per plant, 100-grain weight, plant height and length of main spike showed positive and significant association with grain yield per plant, while under late sowing condition, the characters like harvest index, biological yield per plant, length of main spike, plant height, grain weight per main spike and number of grains per spike showed positive and significant association with grain yield per plant. Under normal sowing condition all of these characters, viz., harvest index, biological yield per plant, 100-grain weight, plant height and length of main spike manifested high and positive direct effect on grain yield per plant, while under late sowing condition among these, harvest index, biological yield per plant, length of main spike and plant height manifested high and positive direct effect on grain yield per plant.
Hence, these characters may be considered as the most important yield contributing characters and due emphasis given on these components, while breeding for high yielding types in wheat.

5.4 HEAT SUSCEPTIBILITY INDEX

Heat stress is a major limitation to wheat productivity in arid, semi-arid, tropical and sub-tropical regions of world. During grain filling stage this abiotic stress reduces the yield considerably at the rate of 270 kg ha⁻¹ degree⁻¹ rise in temperature above 11 °C (Rane et al., 2000). In India, wheat growing regions of central and peninsular India experiencing high temperature stress during post anthesis stage. Hence, now breeding for heat tolerance has become an integral component of wheat improvement at both National and International level. However the progress to breed for high temperature tolerance has been handicapped due to inadequate knowledge about the morpho-physiological parameters and their sophisticated measurement techniques. But in recent past a few desirable heat tolerance parameters with high heritability have been identified for their use in breeding programme notably membrane thermostability, canopy temperature depression (CTD), seedling vigour index and heat susceptability index. In present study, heat sensitivity index had been used for screening heat tolerance genotypes of wheat.

Based upon the value and direction of desirability, ranking was done for different genotypes as highly heat tolerant (HSI<0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76-1.00) and heat susceptible (HSI>1.00).

According to estimation of GW-2011-347, GW-2011-362, LBPY 2011-9, NIAW 2844, RAJ 4445, HS-557, K-1006, GW-366, RAJ-3077 had been highly heat tolerant for grain yield per plant, genotypes JS 6-1, LBPY 2011-2, RAJ 4396, GW2013-478, NIWA 2809, F₆A DALANG 95 were heat tolerant, while the genotypes GW-2011-361, LBPY2011-8, LBPY2011-10, KB2013-05, GW2013-489, LBPY-2014-8, NIAW 2064, NW-5013, PHSL-1104, GW-496 were moderately heat tolerant. The classification of genotypes in rating of heat tolerant has been given in the Table 5.1.

temperature stress conditions with less reduction in grain yield; Sharma et al. (2004) for genotypes JS 6-1, LBPY 2011-2, RAJ 4396, GW2013-478, NIWA 2809, F6A DALANG 95 from the short duration group showed low heat sensitivity index in grain yield per plant; Singh et al. (2005) for genotypes like Lok 3397, WR 546, WR 1068, K 9824, K 9922, NW 2036, NW 2054, GW 326, RAJ 365, Lok 45 and UP 2418, showing a greater degree of tolerance to higher temperature caused by late sowing; Thus, in the present study revealed that genotypes GW-2011-347, GW-2011-362, LBPY 2011-9, NIAW 2844, RAJ 4445, HS-557, K-1006, GW-366, RAJ-3077 found most suitable under selection for grain yield per plant under normal as well as late sowing condition.