DISCUSSION

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The most precious results of Green Revolution in wheat production percent area have reached a plateau. Though, the demand for wheat grain in constantly increasing day by day due to an upward trend of population at our own country level as well as at world level at large. Moreover, the catastrophic climatic changes during this crop season are again playing an important role, in further reducing the yield of this important constituent of staple diet of the majority of our people. Thereby, keeping the later recently developing problem in view, the wheat breeders are compelled to create new high yielding varieties with more stability under diverse climatic conditions, including various types of stress conditions to which they are likely to be exposed. The new plant type approach advocated by Donald (1968, 1979), that is by selecting for plant morphological characters considered to contribute to grain yield, such as reduced plant height, erect leaf and larger sink size (Leihner and Ortize, 1978). International Maize and Wheat Improvement Centre, 1978, 1979, 1980) has become a new field for conventional wheat breeders. To achieve this goal, an thorough screening of indigenous as well as exotic genotypes, cultivated or their wild relatives for important yield contributing characters, collectively or separately, is an essential and primary step of a fruitful breeding programme. Since the existing indigenous germplasm has narrow genetic variability for agronomic traits and disease resistance (Agrawal and Pandey, 1978) a breeding programme to generate new variability through intervarietal hybridization among the desirable character and/or characters containing genotype of **T aestivum** and **T durum,** separately was undertaken, at Research Farm of R. B. S. College, Bichpuri, Agra. Since India is one of the largest producer of durm wheat in the world and this tertraploid Triticum possesses condiderable potential for high yield and are useful in building up various yield components and reduce the compensation effects among these components. In the present investigation, durum intervarietal hybrids and their segregations (F2) were thoroughly investigated to find out their suitability upon which selection may operate profitably. These selective durum types can be used further as an accessible source of many valuable genes for extending genetic variability and further improvements in yielding ability of existing agronomically accepted varietal components. This can be done by interspecific hybridization as suggested by Hadley and Openshaw (1980). The introduction of alien genetic material into common wheat has become a routine practive (Sears, 1981; Gale and Miller, 1987).

In order to achieve the desired goal, the assessment of existing genotypic variability for specific traits is of prime importance followed by selection of suitable parents to be involved in crossing programme through their combining ability, their heterotic effects which decides their possible chances of getting desired improvement through selection in succeeding segregating generations. For character specific improvement, there in need to understand genetic architecture of these characters, their interrelationships and their direct and indirect contributions to a more complex economically important trait like kernel yield per plant. The line X tester analysis (Kempthorne, 1957) was adopted to draw information on the general and specific combining ability of parents and help understand various types of gene effects.

The salinet features of the results obtained in present investigation are discussed in this chapter in the light of available literature under the following heads:

1. Mean performance of parents and hybrids and the analyzing of variance
2. Analysis of combining ability
    (a) Analysis of variance for combining ability
    (b) General combining ability effects
    (c) Specific combining ability effects
3. Analysis of heterosis in percentage
4. Genetic variability, compornents of variances, genetic advance, heritability and coefficient of variation.
5. Correlation studies

6. path coefficient analysis.

1. Mean performance of parents and hybrids and the analysis of variance

The perusal of **Table 1** to **2** containing per se performance of parents and hybrids for the characters under study indicated that among the testers of **T aestivum,** DL-1266-5 and DL-788-2 were early maturing dwarf types showing high per se performance for number of spikelet's per spike and 1000 kernel weight also. In **T durum,** the tester CPAN 6214 was found to be dwarf type and LOKOS-3 and P_6 were recorded to be bold seeded and high yielding.

Among the lines GW 190, PBW 498 and HP 1731 were found to be early maturing having highest number of kernels per spike, bold seeded and high yielding. The line GW 322 was the highest performer for 1000 seeding weight.

The lines MACS 3125 and MACS 2846 of **T durum** were early flowering and early maturing. The lines CPAN 6207 and HD 4645 were good performer for number of effective tillers per plant, number of kernels per spike, 1000 kernel weight and kernel yield per plant.

The Performance of **T aestivum** hybrids was poor when compared with the early flowering and early maturing parents. The hybrids of parents HD 2428, DL-788-2 and DL-1266-5 with GW 322 were noted to be early flowering. The hybrids of UP 2338 with HD 2428, DL-788-2 and DL-788-2 with all the lines performed better, indicating that the tester DL-788-2 with all the lines performed better, indicating that the tester in worthwhile e involved in hybridization to improve spike length, number of kernels per spike, 1000 kernel weight and kernel yield per plant.

The crosses in **T durum** were mostly giving desirable performance for individual characters. MACS 3125 X CPAN 6214 and MACS 3125 X LOKOS-3 were early flowering and dwarf types whereas CPAN 6207 XP_6 was bold seeded. The crosses HD 4645 X CPAN 6214 and HD 4645 XP_6 were high yielding.

The analysis of variance of **T aestivum (Table 10** and **11)** and **T durum (Table 12)** revealed highly significant differences among genotypes, parents and hybrids for all the characters indicating the existence of sufficient variation for effective selection. Further, partitioning of genotypes indicated significant differences among females, males, hybrids and parents vs hybrids. The significance of parents vs hybrids confirmed that the average performance of hybrids was quite different from that of parents for kernel yield per plant and its other contributing characters. The non significance of female us males for kernel yield per plant indicated less variation available for this trait.

In **T durum,** significant variation observed for parents, females, hybrids and parents v shy indicated sufficient variability available in F_1.

However, in F_2, the males female vs males and hybrids did not show much variation for spike length.

2- Analysis of combining ability

(a) Analysis of variance for combining ability

The study of this biometrical parameter was undertaken in order to find out suitable parents with better potential to transmit desirable traits to their progenies and sort out the best specific combinations for kernel yield and its contributing characters. The analysis of quantitative inheritance, an equally important objective to unravel the nature and magnitude of gene action operating in the expression of characters undertaken, has an important bearing, concerning the choice of most appropriate and efficient breeding procedures.

The significance of parents vs hybrids, source of variation for all the characters except spike length in both the generations of **T aestivum** indicated existence of heterosis in the material investigated. Further, the maen sum of squares attributed to the male of female parents of the hybrids in the line X tester design and the interaction between female and male parents were significant for all the characters studied except spike length and number of effective tillers per plant in first year of F1 and F2, indicating the importance of both addition and non-additive gene effects. Similar results were also observed in **T durum,** where females,

males and female vs males source of variation was highly significant except for spike length.

Estimates of the relative contribution of general and specific combining ability whithini genetic variability present in a population are of interest to plant breeders, as breeding methods differ appreciably depending upon the type of gene action. The estimates of components of variation (**Table 15a and 15b)** and the ratios indicated the preponderance of additive gene action operating in the inheritance of all the yield contributing traits except for days to ear emergence and days to maturity in **T aestivum** thereby indicating that these two important short duration crop characters were under the control of non-additive gene action. Preponderance of non-additive gene action (i.e., additive X dominance and dominance X dominance) was reported for days to ear emergence by Somayajulu et al., (1970), Eske and Demir (1984), Yadav (1998), singh et al., (2000, 2003); for days to maturity by Malik (1980), Sharma et al., (1988), Pandey et al., (1994), Singh and Singh (2003). Most of the yield contributing traits in the present investigation has been found under the influence of additive genetic component of variation. Similar results are reports by earliar workers for plant height (Bhatt, 1971; Sharma et al., 1991; Sharma, 1995; Masood and Kronstad, 2000; Singh and Singh, 2003; Kumar and Sharma, 2005), for number of effective tillers per plant (Mani and Rao, 1977; Malik, 1980; Malik and Bhatnagar, 1991; Mishra et al., 1988; Asif et al., 2001), for spike length

(Malik, 1980; Sohanpal; 1983; Malik et al., 1988; Masood and Kronstand, 2000), fro number of kernels per spike (Kim, 1994; Singh et al., 1997; Pandey, 1998; Yadav, 1998; Asif et al., 2001), for 1000 kernel weight (Paroda and Joshi, 1970; Mani and Rao, 1977; Kumar, 1987), for kernel yield per plant (Bhatt, 1972; Malik 1980; Pandey, 1998; Sharma et al., 2001; Singh, 2003)

In **T durum**, additive gene action has played an important role to influence plant height, number of effective tillers per plant and number of kernels per spike in F_1 and F_2 generations. These findings lend support from the results reported for plant height (Kaltsikes and Lee, 1972; Amaya, 1972), for number of effective tillers per plant (Kaltsikes and Lee, 1971; Winder and Lebsock, 1973; Quick, 1978; Ahmad, 1979; Singh and Chatrath, 1997; Asif et al., 2001) and for number of kernels per spike (Winder and Lebsock, 1973; Quick, 1978; Talwar, 1978; Yadav, 1998).

The preponderance of non-additive gene action observed for days to ear emergence (Quick, 1978; Yadav, 1998; Singh et al., 2003), for days to maturity (Sharma et al., 1988; Singh and Singh, 20030, for spike length (Kumar et al., 1977; Talwar, 1978), for 1000 kernel weight (Kumar et al., 1977; Gupta and Ahmad, 1979; Yadav, 1998; Singh et al., 2000) and for kernel yield per plant (Gupta and Ahmad, 1979; Khan, 1992; Singh et al., 2000, 2003).

(b) General combining ability effects

A comprehensive representation of significant and desirable general combining ability effects for all the parents in two years of F_1 and one year of F_2 is given in **Tables 16, 17** and **18** for **T aestivum** and in **Tables 19** and **20** for **T durum** experiments. None of the parents involved in the line X tester crosses showed desirable g.c.a. effects for all the characters simultaneously. It is evident from the tables that the parents were good general combiners for some of the specific yield contributing traits. The results confirmed that the parents selected for this crossing programme were genetically diverse, which is a prime necessity of any hybridization maximum concentration programme. This also increases the chances of obtaining maximum concentrationm of desirable genes in the segregating generations upon which selection may operate successfully in desirable direction.

Thee parents GW 190 and PBW 498 among the lines and the parents HD 2428 and DL-788-2 among the testers were observed to be best general combiners for kernel yield per plant, number of kernels per spike and 1000 kernel weight. The lines PBW 498, G 322, VL 840 and GW 173 and the testers DL-788-2 and DL-1266-5 exhibited significantly negative g.c.a. effects for early flowering suggesting that they were good general combiners for earliness.

In **T durum**, the parents MACS 3125, MACS 2846 and P_6 with significantly negative g.c.a. effects were found to be good general combiners for days to ear emergence.

For days to maturity and dwarf plant type, the parents PBW 498, GW 190, HP 1731, UP 2338 and HD 2428 showed significantly negative g.c.a. effects and hence proved their suitability for involving them in crossing to improve these characters.

In **T durum**, the parents NIAW-34, MACS 3125 and P_6 were good general combiners for days to maturity. The parent CPAN 6214 was the best general combiner for plant height.

The parent GW 173 and DL-1266-5 aestivum types and H 4645 and LOKOs-3 in durum types were found to be best general combiners for number of effective tillers per plant. UP 2338 and DL-788-2 exhibiting positively significant g.c.a. effects were observed to be best combiners for spike length in **T aestivum** genotypes and MACS 2846, CPAN 6207, LOKOS-3 and P6 in **T durum** types.

The parents PBW 498, GW 322, VL 840, GW 190 and DL-788-2 recorded high g.c.a. effects for 1000 kernel weight in **T aestivum** and MACS 3125 and P_6 in **T durum** indication that the segregating populations of the crosses involving these as one of the parents would give rise to bold seeded types. The inconsistency in g.c.a. effects of some of the parents observed for certain characters may arise due to differential genotypic and environmental interactions. Galkin (1972) has also emphasized that combining ability greatly influenced by seasonal weather. Hayman (1958), therefore, suggested that the genetic variance that remains unchanged at least for two consecutive years of experimentation should be considered for identifying the reliable portions of the genetic variance.

(c) Specific combining ability effects

The estimates of s.c.a. effects summarized in **Tables 21, 22** and **23** for **T aestivum** and Tables **24** and **25** for **T durum** indicate that none of the crosses in both the experiments have shown highly significant s.c.a. effects for all the characters simultaneously except GW 173 X DL-1266-5 in first year F_1 and VL 840 X HD 2428 and HP 1731 X DL -1266-5 in second year F_1 of **T aestivum** experiment only.

For days to ear emergence 10 out of 32 crosses in **T aestivum** and almost all the 12 crosses in **T durum** have shown negative and highly significant s.c.a. effects in both the generations. The crosses GW 322 X HD 2428, HP 1731 X DL-1266-5 and UP DL-788-2 which shoed high negative s.c.a. effects have good X poor general combiners. The other cross GW 173 X DL-788-2 involved high X high combiners indicting that these parents would have less genetic diversity among them and also some internal cancellation of favourable gene effects as suggested by Jenks and Jones (1958). The crosses MACS 3125 X LOKOS-3, HD X CPAN 6214 and HD 4645 X P_6 of **T durum** with consistently negative and high s.c.a. effects may also be considered to breed earliness.

For days to maturity 11 out of 32 crosses showed highly significant negative s.c.a. effects in both the years of T aestivum and 5 out of 12 crosses in **T durum** were found to have desirable s.c.a. effects. It is evident from the observations that a poor general combiner DL-1266-5 when combined with other poor and/or good general combiners gave crosses with desirable high s.c.a. effects for this trait. This may be due to high heterotic effects produced in such combinations.

In **T durum**, the crosses MAACS 3125 X LOKOS-3, MACS 2846 X CPAN 6214, CPAN 6207 X P_6 and HD 4645 X P_6 showing highly desirable s.c.a. effects at least have one parent as a poor general combiner. The only cross MACS 2846 X CPAN 6214 consisted both the best general combining parents.

The best crosses PBW 498 X DL-788-2 and HI 977 X HD 2428 in **T aestivum** and MACS 2846 X LOKOS-3, MACS 2846 X P_6, CPAN X CPAN 6214 and HD 4645 X CPAN 6214 involving poor X good combination exhibited high s.c.a. effects for dwarf plant height which may be due to complementary epistasis.

For number of effective tillers per plant, the best 5 crosses with consistently high positive s.c.a. effects were found to have poor X poor combinations which suggest sufficient availability of heterotic effects. The segregating populations of these crosses of the parent LOKOS-3 with MACS 3125 and MACS 2846 and the crosses of a good general combiner HD 46 with desirable s.c.a. effects for this trait in **T durum**.

For the improvement of spike length the crosses VL 840 X DL-788-2, GW 173 X NIAW-34 and UP 2338 X HD 2428 involving poor X good and X poor combinations and consistently high s.c.a. effects would be desirable for further exploration. Almost all the crosses showed significantly desirable s.c.a. effects for this trait in **T durum**.

The crosses of NIAW-34, a poor general combiner with PBW 498, VL 840 and GW 190 parents were found to have high desirable s.c.a. effects in T aestivum and CPAN 6207 X CPAN 6214, HD 4645 X P_6 and MACS 2846 X LOKOS-3 in **T durum**.

For number of kernels per spike, s.c.a. effects of 14 crosses out of 32 revealed significant and useful values in the desirable direction in **T aestivum**. The cross of a poor general combiner NIAW-34 with PBW 498, VL 840 and GW 190 showing high positive s.c.a. effects are suggested for use to increase number of kernels per spike.

The crosses CPAN 6207 X CPAN 6214, HD 4645 X P_6 and MACS 2846 X LOKOS-3 of **T durum** with high desirable s.c.a. effects can be used to improve this trait through intervarietal hybridization.

Significant and positive s.c.a. effects were recorded for 1000 kernel weight and kernel yield per plant for 8 crosses in T aestivum and two crosses in **T durum**. Few promising crosses with high *per se* performance, high heterotic effects coupled with high s.c.a. effects identified for improvement of these characters are GW 322 X DL 788-2,

GW 322 X DL-1266-5, HI 977 X DL-1266-5, GW 190 X DL-788-2, GW 190 X NIAW-34, HP 1731 X HD 2428, HP 1731 X DL-1266-5 and UP 2338 X UP 2338 X HD 24228 in **T aestivum** and MACS 2846 X LOKOS-3, MACS 2846 X P_6 and CPAN 6207 X CPAN 6214 in **T durum**. It is evident that the above mentioned outstanding crosses have poor X good combination of general combiners. Since the hybrid breeding has not been effectively and practically feasible in the self pollinated crop like wheat, it was felt essentially desirable to utilize above mentioned crosses to derive pure lines by conventional breeding procedures. Arunachalam (1980) also emphasized that such crosses provide the breeder with a safe starting point for producing purelines, as the initial choice of non-epistatic gene effects help in sustenance of more additive gene combinations in subsequent generations.

3. Analysis of heterosis in percentage

The commercial exploitation of heterosis in crop plants is regarded as a major breakthrough in the realm of plant breeding. Economic significance of heterosis in crop breeding was appreciated after the success of hybrid maize. The work of Shull (1914) provided the essential framework for commercial exploitation of this biological phenomenon. Hays et al., (1955) suggested that the increased performance of F_1 hybrids over the mean performance of their itwo parents may be taken as indication of hybrid vigour. Heterosis breeding has led to considerable yield improvement of several cereals and other crops (Rai, 1979). A substantial degree of heterosis for yield and related traits has also been reported in single crosses of wheat (Saakyan, 19775; Bhadouria et al., 1976; Norik and Knysh, 1981; Zhuang, 1982; Shen et al., 1989; Atale and Virtane, 1991; Sadeque et al., 1991; Krishna and Ahmad, 1992; Borghi and Parenzin, 1994; Amawate and Behl, 1995; Larik et al., 1995; Ronga et al., 1995; Singh et al., 1997; Prasad et al., 1998; Mishra et al., 1999; Sharma and Sain, 2002; Singh 2003 and Sharma et al., 2004).

The aim of heterosis analysis in the present investigation was to identify the best combinations of parents giving high degree of useful heterosis. The results of analysis of variance and heterotic effects for parents, hybrids and parents vs hybrids have revealed significant variations, thereby indicating that some amount of heterosis has been displayed by hybrids. Many of the crosses have shown significant and negative heterosis for days to flower and days to maturity such as HP 173 X DL-1266-5 and GW 322 X HD 2428 in **T aestivum** and CPAN 6207 X CPAN 6214 and CPAN 6207 X P_6 in **T durum**. The extent of desirable heterosis for days to maturity was recorded to the tune of -10.24% for UP 2328 X DL-1266-5 and upto -5.48% for MACS 2846 X CPAN 6214. The results for these two characters and plant height showed fluctuating values indicating that these traits are highly influenced by environmental conditions. Budak (2001) and Singh (2003) had also reported heterotic effects for these characters. Galkin (1973) has also reported that the extent of heterosis is greatly affected by the conditions of cultivation and choice of parents. He also suggested that geographically distant parents show better heterosis amongst their hybrids. Fabrizius et al., (1998) while studying F_1 and F_2 generation of genetically unrelated line also reported that high heterosis in F_2 bulk was related with genetic diversity of their parents. Sicne most of the characters are controlled by dominance and epistatic gene action and therefore amount of heterosis shown is not evidently fixable and hence a proposal for hybrid seed production is not feasible. The increase in the mean performance of hybrids over mid parent is considered beneficial for kernel yield and its many of the contributing characters.

In **T aestivum**, the manifestation of heterosis in F_1 hybrids over mid parent is to the extent of 67.41% for number of effective tillers per plant, 37.14% for spike length, 29.08% for number of kernels per spike, 15.18% for 1000 kernel weight and 131.05% for kernel yield per plant. However, in T durum this value reached upto 52.94% for number of effective tillers per plant, 12.20% for spike length, 4.75% for number of kernels per spike, 12.60% for kernel weight and 56.31% for kernel per spike, 12.60% for 1000 kernel weight and 56.31% for kernel yield per plant.

The expression of heterosis over mid parent was most evident for kernel yield per plant followed by number of effective tillers per plant, spike length, number of kernels per spike and 1000 kernel weight in order of merit in T aestivum. However, in T durum the heterotic effects were noted for number of kernels per spike. Many workers have also reported the presence of considerable degree of heterosis for kernel yield in wheat such as Saakyan (1997), Shen (1982), Kim (1985), Borghi and Penenzin (1994), Singh et al., (1997), Prasad et al., (1998), Yadav (1998) reported best heterotic effects for grain yield per plant, number of grains per ear and 1000 grain weight. The findings of the workers like Singh (2003). Mohammad and Khaliq (2004) substantiate the findings of the present worker as they also reported high heterotic effecter over mid parent for grain yield per plant, grains per spike, spike length, number of spikelets per spike and 1000 grain weight. The heterosis for kernel yield per plant was comparatively higher than other agronomic traits in the present investigation similar to the findings of Maeing (1984), Kim (1985) and Haranadh (1996). The high expression of heterosis among the hybrids for kernel yield per plant was perhaps due to simultaneous manifestation of heterosis for 1000 kernel weight, number of effective tillers per plant. Zhuang (1982), Sehrawat and Rana (1993) and Haranadh (1996) reported similar associations among these characters.

Thus, it can be inferred that kernel yield is a complex character and not unitary. Hence, any design for kernel yield improvement will be futile if the selection is made directly for kernel yield. It seems to be imperative that to get higher yielding varieties, a scheme for improvement considering most of the yield contributing characters together will be useful.

It has also been inferred from the present investigation that most of the productive hybrids with high kernel yield and heterosis involved atlest one parent with high g.c.a. as also reported by Gupta (1989).

Hybrid breeding programmers involve the identification of most heterotic and useful combinations. For this purpose some promising hybrids expected to give more desirable segregants were identified for ivividual yield contributing characters and/or kernel yield per plant as final target.

The best combinations in **T aestivum**, s howing desirable heterotic effects in F_1 and F_2 both for many of the characters in the present investigation are GW 322 X DL-788-2, GW 322 X DL-1266-5, VL 840 X HD 2428, VL 840 X DL-788-2, GW 190 XDL-788-2, GW 190 X NIAW-34 and the crosses of HP 1731 with HD 2428, DL-788-2 and DL-1266-5, GW 173 X DL-788-2, GW 173 X DH 2428 and UP 2338 X DL-788-2. These potential crosses may be used to isolate transgressive segregants in F_2 populations for specific traits.

4. **Variability studies**

Range, mean, phenotypic and genotypic variances, heritability in broad sense, genetic gain and coefficient of variability in **T aestivum** and **T durum** presented in **Tables 31** to **34** for two consecutive years in the present investigation reveal that parents selected for crossing and their hybrids has sufficient range of variation for each character and their hybrids have sufficient range of variation for each character therby increasing the chances of achieving transgressive segregants in the succeeding generations. The results of the *durum* investigation may be used to find out the effectiveness of these donors in generation usable usable variability for bringing desired improvement in its own types as well as their use in interspecific hybridization for the transfer of alien chromosomes and genes for specific characters.

The maximum range was recorded for kernel yield per plant and number of effective tillers per plant while the least range was recorded for days to maturity.

The phenotypic coefficient of variation was generally high and the genotypic coefficient of variation was relatively smaller in magnitude for all the characters. Present findings are substantiated by the similar results of Ghimiray and Sarker (2002) and Kumar et al., (2003) indication greater influence of environment on these characters. The PCV values were high for kernel yield per plant, number of effective tillers per plant, 1000 kernel weight, spike length and number of kernels per spike whereas the lowest values were observed for days to ear emergence and days to maturity in both the experiments. Similar results were observed by Pawar et al., (1988), Mandal et al., (1991), Mishra (1992), Thkur et al., (1999) and Dwivedi (2002).

However, for days to ear emergence and number of effective tillers and plant height, the magnitude of PCVs and GCVs were very close and the estimates of heritability in broad sense were also sufficiently high indication that selection is likely to be effective for further improvement. Gill and Brar (1977) in **T durum** also reported high heritability for plant heritability for plant height. Bhatia et al., (1978), Sharma et al., (1978), Khan et al., (1985), Mahmood and Shahidi (1991) Subhani and Khaliq (1994), Khan et al., (2003), Kumar and Dwivedi (2003), Sachan and Singh (2003), Sahu et al., (2005) also substantiated the findings of the present worker reporting high heritability in broad sense for most of the characters. Moreover, Gupta and Verma (2002) contradicted the present findings medium to low heritability estimates for days to earing, plant height, tillers per plant, 1000 grain weight and harvest index under different environments. They emphasized that selection based on number of grins per ear and biological yield per plant may be effective for improvement in *durum* grain yield under normal and rainfed conditions. However, Sing at al., (1999) like the present author also reported high magnitude of heritability coupled high genetic advance for grain yield per plant, number of grains per spike in **T aestivum**. In the present investigation lower genetic gain was noted for 1000 kernel weight in **T durum**.

High values of genetic gain was noted for plant height, number of kernels per spike, 1000 kernel weight and kernel yield per plant in T aestivum. Nevetheless, it is not always necessary that high estimates of heritability are always associated with high genetic gain (Swaroop and Chaugale, 1962). Similar situation was observed for days to ear emergence, number of effective tillers per platn and spike length in **T aestivum**. However, in **T durum**, the character days to ear emergence showed maximum genetic gain associated with high heritability. The studies of Maloo (1994), Singh et al., (1999), Thakur et al., (1999), Surya et al., (2000) and Ali et al., (2003) have reported substantial genetic gain for the main yield contributing characters. Sidwell et al., (1976), Pathak and Nema (1985) and Ehdaie and Waines (1989) also reported moderate to low values of heritability and expected genetic gain for kernel yield per plant in wheat. Therefore, selection of superior genotypes on the basis of yield *per se* would not be as effective as selection for its components, namely, spike length, number of kernels per spike and 1000 kernel weight. Thus, the association of these yield contributing characters with yield and the interrelationship among these characters assume importance as the basis for selecting high yielding genotypes.

For the improvement of genotypes for earliness in flowering and maturity and dwarf plant types, the existing material has shown little scope for direct selection because of least coefficient of viability.

5. Correlation studies

The principal aim of a plant breeder is always to improve the yielding ability of the existing varieties of a crop by manipulating the genetic architecture of its quantitative traits. The final expression of a quantitative trait is complex in nature and is always an outcome of interactions of many component in nature and is always an outcome of interactions of many component characters. Since seed yield is aa polygenically controlled character and hence improvement in its is ot feasible through direct selection. The nature of association between yield and its contributing components provides more efficient selection tools for the plant breeder because the complexity and preponderance effects of environment of yield, further restrict direct selection for yield. To overcome this problem, earlier plant breeders have suggested the indirect method by manipulating the yield contributing characters.

The correlation studies supply most reliable information about the nature, extent and direction of selection. The knowledge of genetic correlations between yield and its contributing characters become of paramount importance when a breeder takes the target of introducing a quantitative character into some otherwise agronomically accepted superior cultivar from an uneconomic genotype. The knowledge of interrelationship between a desirable and undesirable gene and/or genes restrains the breeder from operating exhaustive unidirectional selection as it all lead to drastic and disastrous consequences.

The correlation studies at phenotypic and genotypic levels both in the present investigation in T aestivum indicated that kernel yield per plant was emergence. Similar positive association with yield component traits was also reported by earlier workers. Yield was reported to be positively associated with days to maturity (Nirala and Jha, 1996; Kumar et al., 2004), plant height (Sinha and Sharma, 1980; Tavella et al., 1987; Gee and Zhang, 1990; Kumar et al., 2002; Asif et al., 2004; Kasif and Khaliq, 2004), number of effective tillers per plant (Kumar and Choudhary, 1986; Raut and Khorgade, 1989; Baishakh and Nayak, 1991; Pali et al., 1993; Nirala and Jha , 1996; Kumar et al., 2002; Kasif and Khaliq . 2004), number of kernels per spioke (Larik, 1979; Shek, 1979; Srivastava, 1980; Singh, 1982; Kolomiets, 1985; Samsuddin, 1987; Raut and Khorgade, 1989; Yadav and Mishra, 1992; Pali et al., 1993; wei, 1993; Sanjari, 1994; Kumar et al., 2004), 1000 kernel weight (Jaimini et al., 1974; Talwar, 1978; Sinha and Sharma, 1980; Burcha, 1983; Bhullar and Nijjar, 1984; Lisnichuk, 1985; Tavella et al., 1987; Yadav and Mishra, 1992, Belay et al., 1993; Getchow et al., 1993; Dhaliwal and Sukhchain, 2003).

The study of character association among yield contributing traits revealed nonsignificant but negative association of days to maturity with plant height and 1000 kernel weight at phenotypic and genotypic levels both. Similar results of significant negative correlation of days to maturity with 1000 kernel weight were reported by Yunus and Paroda

(1982), Belay et a., (1993) and Palve (1998). Plant height with spike length had significant and negative association. Similar magnitude nature of association of number of effective tillers per plant with spike length and 1000 grain weight was also reported by Walton (1971). Spike length showed significant and positive correlation at phenotypic level with number of kernels per spike and 1000 grain weight. Similar nature of association has been reported by Larik (1979), Li and Yang (1985). The character, number of kernels per spike has shown highly significant and positive association with 1000 kernel weight as also reported by Talwar et al., (1979), Srivastava et al., (1980), Dhaliwal and Sukhchain (2003).

However, in **T durum** kernel yield per plant had shown significantly positive association with days to ear emergence (Srivastava et al., 1988; Deshmukh et al., 1990; Naim and Baig, 2005), days to maturity and number of effective tillers per plant (Lebsock and Amaya, 1969; Dunder, 1974; Gill and Brar, 1977; Sharma and Gandhi, 1977; Staena and Stoeba, 1981; Srivastava et al., 1988; Deshmukh et al., 1990; Moghaddam and Wains, 1997; Palve, 1981) and 1000 kernel weight (Dunder, 1974; Belay et al., 1993; Villreal et al., 1997; Pavle, 1998; Nayeem and Brar, 2003).

Kaltsicckes aand Lee (1971, 1973) also reported that most of the agronomic traits were positively aassociated with grain yield as also observed in the present investigation except for plant height. However, kernel yield has shown weak but negative association with plant height indication that increase in height will decrease the yield potential and hence dwarf *durum* types will be more advantageous. It has also shown significantly negative association with number of kernels per spike. The highly significant and positive association among the main yield contributing characters i.e., between number of effective tillers and 1000 grain weight and between spike length and 1000 grain weight has also been found.

In the present investigation in **T aestivum**, the study of character association revealed higher values for genotypic correlations in comparison to phenotypic correlations. This is in agreement with the earlier reports by Aruna (1994) anad Sahu et al., (2005). The nature and magnitude of phenotypic and genotypic correlations was further observed to be almost similar for all the characters under study (Harangnadh, 1996) except days to ear emergence and days to maturity, indicating considerable role of environment in modifying the total expression of the genotypes (Nandpuri et al., 1973).

In T durum d erivatives also, the genotypic correlations were higher in magnitude in comparison to phenotypic correlations for alal the characters studied. This suggested that association between these characters, in general, was genetically controlled. This is in confirmation with the results of Yunus and Paroda (1982) and Palve (1998). All the reported cited above indicating an association among yield and its contributing characters reveals that variability generated through inter- and/or intraspecific hybridization in *durums* can help in ameliorating individual yield components as well as total yielding ability of a genotype.

6. **Path coefficeint analysis**

It is well established on the basis of finfings of several earlier workers that grain yield is a polygenically controlled complex and ultimate product of interactions mean indirect effects of these attributes apart from their direct contribution towards yield. Since correlation coefficients speak only about the association between any two characters which do not give complete picture of a complex character like grain yield. It is because of this selection based merely on such simple correlations only will not give the desired improvement. Therefore, in addition to determining the interrelationships among the grain yield components on one hand and between grain yield and its contributing characters on the other hand, it is necessary to understand their direct and indirect effects on the grain yield. It is very likey thata yield may get diluted though other characters. Further, the information oon relative contribution (direct and indirect) of components to yield helps in giving appropriate weightage for the purpose of selection.

Path coefficient analysis which provides nature anad magnitude of direct and indirect effects of one variable on the other, has been used in the present investigation, the results of which (**Tables 39, 40, 41** and **42**) crearly reveal a considerable disparity in estimates of simple correlations and direct as well as indirect contributions.

(a) Phenotypic Path

The **Table 39** and **40** provide much explanatory picture about the validity of correlation coefficients and their direct and indirect effects for considering them in the improvement of this cereal crop. It is evident from the perusal of these tables that kernel yield per plant is an outcome of the contributions of number of effective tillers per plant, spike length, number of kernels per spike and 1000 kernel weight because of their high positive direct effects. These results are substantiated by the studies of Paroda and Joshi (1970), Fatin (1986), Atal and Zope (1988). Shelembi and Wright (1992), Agrawaa; and Mishra (1996), Kumar and Hunshan (1998), Kumar et al., (2002), Dhaliwal and Sukhchain (2003) and Kumar et al., Kumar et al., (2004) also suggested the effectiveness of number of effectiveness of number of effective tillers per plant, number of kernels per spike and 1000 kernel weight to select and identify desirable genotypes of wheat for a targeted improvement. The character days to ear emergence had negative direct effects on kernel yield mainly due to negative indirect effects through plant height and 1000 kernel weight ultimately resulting into negative correlation coefficient.

Path analysis in *durums* revealed that days to maturity, number of effective tillers an 1000 grain weight having high direct positive effects are the main contributors to kernel yield. These indirect effects are also of similar nature and magnitude.

The character showing highly significant and psotiove correlation with kernel yield has mainly contributed indirectly through days to maturity, number of effective tillers per plant and 1000 kernel weight. These present findings lend support from the studies of Sharma anad Singh (1983, 1991), Kumar and Choudhary (1986), Atale and Zope (1988), Deshmukh et al., (1990). The characters plant height and number of kernels per spike have negative direct effects but the latter has influenced the kernel yield indirectly though days to maturity, plant height and number of effective tillers per plant. The negative direct effect of plant of plant height has also been reported by Singh (1982). Deckand et al., (19970 and Pavle (1998). Spike length had made negative direct effect to kernel yield.

Based on correlation and path analysis studies, it was observed that in addition to 1000 kernels per spike in T aestivum and days to flowering, days to maturity and number of effective tillers in T durum were important attributes to improve kernel yield, which was in accordance with the findings reported by Das (1976), Sip and Skorpik (1979), Singh Singh (1982), Srivastava et al., (1985), Pandey et al., (1992), Kumar et al., (2002, 2004).

(b) Genotypic path

A perusal of the Table 41 indicates that most of the yield contributing characters except days to maturity has been noticed to have positive direct effects to grain yield at genotypic level. The positive direct effects of days to ear emergence has been diluted through high negative indirect effects via days to maturity, plant height and 1000 kernel weight as is confirmed by its negative correlation with kernel yield. Plant height has shown negative indirect effects through almost all the characters except 1000 kernel weight. The characters, number of effective tillers per platn and spike length, have positive indirect contribution via number of kernels per spike and 1000 kernel weight. Fatin (1986) also suggested the possibility of selecting trangressive segregants with high yield if these two characters are considered simultaneously. Similar results have also been reported by Agrawal and Mishra (1996), Kumar and Hundhan (1998). The genotypic correlation of these characters with kernel yield have been observed to be significantly positive which are perhaps due to high direct and indirect effects of main yield components on each other.