CHARACTER ASSOCIATION AND GENETIC DIVERGENCE IN SPRING WHEAT (*Triticum aestivum* L.)

By

SYED GULAM MASTAFA

REGISTRATION NO. 07-02504

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

GENETICS AND PLANT BREEDING

SEMESTER: JANUARY-JUNE, 2014

Approved by:

(Dr. Md. Sarowar Hossain)
Professor
Supervisor

(Dr. Md. Shahidur Rashid Bhuiyan)
Professor
Co-supervisor

(Prof. Dr. Md. Sarowar Hossain)
Chairman
Examination Committee

Dr. Md. Sarowar Hossain
Professor
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka.
E-mail: saraowar2001@rediffmail.com
Mob: 01552499169

CERTIFICATE

This is to certify that thesis entitled, **"CHARACTER ASSOCIATION AND GENETIC DIVERGENCE IN SPRING WHEAT (*Triticum aestivum* L.)"** submitted to the Faculty of **Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona field research work carried out by **SYED GULAM MASTAFA , Registration no. 07-02504** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date: June, 2014
Place: Dhaka, Bangladesh

Prof. Dr. Md. Sarowar Hossain
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENT

First of all, the author is indebted to "Almighty Allah" to complete the research work.

The author would like to express his heartfelt gratitude and thanks to his research supervisor and chairman, Dr. Md. Sarowar Hossain, Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant supervision, valuable suggestions, scholastic guidance, continuous inspiration, constructive comments, extending generous help and encouragement during his research work and guidance in preparation of manuscript of the thesis.

The author sincerely expresses his heartiest respect, deepest sense of gratitude and profound appreciation to his Co-supervisor, Dr. Md. Shahidur Rashid Bhuiyan, Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice during the research period and preparing the thesis.

The author would sincerely expresses his deepest respect and boundless gratitude to all the respected teachers of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and suggestions and encouragement to research work. The author would like to express his cordial thanks to the departmental and field staffs for their active help during the experimental period.

The author is grateful to his parents for giving birth to him at the first place. Thank you for your love, unwavering belief and supporting spiritually throughout the life.

The Author

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ABSTRACT

The present research work was aimed at to study the genetic divergence and relationship between yield and yield contributing characters in 40 genotypes of spring wheat. The characters viz. plant height, spikes/plant, spike length, grains/spike, 1000 grain weight, harvest index, vegetative period, grain filling period, days to maturity, and grain yield/ plant were investigated and significant variations were observed among the genotypes. Divergence analysis clustered the studied genotypes into 7 diverse groups. The maximum number of genotypes were clubbed in cluster I followed by Cluster II, IV, V and VI. The cluster III and VII contained minimum numbers of genotypes. Comparison of cluster means for all the characters indicated considerable genetic divergence between the groups. The highest intra-cluster distance was obtained for cluster VII followed by Cluster VI and cluster III. The maximum inter-cluster distance was observed between genotypes of cluster V and VI followed by cluster VI and VII, and cluster II and V. The scattered diagram revealed that the genotypes G2, G16, G19, G22, G28, G36 and G37 took positions at the periphery of the diagram suggesting that these varieties/lines were more diverged from rest of the genotypes. Considering yield and contributing characters it appears that the genotypes G19 (6.54) and G37 (6.65) were promising for high yield potentiality. Therefore, these two genotypes could be selected for yield improvement program in spring wheat. Study of correlations showed that grain yield/plant was significantly and positively correlated with grains per spike at both phenotypic and genotypic levels and with spikes/plant at phenotypic level. Among the studied characters, spikes/plant showed the highest phenotypic coefficient of variation followed by grain yield per plant, harvest index and 1000-grain weight. Study of heritability indicated that the characters spikes/plant, 1000-grain weight, harvest index and grain yield/plant were highly heritable. Path coefficient analysis also confirmed that spikes/plant, grains/spike, spike length, 1000-grain weight, and harvest index influenced grain yield directly in positive direction. So, these characters should be taken into consideration in selection for yield improvement

CONTENTS

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Wheat, a cereal grass of the *Graminae* (*Poaceae*) family and of the genus *Triticum*, is the world's largest cereal crop. It has been described as the 'King of cereals' because of the acreage it occupies, high productivity and the prominent position it holds in the international food grain trade. According to the earliest historic records, wheat was an important cultivated cereal in South-western Asia, its geographical centre of origin. Many wild species of *Triticum* are found in Lebanon, Syria, Northern Israel, Iraq and Eastern Turkey. Wheat was cultivated in ancient Greece and Egypt in pre-historic times. The central Asia, Near East, Mediterranean and Ethiopian regions are the world's most important centers of diversity of wheat and its related species (Perrino and Porcedu, 1990; Kundu and Nagarajan, 1996). Hindukush area is the centre of diversity of hexaploid wheat (Kundu and Nagarajan, 1996). The majority of the cultivated wheat varieties belongs to three main species of the genus *Triticum*. These are the hexaploid, *T. aestivum* L. (bread wheat), the tetraploid, *T. durum* and *T. dicoccum*. Schrank and the diploid *T. monococcum.* Globally, *aestivum* wheat is most important species which covers 90 percent of the area. Second popular wheat being durum wheat which covers about 9 percent of the total area while *T. diccoum* wheat and *T. monococcum* wheat cover less than the one percent of the total area. Wheat has now become the second staple food crop in Bangladesh. Bangladesh, although still a small producer of wheat has made substantial progress in the increasing production of wheat indicating that the climatic and soil condition of Bangladesh is suitable for wheat cultivation (Swaminathan, 1986). The yield potentiality of the varieties cultivated in Bangladesh is much less than cultivars of other developed countries.

Yield in wheat is a complex character and various morphological and physiological characters contribute to grain yield. These yield contributing characters are related between themselves showing a complex chain of relationship of them on yield.

The effectiveness of increasing yield depends on the extent to which the variability of yield is dependent on genetic factors (Julfiquar, 1977). Since, many of the quantitative plant characters which are of economic value are highly influenced by environmental condition; the progress of breeding in such a population is primarily conditioned by the magnitude and nature of variation and interrelationship of plant characters (Gandhi *et al.,* 1964). The magnitude of heritable variability for crop improvement is clearly the most important aspect.

The importance of genetic diversity in the improvement of crop has been stressed in both self and cross pollinated crop (Griffing and Lindstrom, 1954; Murty and Anand, 1966; Gaur *et al.,* 1978). The quantification of genetic diversity through biometrical procedures (Rao, 1952; Anderson, 1957) has made it possible to choose genetically diverse parents for successful hybridization programme. Moreover, evaluation of genetic diversity is important to know the source of genes for particular trait within the available germplasm (Tomooka, 1991). The Utility of multivariate analysis for measuring the degree of divergence and for assessing the relative contribution of different characters to the total divergence in self-pollinated crops has been established by several workers (Golakia and Makne, 1992, Natrarajan *et al.* 1988; Das and Gupta, 1984 and Sindhu *et al.,* 1989).

Practices of unilateral selection for them frequently end up in retrograde or less than optimum results in plants breeding (Bhatt, 1973). Information on correlation coefficient between yield and its contributing characters has always been helpful as a basis for selection for yield in a breeding programme. Therefore, correlation between different characters is an important aspect which should be kept in mind for better planning of selection programmes. Thus, the study of correlation coefficient and also path coefficient between the characters is important in fact for selection practice, since it permits the prediction of correlation response.

Therefore, the present investigation was carried out in wheat to determine the following objectives:

1. To evaluate the performance of some wheat genotypes for yield and yield contributing characters.
2. To study the variability for yield and yield contributing characters.
3. To study the heritability and genetic advance for different characters.
4. To study the genetic divergence among the genotypes.
5. To study the interrelationship between yield and yield contributing characters.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Planning a successful breeding programme for yield improvement in wheat requires information on parental materials for variation of yield contributing characters and relationship between them. The present research programme was aimed to study the performance, genetic divergence of bread wheat genotypes, the relationship between yield and yield contributing characters. The relevant information in this respect has been reviewed in this chapter.

2.1. Performance of wheat varieties in Bangladesh

Sharma *et al.* (2007) conducted an experiment with 21 wheat genotypes selected from a regional wheat screening nursery in South Asia in six wheat growing seasons (2000-2005). There were four check cultivars (Kanchan. Sonalika, Bhrikuti and PBW 343). In each year, one or more of the experimental genotypes showed high and stable grain yield and acceptable maturity, plant height, and disease resistance compared to the check cultivars. Identification of wheat genotypes with high-grain yield in individual sites and high and stable yield underlined their value for regional wheat breeding programs attempting to improve grain yield and agronomic performance.

Joshi *et al.* (2007) studied seven hundred twenty-nine lines of diverse wheat germplasm collections in eight locations of three countries (India, Nepal and Bangladesh) for 5 years (1999-2000 to 2003-2004) for agronomic performance and tolerance to spot blotch of wheat. Many lines yielded significantly more than the best check and possessed high levels of spot blotch resistance under warm humid environments of South Asia. The most promising 25 lines have been identified as source of strong resistance with 9 lines better yielding than the best resistant check PBW 343. The line EGPYT 67 and Kauz were the best for spot blotch resistance, yield, days to maturity, and 1000 grain weight. The next two lines in the order of merit were EGPYT 84 and EGPYT 69.

Rashid *et al.* (2004) evaluated the performance of 30 wheat genotypes under late sowing conditions (sowing date: 15 and 30 December) in Bangladesh during 1999-2000. The grain yield 1.62 t/ha was obtained from sowing on 15th December which was significantly higher than that obtained from sowing on 30 December (0.98 t/ha). The genotypes did not significantly vary with respect to grain yield. The interaction effect showed that plant height, ear length, number of grains/ear and straw yield were greater with sowing on 15 December than sowing on 30 December. The number of effective tillers/plant and grain yield were not significantly affected by the date of sowing.

Miah and Shamsuddin (2002) in their study evaluated source-sink and grain yield traits (dry weight of green leaf at 50% booting stage, dry weight of stem and leaf sheath at 50% booting stage, number of tillers at 50% booting stage, spike weight at final harvest, number of grains/spike at final harvest, 1000-grain weight, vegetative period and grain-filling period) in 16 bread wheat cultivars grown in Mymensingh. Bangladesh during winter of 1992-93. Significant variation was observed among the cultivars for all traits except dry weight of green leaf at 50% booting stage. Akbar, D-150 and Kanchan recorded the highest yield, spike weight, 1000-seed weight and number of grains/spike, and longest grain-filling period.

Sikder *et al.* (2001) conducted a field experiment with 10 wheat cultivars to evaluate the performance of heat tolerant and heat sensitive cultivars under late sowing conditions in Bangladesh from November 1997 to April 1998. The 10 cultivars were sown on 30 November (optimum sowing) and 30 December (late sowing). The cultivars Ananda, Pavon, Aghrani and Barkat were classified as heat tolerant; cultivars Akbar, Kanchan and Provita were moderately tolerant; and cultivars Balaka. Sagwat and Sonora were sensitive to heat stress. The grain number/spike, 1000-grain weight and main shoot weight of tolerant and moderately tolerant cultivars were higher compared to sensitive cultivars but the relative ear number /plant and relative grain yield of these moderately tolerant and tolerant cultivars ranged from low to high. Tolerant and sensitive cultivars sown late had lower grain yield than those sown during the optimum sowing date.

2.2. Variability, Heritability and Genetic Advance

2.2.1. Plant height

Plant height is considered an important plant character related to grain yield in wheat. Plant height has been found to vary from variety to variety in wheat. In a study of genetic variability and correlation, Randhawa *et al.* (1975) observed wide range of variation for plant height in bread wheat. They reported high heritability with high genetic advance which indicated that high genetic advance for the character was achieved by both wide variation and high heritability. Johnson *et. al* (1995) also suggested that heritability estimates along with genetic advance was more useful for effective improvement. Saha and Foridi (1987) observed little environmental effect on plant height in bread wheat. Pathak and Nema (1985) reported medium genotypic and phenotypic coefficient of variation with high estimates of heritability.

Maloo (1984) reported moderate genotypic coefficient of variation with high heritability value indicating high transmission index for plant height in bread wheat. Singh *et al.* (1978) observed that plant height had the lowest coefficient of variation at both genotypic and phenotypic level. They discussed their results and suggested that might be due to inter selection pressure towards the selection of dwarf plant types.

2.2.2. Spikes/plant

Spikes plant is one of the three primary yield components of wheat. Variations of this character were invariably studied in connection with yield. Maloo (1984) observed high genotypic coefficient of variation for spikes/plant in wheat. He reported high heritability accompanied by high genetic advance. Pawar *et al.* (1988) observed high genotypic and phenotypic coefficients of variation for this character. They also reported high heritability coupled with high genetic advance. High value of both heritability and genetic advance for spikes/plant indicated that the character was mostly controlled by additive gene effects and could be improved upon by simple selection. Mahmood and Shahid (1993) reported high heritability with high genetic advance for number of spikes/plant. High heritability estimates with high genetic advance for number of spikes/plant indicated that genetic effect was more pronounced for this character. This character could be fixed by resorting to simple selection. Tripathi *et al.* (1973) reported moderate genotypic coefficient of variation, low heritability and low genetic advance for spikes/plant. The low genetic advance in this case could be explained as the results of low heritability and moderate genotypic coefficient of variation. (Singh *et al.*, 1990) observed low genotypic coefficient of variation and high phenotypic coefficient of variation. They also reported low heritability and low genetic advance for spikes/plant. They opined that poor estimates of heritability and genetic advance were due to influence of environment on the trait.

2.2.3. Spike length

Biju and Malik (2007) and Bhutta *et al.*, (2005) observed significant variation for spike length and grains/spike.

2.2.4. Grains/spike

Grain/spike is an important primary yield component. Joshi *et al.* (1982) conducted an experiment with thirty elite and diverse varieties of common wheat and noticed a wide range of variation for grains/spike. They also reported high phenotypic and genotypic coefficients of variation. In a study with land races of bread wheat from south western Iran, Ehdaie and Waines (1989) reported high phenotypic and genotypic coefficients of variation. They also observed high heritability with moderate genetic advance.

Maloo (1984) observed high genetic coefficient of variation with high heritability accompanied with high genetic advance. On the contrary, Singh *et al.* (1978) reported low genotypic and phenotypic coefficients of variation, along with low heritability and low genetic advance. They opined that the character was influenced by environment under which the genotypes were grown.

2.2.5. Thousand grain weight

It is an important grain character which is directly related to grain yield of bread wheat Nessa *et al.* (1994) reported high genotypic and phenotypic coefficients of variation for 1000-grain weight in bread wheat. They estimated high genetic advance accompanied by high heritability suggesting effects of additive gene for this character. Trehan *et al.* (1970) estimated high heritability value in broad sense and high value of genetic advance which indicate the scope for further improvement of this character by selection. Pawar *et al.* (1988) observed moderate genotypic and phenotypic coefficient of variation for 1000-grain weight. They also reported high heritability with high genetic advance.

Singh and Tewari (1990) observed low genotypic and phenotypic coefficients of variation. They also reported low heritability with low genetic advance. They suggested that the trait was influenced by environment under which the genotypes were grown. Amin *et al.* (1992) reported low genotypic and phenotypic coefficients of variation and high heritability with low genetic advance. It was interesting to observe that some of the characters inspite of having high heritability estimates did not reveal equally high genetic advance is chiefly due to the additive gene effect but if the heritability is mainly due to dominance and epitasis, the genetic advance would be low.

2.2.6. Harvest index

Harvest index is the ratio of grain yield to biomass (above ground biological yield). Progress in breeding higher yielding cultivars has been associated with an increase in harvest index (HI) in small grains such as wheat (Austin *et al.* 1980), oats (Wych and Stuthan, 1983) rice (Vengara and Visperas, 1977) and barley (Wych and Stuthan, 1983). Harvest index measures the partitioning of photosynthates to economic yield and is considered as one of the most important physiological yield component (Donald and Hamblin, 1976).

In most cases the increase in harvest index is considered to be an indirect result of breeding for higher grain yield, shorter straw and earliness. We are aware of very few small breeding programmes that have routinely selected for harvest index to improve grain yield (Tanka *et al.*, 1966, Vergara and Visperas, 1977).

To increase the probability of selecting genotypes with high grain yielding capacity, Donald and Hamblin (1976) suggested use of harvest index and biomass as early generation selection criteria in addition to grain yield. Several studies have indicated that harvest index could be an effective selection criteria for increasing grain yield in segregating generations of oats and spring wheat (Syme, 1972; Nass, 1973; Rosielle and Frey, 1975;. Fischer and Kertesz, 1976; Bhatt , 1977) reported that increasing rain yield via indirect selection for higher harvest index in F2 generation of spring wheat was better than direct selection for grain yield.

Amin *et al.* (1992) reported wide range of variation for harvest index. They observed high genotypic and phenotypic coefficients of variation with high heritability accompanied by high genetic advance. Ehdaie and Waires (1989) observed low genotypic and phenotypic coefficient of variation with high heritability associated with low genetic advance. The poor genetic advance as they observed was due to low coefficient of variation. Singh *et al.* (1980) observed moderately high genotypic and phenotypic coefficients of variation. They also reported low heritability with low genetic advance. It might be due to influenced by environment upon the expression of the character.

2.2.7. Vegetative period

Vegetative period is an important physiological character related to yield and duration of crop. Tripathi *et al.* (1973) reported wide range of variation and high genotypic coefficient of variation for vegetative period in wheat. They also observed high heritability with moderate genetic advance for this character. Nessa *et al.* (1994) observed moderate genotypic and phenotypic coefficients of variation for this character. There was very little difference between genotypic and phenotypic coefficients of variation which suggested that environment influenced on this trait was very small. They also reported high heritability with high genetic advance.

Sharma and Kaul (1986) reported low genotypic and phenotypic coefficients of variation accompanied by high heritability but low genetic advance. They explained such low genetic advance as they noticed as the cause of presence of dominace and epistasis in the population. Similar results were observed by Singh *et al.* (1978), Pawar *et al.* (1988), and Amin *et al.* (1992)

2.2.8. Grain filling period

Plant breeders and physiologist are interested in the possibility of identifying an optimum grain filling period for improving grain yield (Debra *et al.* 1984). Several studies have dealt with the relationship between grain filling duration and grain yield in various crop species. There is considerable evidence suggesting that grain filling period is important in determining yield in corn (*zea mays*). Yagbasanlar (1987) reported that the length of the grain filling period was one of the important factors to increase the yield in wheat and critical under Mediterranean climatic condition. But Nass and Resier (1975) and Metzger *et al.* (1984) reported that the length of grain filling period was not an important factor in determining yield in wheat and barley. Miah (1997) reported low genotypic and phenotypic coefficient of variation with high heritability but low genetic advance. Amin *et al.* (1992) observed low genotypic and phenotypic coefficients of variation for grain filling period in breads wheat. They also reported low heritability and low genetic advance.

Yagbasanlar *et al.* (1995) reported that coefficient of variation for grain filling period was lower than other traits. However, Samarria *et al.* (1987) suggested that grain filling period could be increased by selection.

2.2.9. Days to maturity

Variation, heritability and genetic advance for days to maturity are usually studied for developing early maturing varieties. Sharma and Kaul (1986) carried out an experiment with weat and ovserved high genotypic and phenotypic coefficients of variation with high heritability and moderate genetic advance for this character. Tripathy *et al.* (1973) conducted an experiment with sixteen varieties of wheat and repored moderate genotypic and phenotypic coefficients of variation. They also observed low genotypic and phenotypic coefficients of variation, but high heritability with moderate advance for this character. Nessa *et al.* (1994) reported low genotypic and phenotypic coefficients of variation for days to maturity in wheat. The difference between them was very small indicating less influence of environment on this trait. They observed high heritability with moderate genetic advance.

2.2.10. Grain yield/plant

Inheritance of grain yield in bread wheat is a complex one. Grain yield in cereals is determined by some yield components. Grafious (1964) suggested that these yield components express their genetic and environmental effects finally through grain yield. Nessa *et al.* (1994) reported high genotypic and phenotypic coefficients of variation and high heritability with high genetic advance for grain yield in bread wheat. Tripathi *et al.* (1973) observed high genotypic coefficients of variation and high heritability with moderate genetic advance. Sharma and Kaul (1986) reported high genotypic and phenotypic coefficients of variation and high heritability with high genetic advance. Pathak and Nema (1985) also observed high genotypic and phenotypic coefficient of variation and high heritability with high genetic advance for grain yield in bread wheat. Tripathi *et al.* (1973) observed high genotypic coefficients of variation and high heritability with moderate genetic advance. Sharma and Kaul (1986) reported high genotypic and phenotypic coefficients of variation and high heritability with high genetic advance. Pathak and Nema (1985) also observed high genotypic and phenotypic coefficient of variation with high heritability and genetic advance. Pawar *et al.* (1988) reported high genotypic and phenotypic coefficients of variation with high heritability and high genetic advance.

High genetic advance for grain yield as observed in these studies was probably the function of high coefficient of variation and high heritability for grain yield in wheat.

2.3 Genetic Divergence among Wheat Germplasms

Study of genetic divergence is essential to meet the diversified goals of plant breeding such as breeding cultivars for increasing yield, wider adaptation, desirable quality, pest and disease resistance etc. (Joshi and Dhawan, 1966). In addition genetic divergence is studied to identify specific parents for heterosis and recombination and breeding programmes (Aditya, 1995).

Several statistical methods are usually used for discriminating among the genotypes viz., Mahalanobis's generalized distance (Mahalanobis, 1936), the algorithm methods of Williams and Lambert (1960), Copper's statistical classification with quadratic forms (Cooper, 1963) and principal component analysis. Of them Mahalanobis' D^2-statistics and principal component analysis were extensively used by the researchers.

The Mahalanobis technique has been followed by several workers on wide range of crop species. The example are in wheat (Yadav and Murty, 1981; Dasgupta and Das, 1982; Jatasra and Paroda, 1983), Varma and gulati, 1982, in sorghum (Giriraj and Goud, 1981), in pear millet (Upadhyay and Murty, 1970). The principal component analysis was performed in Soybean, (chawdury, 1994) and in pea (Mian *et al.*,1991) in order to asses the genetic diversity among the germplasms of these crops.

2.4 Mahanobis' D^2-statistics analysis

Mahalanobis' D^2-statistics is a powerful tool for estimating genetic divergence between the genotypes. Chaturvedi and Gupta (1995) studied twelve yield components in 44 genotypes of wheat for genetic divergence using Mahalanobis' D^2-statistics and reported that genotypes were clustered in 13 diverse groups. Comparison of cluster means for all the characters indicated considerable genetic divergence between the groups. Yadav and Murty (1981) showed that the maximum range of cluster mean was for plant height and the most divergences at both intra and inter cluster levels were contributed by culm length and 100-grain weight in wheat. In a study of genetic divergence in wheat, Somayajulu *et al.* (1970) obtained 19, 15 and 2 clusters in three different environments for 67 genotypes. The numbers of clusters were the maximum in the first environment, intermediate in the second environment and the lowest in third environment. The cluster means showed wide difference in days to heading, plant height, grains/ear, 250-grain and ear length. At the intra-cluster level, there was similarity between the strains with in each cluster for flowering time and plant height, flowering time and plant height had a more profound effect on genetic divergence. In tetra-ploid triticum species, Joshi and Sing (1979) found four cluster from nine genotypes. In triticale, Ahmad *et al.* (1980) obtained nine clusters from 40 strains. In their study, test weight and spike length were found to be the potent variables which could be used as parameters in selecting genetically diverse parents for hybridization.

In durum wheat, Lee and Kaltsikes (1973) reported 5 clusters for ten genotypes. Multivariate analysis by means of Mahalanobis' D2-statistics was done by Sinhal and Upadhyay (1977) and they constructed five clusters 35 genetic stocks of common wheat. Plant height, grain number of the main shoot and growth habit were most potent factors for divergence in these crops. Dasgupta and Das (1982) conducted and experiment for study of divergence in bread wheat. They grouped the varieties into nine clusters. In their study 250-grain weight gave maximum contribution to the total genetic divergence.

Shamsuddin (1985) studied genetic diversity among the varieties of spring wheat used as parents in a diallel cross. He related genetic divergence between the parents with heterosis and SCA effects of the hybrids and found a positive relationship between them. Srivastave *et al.* (1985-1986) also studied genetic divergence for 40 and 30 selected wheat varieties from two separate screening nurseries. They reported that the varieties studied in two screening nurseries could be grouped into 7 and 10 clusters respectively. Bhatt (1970) studied the relative contribution of yield component characters to total divergence and observed that kernel weight in wheat was the most important character for total divergence in bread wheat. From his studies it was observed that the yield per se had a low contribution to the total divergence.

Geographical distribution of the genotypes also provides some information on genetic divergence between them. The genotypes developed and adapted in more diverged environments' usually seems to have wide genetic diversity between them. Therefore, many researchers tried to relate the choreographic diversity for origin of the genotypes to the genetic diversity assess through D2-statistics. But Dasgupta and Das (1982) did not find any relationship between the clustering pattern and geographical distribution of the genotypes of bread wheat. Somayjulu *et al.* (1970) reported that they found no evidence of relationship between the clustering pattern and geographical distribution in wheat. In work at the Indian Agricultural Research Institute (IARI), it was found that geographical distribution and genetic diversity as estimated by D2-statistics were not directly related in a number of crop plants (Murty and Arunachalam, 1966). In durum wheat, Lee and Kaltsikes (1973) found no relationship between genetic divergence and geographic origin.

On the other hand geographical diversity has been largely relied upon as an index of genetic diversity has been emphasized by vavilov (1926), Wienhues (1960), Joshi and Dhawan (1966).

2.5 Principal component analysis (PCA)

Principal component analysis, one of the multivariate techniques, is used to examine the divergence among a set of genotypes and to identify the most discriminating character/ characters contributing towards the divergence. PCA finds linear combinations of a set of varieties that maximize the variation contained within them, thereby displaying most of the original variability in smaller number of dimensions.

Information on divergence studies in bread wheat through principal component analysis (PCA) is scant. However, the method has been used in other crops. Chowdhury (1994) conducted an experiment with 85 genotypes of soybean and he grouped the genotypes into five clusters through principal component analysis. He found no relationship between geographic distribution and genetic diversity. Mian *et al.* (1991) studied the genetic divergence in 128 germplasm of pea through PCA. They classified the whole germplasm into 16 clusters. They also observed that there was no parallel relationship between genetic and geographical diversity in pea.

2.6 Relationship between Yield and Yield components

Grain yield in wheat is related to many yield contributing characters. In cereal crops, the yield components have been identified as number of spikes/plant, number of grains/spike and average grain weight (Engledow and Wadham, 1923). It has been observed that the yield through a complex chain of interrelationships. Many developmental and physiological characters like plant height, biological yield and harvest index are correlated the grain yield through their direct and indirect influences.

It was observed that relationship of yield components with yield were positive and significant in most of the cases. Shamsuddin and Ali (1989) reported significant and positive correlation of spikes/plant, grains/spike, 1000-grain weight and plant height with yield in spring wheat. In their study hundred grain weight displayed a non significant phenotypic correlation with yield but its genotypic correlation was considerably high and positive. Sharma and Kaul (1986) reported that grain yield was positively and significantly correlated with spikes/plant, spikelets/spike, grains/spike, 1000-grains weight, days to maturity and plant height but negatively correlated with vegetative period. Positive and significant correlation of yield with spikes/plant, plant height and vegetative period but negatively correlated with days to maturity and 1000-grains weight in wheat were reported by Nessa *et al.* (1994). Balyan and Singh (1983) observed positive phenotypic correlation of plant height and grains/spike with grain yield but genotypic correlations between them were negative.

Ahmed *et al.* (1978) observed significant and positive correlation of spikes/plant, grains/spike, 1000-grain weight and plant height with grain yield. Amin *et al.* (1992) reported grain yield was positively and significantly correlated with vegetative period, grains/spike, 1000-grain weight but negatively correlated with spiked/plant.

Shandu and Mangat (1985) observed significant and positive correlation between yield and 1000-grain weight, grains/spike, spikes/plant and plant height but negative with spikelets/spike. Sinha and Sharma (1979) reported positive and significant correlation of spikelets/spike, 1000-grain weight, grains/spike, plant height, spikes/plant and days to maturity with yield. Jadhav (1989) observed positive correlation of plant height, spikelets/plant, vegetative period, days to maturity, spikelets/spike and grains/spike but positive and significant correlation with plant height, spikes/plant, 1000-grain weight. Miah (1997) observed positive correlation of grains/spikes, 1000-grain weight and grain filling period but negative correlation of vegetative period, spkes/m2 with yield. Malek (1997) reported positive correlation between plant height, biological yield/plant, seed/spike and 100-grain weight. In a study of relationship of grain yield and test weight in soft red winter wheat. Dawari and Luthra (1991) reported harvest index, spikes/plant and grain weight are highly significant positive association with grain yield. Yagbasanlar *et al.* (1995) observed positive and significant correlation between days to maturity, grain filling period, plant height, biomass and harvest index. Ehdaie and waines (1989) showed positive and significant correlation of days to maturity, 1000-grain weight with grain yield but negative correlation of vegetative periods, spikes/plant and plant height with grain yield. Srivastave *et al.* (1988) observed positive correlation yield with 1000-grain weight but negative with plant height, vegetative period, days to maturity and grain filling period. Singh *et al.,* (1978) estimated genotypic and phenotypic correlation in forty genotypes of bread wheat. He observed that yield/plant was highly and positively correlated with vegetative period, spikes/plant, plant height, spikelets/spike and 1000-grain weight. They noticed in general the genotypic correlation coefficients were higher than their corresponding phenotypic ones. Jaimini *et al.* (1974) in estimating correlation and path coefficient analysis in bread wheat observed that yield was significantly and positively correlated with spikes/plant, spikelets/spike and 1000-grain weight and negatively correlated with vegetative period. Raina *et al.* (1982) studied interrelationship among yield and some quality characters in bread wheat and they reported significant and positive correlation for grains/spike and 1000-grain weight with grain yield/plant. But number of grains/spike and 1000-grains weight showed negative relationship. Rahman *et al.* (1983) in simple correlation studies reported significant and positive correlation of grain yield with tillers/plant and kernels/spike but negative with plant height and 1000-grain weight.

Correlation coefficient can not define a complete picture to study the casual basis relationship. Path coefficient analysis partition the components of correlation into direct and indirect effects.

Paroda and Joshi (1970) observed that 1000-grain weight and weight of grains/spike had positive direct effects on yield. Das (1972) studied path analysis and reported that the highest direct effect was obtained for number of spikes/plant on grain yield. Razzaque *et al.* (1981) reported negative direct effects of grain filling period on yield. Rahman *et al.* (1983) observed negative direct effects of vegetative period on yield. Das and Mondal (1984) observed number of grains/spike and a moderate direct effect on grain yield. They identified that number of grains/spike was one of the major component of yield in bread wheat.

Bhullar *et al.* (1985) suggested from path analysis that 1000-grain weight was one of the most important yield component in durum wheat. Shamsuddin and Ali (1989) studied genotypic and phenotypic correlation and path analysis in spring wheat and reported that grains/spike displayed considerable amount of direct effects on grain yield followed by length of spike and 1000-grain weight. These direct effects were the principal components of their relationship with yield. Shamsuddin (1987) studied path analysis in bread wheat and observed that spikes/plant, grains/spike and 100-grain weight had direct effects on yield/plant. Amin *et al.* (1990) observed that 1000-grain weight contributed maximum positive and direct effect to grain yield. Shelembi and Wright (1991) reported that number of grains/spike had direct and strong effects on grain yield. Barma *et al.* (1991) observed negative direct effect of plant height on grain yield. Khan *et al.* (1994) found that 1000-grain weight exhibited positive association and high direct effect on grain yield and suggested hybridization programme should include genotypes with greater number of grains/spike, high grain weight and high grain yield to obtain further improvement grain yield in bread wheat.

Chapter 3
Materials and Methods

CHAPTER III
MATERIALS AND METHODS

The study was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207. The sowing date was 20 th November 2012. The materials and methods were adopted for conducting the experiment is discussed under the following headings:

3.1. Experimental site

3.1.1 Location

The experimental field was located at 90° 33.5′ E longitude and 23° 77.4′ N latitude at an altitude of 9 meter above the sea level. The field experiment was set up on the medium high land of the experimental farm.

3.1.2 Soil and climate

The soil of the experiment site was a medium high land, clay loam in texture and having pH 5.47-5.63. The land was located in Agro-ecological Zone of 'Madhupur Tract' (AEZ No. 28).The climate of the experimental site is sub-tropical characterized by heavy rainfall during April to July and sporadic during the rest of the year.

3.2. Experimental details

3.2.1 Plant Materials

The experimental materials of the study comprised of 40 wheat genotypes. The seeds were collected from Bangladesh Agricultural Research Institute (BARI). The details of these genotypes are given in Table 1.

Table 1. List of 40 wheat genotypes along with their sources

Entry No.	Indicating symbol of genotypes	Germplasm	Source
1	G1	Kheri	BARI
2	G2	Kalyansona	BARI
3	G3	Sonora-64	BARI
4	G4	Pavon-76	BARI
5	G5	Ananda	BARI
6	G6	Sonalika	BARI
7	G7	Akbar	BARI
8	G8	Balaka	BARI
9	G9	Aghrani	BARI
10	G10	Barkat	BARI
11	G11	Protiva	BARI
12	G12	Sourav	BARI
13	G13	Gourav	BARI
14	G14	Kanchan	BARI
15	G15	BARI Gom 21	BARI
16	G16	BARI Gom 22	BARI
17	G17	BARI Gom 23	BARI
18	G18	BARI Gom 24	BARI
19	G19	BARI Gom 25	BARI
20	G20	BARI Gom 26	BARI
21	G21	BARI Gom 27	BARI
22	G22	BARI Gom 28	BARI
23	G23	BAW-118	BARI
24	G24	BAW-1130	BARI
25	G25	BAW-1138	BARI
26	G26	BAW-1140	BARI
27	G27	BAW--1051	BARI
28	G28	BD-7550	BARI
29	G29	BD-7606	BARI
30	G30	BD-7620	BARI
31	G31	BD-7615	BARI
32	G32	BD-7575	BARI
33	G33	BD-7607	BARI
34.	G34	BD-7559	BARI
35	G35	BD-7554	BARI
36	G36	BD-7553	BARI
37	G37	BD-7651	BARI
38	G38	BD-7546	BARI
39	G39	BD-7625	BARI
40	G40	BD-7586	BARI

3.2.2 Design and layout

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The genotypes were randomly distributed within the replication.

3.3. Methods

3.3.1 Land preparation and fertilization

The land was prepared by ploughing with power tiller followed by harrowing and laddering. All the stubbles and weeds were removed from the field. Seeds were sown at 120 kg ha^{-1} in lines 20 cm apart. Recommended fertilizer doses, 100-27-40-20-1 kg ha^{-1} of N-P-K-S-B respectively, were applied. Cow dung was applied @ 10 t ha^{-1}. Total amount of compost, all chemical fertilizers (except urea) and one third of urea were applied during final land preparation. The rest of the urea was applied in two splits at tillering and just before panicle initiation stage.

3.3.2 Sowing of seeds and intercultural operations

Seeds were sown on 20 November 2012. Before sowing, seeds were treated with Provax-200 WP an effective seed treating fungicide containing of Carboxin and Thiram. Irrigations were applied at crown root initiation, booting and grain filling stages. Intercultural operations were done properly as and when necessary. Hand weeding was done after first irrigation to control weed.

3.3.3. Data collection

Data on ten characters were collected form the ten plants which were randomly selected from the central rows. These ten plants were harvested by up rooting.

Plant height (cm): Height of the main culm from the base to the top of the panicle excluding awn was measured in cm as plant height.

Spikes/plant: Number of spikes were counted from each of the sample plants and were averaged over per plant.

Spikes length (cm): Spikes length were counted from each of the sample plants and were averaged over per plant.

1000-grain weight (g): One thousand clean sun dried grains were randomly counted from each plot and weighed in gram.

Grains/spike: Grains from ten main spikes of the sample plants were counted and were averaged.

Harvest index: It was recorded as the ratio of grain yield to the biological yield as per plot basis:x

$$\text{Harvest Index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Vegetative period: Days required from germination to 50% flowering were counted as vegetative period.

Grain filling period: days required from 50% flowering to 50% physiological maturity were counted.

Days to maturity: Days required from germination to 50% physiological maturity. 100

Grain yield/plant (g): Weight of the total grains of individual plant in gram was taken as grain yield/plant.

Plate 1. Data collection of forty wheat genotype.

3.4. Data Analysis

The data were recorded for each character was averaged to obtain mean plot data and analysis of variance was performed using the mean values. Duncan's Multiple Range Test (DMRT) was performed using the mean values. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test differences between mean of the genotypes.

3.4.1. Estimation of genotypic and phenotypic coefficients of variation

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1955)

Genotypic variance, $\sigma^2_g = \frac{VMS - EMS}{r}$

Where, VMS = Variety mean square

EMS = Error mean square

r = Number of replication

Phenotypic variance, $\sigma^2_{ph} = \sigma^2 g + EMS$

where, $\sigma^2 g$ = Genotypic variance

EMS = Error mean square.

The genotypic and phenotypic coefficient of variation were estimated as follows:

Genotypic coefficient of variation, GCV $= \frac{\sqrt{\sigma^2_g}}{\bar{x}} \times 100$

where, $\sigma^2 g$ = Genotypic variance

$\bar{x}$ = Population mean

Similarly, the phenotypic coefficient of variation was also calculated by the formula given below:

Phenotypic coefficient of variation, $PCV = \frac{\sqrt{\sigma^2 ph}}{\bar{x}} \times 100$

Where, $\sigma^2 ph$ = phenotypic variance

$\bar{x}$ = population mean

3.4.2 Estimation of heritability

Heritability in broad sense was estimated by the formula suggested by Johnson *et al.* (1955).

Heritability in broad sense, $h^2 b = \frac{\sigma^2 g}{\sigma^2 ph} \times 100$

where, $\sigma 2_g$ = genotypic variance

$\sigma 2 ph$ = phenotypic variance

3.3.4.3 Estimation of genetic advance

The expected genetic advance and genetic advance in percent of mean were calculated according to Allard (1960) and Comstock Robinson (1952)

Genetic advance, $GA = h^2{}_b.K.\sigma_{ph}$

where, $h^2 b$ = heritability in broad sense

K = Selection differential, the value of which is 2.06 at 5% selection intensity σ_{ph} = phenotypic standard deviation.

Genetic advance in percent of mean, $GA\ (\%) = \frac{GA}{\bar{x}} \times 100$

where, GA = Genetic advance

$\bar{x}$ = Population mean

3.4.3. Analysis of genetic divergence

Genetic divergence among the genotypes studied were assessed by using Mahalanobis' D^2-statistics and principal components and its auxiliary analyses. Both techniques estimate divergences among a set of genotypes on multivariate scale.

3.4.4. Mahalanobis; D^2-statistics: First the variation among the materials were tested by wilkin's criteria,

$$= \frac{|W|}{|S|} = \frac{|\text{Deter min ant of error Matrix}|}{|\text{Deter min ant of error + var iety matrix}|}$$

$$\text{Now, 'V'(Stat)} = -\text{ mloge}^\wedge = -\left(n - \frac{p+q+1}{2}\right)\text{loge}^\wedge$$

where, m = n - (p+q+1)/2

P = Number of variables or characters

q = Number of varieties -1 (or d.f. for population)

n = d.f. for error + varieties

e = 2.7183

Data were then analysed for D^2-statistics sccording to Rao (1952). Error variance and covariance matrix obtained fro m analyses of variance and covariance were inversed by pivotal condensation methed. Using the pivotal elements the original means of the character (X_1, X_2.............X_{11}) were transformed into a set uncorrelated variables (Y_1, Y_2..............Y_{11}). Now, the genetic divergence between two varieties/ lines (suppose Vi and Vj) was calculated as $D^2ij = \sum_{k=1}^{11} (V_{ik} - V_{jk})^2$

where, D^2iJ = Genetic divergence between 'i' th and 'j' th genotypes

Vik = Transformed mean of the 'i' th genotype for 'k'th character

Vjk = Transformed mean of the 'j' th genotype for 'k'th character

The D^2 values between all genotypes were arranged in order of relative distances from each other and was used for clusters formation, as suggested by (Rao, 1952). Average intra-cluster distances were calculated by the following formula as suggested by Singh and Chaudhury (1985).

$$\text{Average intra-cluster } D^2 = \frac{\sum D^2 i}{n}$$

where, $\sum Di^2$ = Sum of distances between all possible combinations (n) of genotypes included in a cluster.

n = All possible combinations

3.4.5 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a multivariate technique, is being used to investigate the interrelationships among several characters and can be done from the sum of squares and products matrix for the characters. The principal component analysis finds out the linear combinations of a set of variate that maximize the variation contained within a group of genotypes. So principal compounts were computed by the using correlation matrix and genotypes. So principal compounts were computed by the using correlation matrix and genotypes scores obtained from the first components (Which has the property of accounting for maximum variance) and succeeding components discuss the contribution of the different characters toward divergence.

3.4.6 Estimation of correlation

The genotypic and phenotypic correlation were estimated by the formula suggested by Miller *et al.* (1958)

Genotypic correlation, $r_{g_{1.2}} = \dfrac{Cov.g_{1.2}}{\sqrt{\sigma^2 g_1 \times \sigma^2 g_2}}$

where, Cov, $g_{1.2}$ = genotypic covariance between the trait x_1 and x_2

$\sigma^2 g_1$ = genotypic variance of the trait x_1

$\sigma^2 g_2$ = genotypic variance of the trait x_2

Similarly , phenotypic correlation, $r_{ph1.2} = \dfrac{Cov._{ph_{1.2}}}{\sqrt{\sigma^2 ph_1 . \sigma^2 ph_2}}$

where, Cov. $ph_{1.2}$ = phenotypic covariance between the trait x_1 and x_2

$\sigma^2 ph_1$ = genotypic variance of the trait x_1

$\sigma^2 ph_2$ = genotypic variance of the trait x_2

3.4.7 Estimation of path coefficient analysis

The components of correlation coefficients of different characters with yield/plant were separated into direct and indirect effects through path coefficient analysis. Path coefficient analysis was done according to the procedure quoted by Singh and Chaudhary (1985) and Dabholkar (1992) originally developed by Dewey and Lu (1959). Assuming eight independent (x_1, x_2...............and x_8) and one dependent variable (x_9), the relationship between them can be represented as follows:

$$P_{19} + r_{12}P_{29} + r_{13}P_{39} + r_{14}P_{49} + r_{15}P_{59} + r_{16}P_{69} + r_{17}P_{79} + r_{18}P_{89} = r_{19}$$

$$r_{12}P_{19} + P_{29} + r_{23}P_{49} + r_{25}P_{59} + r_{26}P_{69} + r_{27}P_{79} + r_{28}P_{89} = r_{29}$$

$$r_{13}P_{19} + r_{23}P_{29} + P_{39} + r_{34}P_{49} + r_{35}P_{59} + r_{36}P_{69} + r_{37}P_{79} + r_{38}P_{89} = r_{39}$$

$$r_{14}P_{19} + r_{24}P_{29} + r_{34}P_{39} + P_{49} + r_{45}P_{59} + r_{46}P_{69} + r_{47}P_{79} + r_{48}P_{89} + r_{49}$$

$$r_{15}P_{19} + r_{25}P_{29} + r_{35}P_{39} + r_{45}P_{49} + P_{59} + r_{56}P_{69} + r_{57}P_{79} + r_{58}P_{89} = r_{59}$$

$$r_{16}P_{19} + r_{26}P_{29} + r_{36}P_{39} + r_{46}P_{49} + r_{56}P_{59} + P_{69} + r_{67}P_{79} + r6P_{89} = r_{69}$$

$$r_{17}P_{19} + r_{27}P_{29} + r_{37}P_{39} + r_{47}P_{49} + r_{57}P_{59} + r_{67}P_{69} + P_{79} + r_{78}P_{89} = r_{79}$$

$$r_{18}P_{19} + r_{28}P_{29} + r_{38}P_{39} + r_{48}P_{49} + r_{58}P_{59} + r_{68}P_{69} + r_{78}P_{89} + P_{89} = r_{89}$$

Where, P_{19}, P_{29}............P_{89} = Path coefficient of the variables x_1, x_2, x_3...........x_8 on variable x_9 respectively.

r_{19}, r_{29}, r_{39}................r_{89} = correlation coefficient of x_1, x_2, x_3...............x_8 with x_9 respectively. The residual effect was estimated as follows:

Residual effect, R= $\sqrt{1-(r_{19}P_{19} + r_{29}P_{29} + \ldots\ldots\ldots\ldots + r_{89}P_{89})}$

Chapter 4
Results and Discussion

CHAPTER IV

RESULT AND DISCUSSION

The study includes performance of the genotypes of spring wheat assessment of variation and genetic diversity among the genotypes and relationship between yield and yield contributing characters. The data pertaining to twelve characters have been presented and statistically analyzed with the possible interpretations given under the following headings:

4.1 Performance of the genotypes of wheat

Analysis of variance for the characters showed that there were significant variations among the genotypes for plant height, spikes/plant, grains/spike, spike length, 1000-grain weight, harvest index, vegetative period, grain filling period, days to maturity and grain yield/plant (Table 2). Sharma *et al.* (2007) and Joshi *et al.* (2007) also found similar result.

4.2 Variation, heritability and genetic advance

The extent of variation among the genotypes in respect to ten characters was studied and mean sum of square, phenotypic variance (σ^2p), genotypic variance (σ^2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2b), genetic advance (GA) and genetic advance in percent of mean presented in Table 3. The mean value of all genotypes for each character is shown in Appendix III. Performance of the genotypes is described below for each character.

Table 2. Analysis of variance for different morphological plant characters of 40 wheat varieties

Characters	Sources of variation		Error (d.f.78)
	Replication (d.f.2)	Genotype (d.f.39)	
Plant height (cm)	4.716	136.043**	20.790
Spikes /Plant (no.)	0.625	10.375**	0.274
Grains/spike (no.)	8.764	77.301**	2.827
Spikes length (cm)	3.460	5.204**	1.301
1000 grain weight (g)	2.981	103.269**	1.866
Harvest Index	2.585	276.127**	0.996
Vegetative period (days)	5.081	12.091**	5.069
Grain Filling Period (days)	1.710	25.309**	1.936
Days to Maturity (days)	14.933	54.619**	15.546
Grain yield/plant (g)	0.027	6.002**	0.032

Plant height

Significant differences were observed among the genotypes for plant height which ranged from 67.83 cm (G29) to 104.28 cm (G1) with mean value of 84.76 (Appendix III). Randhawa *et al.* (1975), Johnson *et. al* (1995), Johnson *et. al* (1995) also found similar significant variation for plant height in wheat. The genotypic and phenotypic variance was observed as 38.42 and 59.21, respectively (Table 3). The phenotypic co-efficient of variation (7.31) and genotypic co-efficient of variation (9.08) were moderate for plant height. The heritability estimates for this trait was moderate with low genetic advance and genetic advance in per cent of mean revealed that this trait was governed by additive gene. Singh *et al.* (1978) also reported similar result in wheat.

Spikes/plant

Significant differences were observed among the genotypes for spikes/plant which ranged from 2.33 (G36) to 8.83 (G23) with mean value of 4.19 (Appendix III). Maloo (1984) and Pawar *et al.* (1988) also found similar significant variation for spikes/plant. The genotypic and phenotypic variance were observed as 3.37 and 3.64, respectively (Table 3). The phenotypic co-efficient of variation (43.82) and genotypic co-efficient of variation (45.56) was high for spikes/plant. Maloo (1984) observed high genotypic coefficient of variation for spikes/plant in wheat. Pawar *et al.* (1988) also observed high genotypic and phenotypic coefficient of variations for this character. The heritability estimates for this trait was high with high genetic advance in per cent of mean. Mahmood and Shahid (1993) reported high heritability with high genetic advance for number of spikes/plant. High heritability estimates with high genetic advance for number of spikes/plant indicated that genetic effect was more pronounced for this character.

Table 3. Estimation of genetic parameters for morphological characters related to yield

SL. No.	Characters	Phenotypic variance (δ^2p)	Genotypic variance (δ^2g)	PCV (%)	GCV (%)	Heritability (%)	GA	GA (%)
1	Plant height (cm)	59.21	38.42	7.31	9.08	64.89	10.29	12.13
2	Spikes /Plant	3.64	3.37	43.82	45.56	92.47	3.63	86.80
3	Grains/spike	27.65	24.82	9.04	9.54	89.78	9.73	17.64
4	Spikes length (cm)	2.60	1.30	7.31	10.33	50.00	1.66	10.64
5	1000 grain weight (g)	35.67	33.80	14.33	14.72	94.77	11.66	28.73
6	Harvest Index	92.71	91.71	35.69	35.50	98.93	19.62	72.73
7	50% Flowering	7.41	2.34	2.31	4.11	31.59	1.77	2.67
8	Grain Filling Period	9.73	7.79	6.38	7.13	80.10	5.15	11.77
9	Days to Maturity	28.57	13.02	3.28	4.85	45.59	5.02	4.56
10	Grain yield/plant (g)	2.02	1.99	32.61	32.35	98.42	2.88	66.12

PCV=Phenotypic Coefficient of Variation, GCV=Genotypic Coefficient of Variation, GA=Genetic Advance,

Spike length

The mean spike length was noticed as 15.61 cm with a range of 13.22 cm to 19.18a cm (Appendix III). The genotype G32 showed the minimum spike length and the maximum spike length was recorded in the genotype G23. The genotypic and phenotypic variances were observed as 1.30 and 2.60, respectively (Table 3). The phenotypic co-efficient of variation (7.31) and genotypic co-efficient of variation (10.33) was low for spikes/plant. The heritability estimates for this trait was medium with low genetic advance in per cent of mean. Biju and Malik (2007) observed significant variation for spike length and grains/spike. Bhutta *et al.* (2005) also found highly significant variation for the traits spike length.

Grains/spike

Grains/spike also showed significant difference which ranged from 45.33 (G24) to 64.66 (G36) (Appendix III). Joshi *et al.* (1982) and Ehdaie and Waines (1989) also found similar significant variation for spikes/plant. The genotypic and phenotypic variances were observed as 27.65 and 24.82, respectively (Table 3). The phenotypic co-efficient of variation (9.04) and genotypic co-efficient of variation (9.54) was low for spikes/plant. The heritability estimates for this trait was high with moderate genetic advance in per cent of mean. Maloo (1984) observed high genetic coefficient of variation with high heritability accompanied with high genetic advance indicated additive gene. On the contrary, Singh *et al.* (1978) reported low genotypic and phenotypic coefficients of variation, along with low heritability and low genetic advance which indicated non additive gene.

1000-grain weight

The highest grain weight found in genotype G15 (55.98) and lowest grain weight found in G34 (32.16). The mean value observed 40.58 (Appendix III). The genotypic and phenotypic variances were observed as 33.80 and 35.67, respectively (Table 3). The phenotypic co-efficient of variation (14.33) and genotypic co-efficient of variation (14.72) was good for spikes/plant with high heritability (94.77) and high genetic advance (28.73). Nessa *et al.* (1994) reported high genotypic and phenotypic coefficients of variation for 1000-grain weight in bread wheat. They estimated high genetic advance accompanied by high heritability suggesting effects of additive gene for this character.

Harvest index

Significant differences were observed among the genotypes for spikes/plant which ranged from 47.34 (G16) to 9.99 (G30) with mean value of 26.98 (Appendix III). Austin *et al.* 1980 found similar result. The phenotypic co-efficient of variation (35.69) and genotypic co-efficient of variation (35.50) was good for harvest index with high heritability (98.93) and high percentage of genetic advance (72.73). Amin *et al.* (1992) reported wide range of variation for harvest index. They observed high genotypic and phenotypic coefficients of variation with high heritability accompanied by high genetic advance.

Vegetative period

Vegetative period also showed significant difference which ranged from 63.43 (G10) to 70.90 (G40). The mean value observed 40.58 (Appendix III). The phenotypic co-efficient of variation (2.31) and genotypic co-efficient of variation (4.11) were low for vegetative period with high heritability (31.59) and low percentage of genetic advance (2.67). Sharma and Kaul (1986) reported low genotypic and phenotypic coefficients of variation accompanied by high heritability but low genetic advance. They explained such low genetic advance as they noticed as the cause of presence of dominace and epistasis in the population. Similar results were observed by Pawar *et al.* (1988), Amin *et al.* (1992) and Singh *et al.* (1978)

Grain filling period

Significant differences were observed among the genotypes for spikes/plant which ranged from 50.67 (G38) to 39.67 (G22) with mean value of 43.73 (Appendix III). The phenotypic co-efficient of variation (6.38) and genotypic co-efficient of variation (7.13) was low for harvest index with high heritability (80.10) and low percentage of genetic advance (11.77). Miah (1997) reported low genotypic and phenotypic coefficient of variation with high heritability but low genetic advance.

Days to maturity

Significant differences were observed among the genotypes for days to maturity which ranged from 104.33 (G22) to 119.00 (G35) and (G38) with mean value of 110.12 (Appendix III). The phenotypic co-efficient of variation (3.28) and genotypic co-efficient of variation (4.85) was low for days to maturity with moderate heritability (45.59) and low percentage of genetic advance (4.56). Sharma and Kaul (1986) carried out an experiment with wheat and observed high genotypic and phenotypic coefficients of variation with high heritability and moderate genetic advance for this character. Nessa *et al.* (1994) also found similar result.

Grain yield/plant

Significant differences were observed among the genotypes for days to maturity which ranged from 2.16 (G1) to 7.18 (G26) with mean value of 4.36 (Appendix III). The phenotypic and genotypic co-efficient of variations (32.61) and 32.35) was medium for days to maturity with high heritability (98.42) and high percentage of genetic advance (66.12). Nessa *et al.* (1994) reported high genotypic and phenotypic coefficients of variation and high heritability with high genetic advance for grain yield in bread wheat.

Considering yield and yield contributing characters, it appears that the genotypes G19 and G37 were promising for high yield potentiality. Both the genotypes had high grain yield. The genotype G19 was also ranked high a for harvest index, spike length, grains/spike and 1000-grain weight. It took 105 days to mature. The genotype G37 was the best for plant height, effective tillers/plant and grains/spike. Therefore, in this study, these two genotypes could be selected for yield improvement in spring wheat.

4.3. Genetic divergence

Genetic divergence among forty genotypes of wheat were studied through Mahalanobis' D^2 –statistics and Principle Component Analysis (PCA) which has been discussed below.

4.3.1. Mahalanobis' D^2-statistics analysis

The multivariate analysis using Mahalanobis' D^2-statistics was carried out to study the genetic divergence among the forty genotypes of wheat.

The genotypes were clustered and it was observed that the D^2 values within cluster is low compared to between clusters which indicate diversity is low within a cluster.. The forty genotypes of wheat were grouped into 7 clusters (Table 4). There were 4 genotypes in the cluster III and 3 varieties in the cluster VII. The number of genotypes in the remaining 5 clusters varied from 6 to 9.

The cluster I included 9 genotypes which was the largest one. These were G1, G6, G18, G21, G23, G24, G27, G33 and G34. From the Table 5; it was observed that this cluster produced medium mean values for all the characters. It indicates that the genotypes included in this cluster were semi dwarf and produced medium number of grians/spike.

Table 4. Number, percent and name of genotypes in different cluster

Cluster number	Number of genotypes	Percent (%)	Name of genotypes
I	9	22.50	G1, G6, G18, G21, G23, G24, G27, G33 and G34
II	6	15.00	G2, G3, G4, G5, G13 and G22
III	4	10.00	G7, G8, G10 and G29
IV	6	15.00	G9, G11, G12, G14, G17 and G20
V	6	15.00	G15, G16, G19, G25, G26 and G28
VI	6	15.00	G30, G31, G36, G38, G39 and G40
VII	3	7.50	G32, G35 and G37

grains/spike. These varieties also gave moderate grain yield with moderate seed size (as 1000 grain weight and lest weight was medium).

The cluster II composed of six genotypes namely G2, G3, G4, G5, G13 and G22. It produced minimum mean value for spike length and intermediate values for all the characters. This suggests that the varieties lines included in this group produced semi dwarf plant, with medium number of spikes plant, grains/spike, these genotypes also produced moderate grain yield with medium seed size.

The cluster III contained four genotypes namely G7, G8, G10 and G29. These genotypes produced the lowest mean value for spikes/plant and intermediate values for all the remaining characters indicated that this group had minimum spikes/plant with medium number of spikelets/spike, grains/spike, semi dwarf plant and medium duration. It also produced moderate grain yield/plant.

The cluster IV consisted of six genotypes; they are G9, G11, G12, G14, G17 and G20. The genotypes of this group produced the highest 1000-grain weight, the maximum number of grain/ spike and with long vegetative period and days to maturity. It gave minimum grain yield/plant .

The cluster V contained six genotypes namely G15, G16, G19, G25, G26 and G28. This group produced the highest grain yield/plant and the dwarf plant with higher number of spikes/plant and grains/spike. The growth duration of the genotypes of this group was maximum. It also produced medium size of seeds (as 1000 grain weight) with the highest harvest index.

The cluster VI contained six genotypes namely G30, G31, G36, G38, G39 and G40. It produced medium grain yield with the lowest harvest index and lowest 1000-grain weight. It had semi dwarf plant and the medium number of spikes/plant. It took medium days for vegetative period, grain filling period and days to maturity.

The cluster VII composed of three genotypes namely G32, G35 and G37. It produced the highest number of spikes/plant and grains/spike. It had highest vegetative period and medium days to maturity but medium grain filling period. It also produced medium 1000-grain weight and harvest index. It contains semi dwarf plant and produced higher grain yield.

It was observed from the cluster mean values that all the characters in group I, II and III were more or less similar except harvest index. Group IV contained the tallest plants and the highest 1000-grain weight. Group V had the capability to produce highest grain yield. Group VI produce average grain yield. Group VII contained the highest grains/spike.

Shamsuddin (1985) calculated genetic diversity among ten varieties of spring wheat used, as parents in diallel cross through Mahalanobis' D^2-statistics. He grouped the genotypes into three clusters. Chaturvedi and Gupta (1995) studied genetic divergence of 44 genotypes by using Mahalanobis' D^2-statistics. Genotypes were grouped into 13 diverse clusters. Redhu *et al.* (1995) grouped 121 genotypes of wheat into 27 clusters.

Table 5. Cluster mean for twelve yield and yield characters of 40 wheat genotypes

Characters	I	II	III	IV	V	VI	VII
Plant height (cm)	87.63	79.99	86.59	92.43	79.40	83.82	83.46
Spikes /Plant	3.40	3.58	2.96	3.44	7.75	4.08	7.99
Grains/spike	53.85	50.12	57.40	58.52	56.83	60.33	61.66
Spikes length (cm)	15.38	14.69	15.65	16.26	15.52	18.81	17.12
1000 grain weight (g)	39.97	38.16	42.08	50.25	36.56	34.56	39.27
Harvest Index	29.44	23.43	33.41	20.51	36.68	17.74	30.23
Vegetative Period	66.61	64.50	64.85	65.88	68.93	68.98	69.79
Grain Filling Period	43.40	42.90	41.04	42.96	48.08	47.53	42.21
Days to Maturity	110.20	107.49	106.00	109.06	117.09	116.56	112.00
Grain yield/plant (g)	3.76	3.42	5.38	3.05	6.21	4.53	5.34

Intra-inter cluster distances

The average intra and inter cluster distances (D^2 and D values) are presented in Table 6 and Fig. 1. The highest distance was noticed between the clusters V and VI and it was followed by the distances between clusters VI and VII, II and VI. I and VI, V and VII. The distances between clusters I and IV was the minimum preceded by the distance between clusters II and IV, I and II, I and III, and III and IV.

From this study, it was also observed that the distances among the genotypes of the cluster VII were higher than genotypes of other clusters. It suggests that cluster VII included more diverse materials. Where the distances among the genotypes of the cluster IV were lowest which suggests that cluster IV included less diverse materials. The Somayajullu *at el.* (1970) reported that the clustering revealed instability due to relatively lesser divergence, whereas the widely divergent clusters remained distinct in different environment. This result supported by Raut *et ai* (1985) and Singh *el al.* (1980). Therefore, cluster stability dependent on divergence. In present study it was observed that the cluster V and VI, VI and VII, II and VI. I and VI, V and VII were highly diverged. So they would be more stable.

Table 6. Intra-inter cluster distance

Characters	I	II	III	IV	V	VI	VII
I	519.14 (**22.78**)	584.91 (24.18)	744.84 (27.29)	542.70 (23.30)	890.91 (29.85)	1254.03 (35.41)	1032.66 (32.14)
II		645.97 (**25.42**)	969.09 (31.13)	563.39 (23.74)	1339.14 (36.59)	1131.89 (33.64)	1194.98 (34.57)
III			657.59 (**25.64**)	1215.65 (34.87)	840.58 (28.99)	1299.95 (36.05)	1152.41 (33.95)
IV				184.90 (**13.60**)	1160.12 (34.06)	1223.14 (34.97)	1185.99 (34.44)
V					517.21 (**22.74**)	2007.23 (44.80)	1238.66 (35.19)
VI						842.82 (**29.03**)	1508.12 (38.83)
VII							1861.49 (**43.14**)

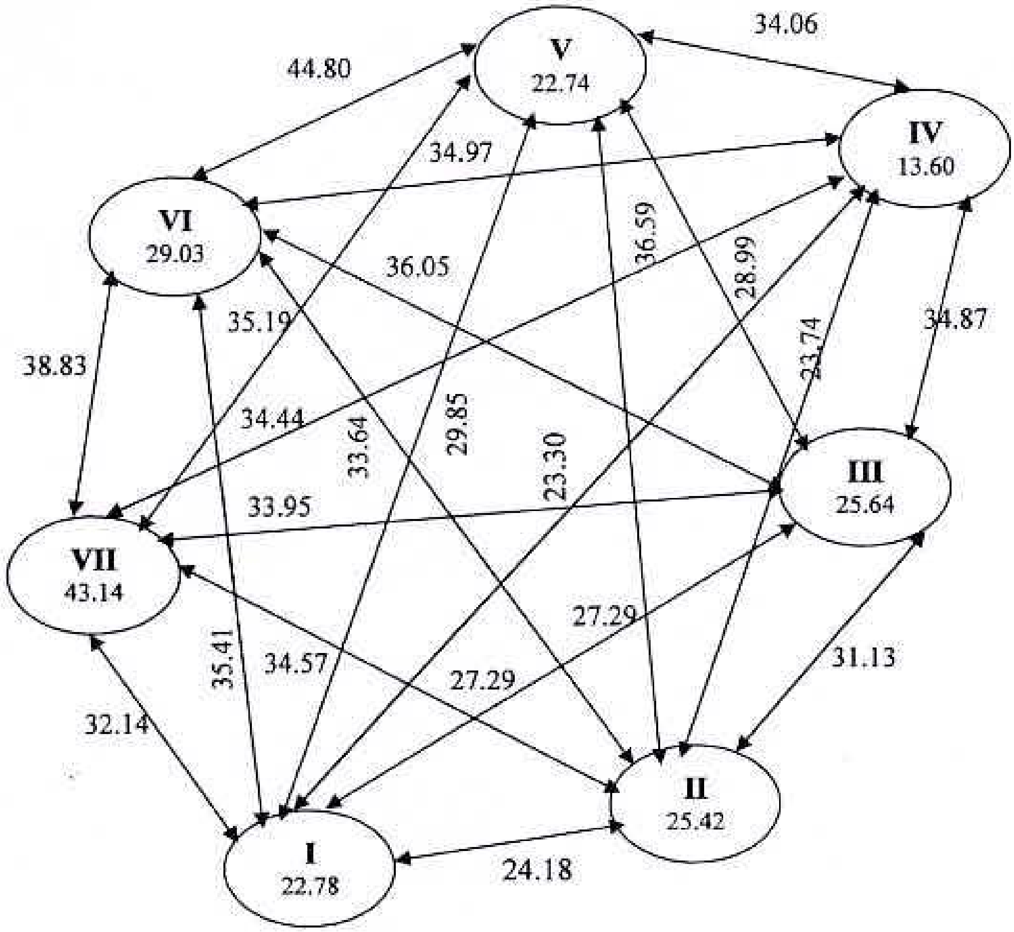

Fig. 1 Diagram showing intra and inter cluster distance of 40 genotypes.

4.3.2. Principal Component Analysis

Principal Component Analysis (PCA) also helps in assessment of diversity for multivariate scales. The results of PCA are presented in the Table 7. The latent roots and percent of variation associated with them abstracted ten principal components. All this ten components accounted 100% of variability of which first and second component accounted for 36.92% and 22.54%. Total of these 1st two components summed to give 59.46% which covered the major part of the total variation. Based on these two principal components using them in axis 1 and 2 a two dimensional scattered diagram of the genotypes were constructed. The scattered diagram revealed that the variety/line G2, G16, G19, G22, G28, G36, G37 took positions at the periphery of the diagram suggesting that these genotypes were more diverged from rest of the genotypes.

Latent vectors or eigen values in 1st and 2nd principal component were estimated and shown in the Table 8. The eigen values for all the characters showed less than one in both components (axises). In the first component the character day to maturity, spikes/plant, vegetative period, grain filling period had comparatively high values than others. In the second component the character grain yield/plant, 1000-grain weight and grains/spike had high values.

In the first component, the eigen values for the grain yield/plant were positive and that plant height was negative. This suggests that the first principal component distinguished those genotypes which had higher grain yield/plant but short plant height. In the second principal component the eigen values of both harvest index and grains/spike were negative suggesting these components distinguished those genotypes which had higher grains/spike with higher harvest index.

Table 7. Percent of variation in respect of 10 principal components

Principle components	Eigen value	Percent of variance	Cumulative Percentage
1	3.69	36.923	36.923
2	2.25	22.545	59.467
3	1.14	11.419	70.886
4	0.786	7.870	78.756
5	0.647	6.474	85.230
6	0.527	5.278	90.507
7	0.447	4.476	94.983
8	0.295	2.955	97.938
9	0.204	2.049	99.987
10	0.0013	0.013	100.000

Table 8. Latent vectors yield and yield contributing characters in 1st and 2nd principal components

Principle components	PCA 1	PCA 2
Plant height (cm)	-0.170	0.336
Spikes/Plant	0.439	-0.037
Grains/spike	0.223	0.418
Spikes length (cm)	0.162	0.319
1000 grain weight (g)	-0.155	0.455
Harvest Index	-0.174	0.377
Vegetative Period	0.436	0.119
Grain Filling Period	0.436	-0.110
Days to Maturity	0.499	-0.013
Grain yield/plant (g)	0.141	0.483

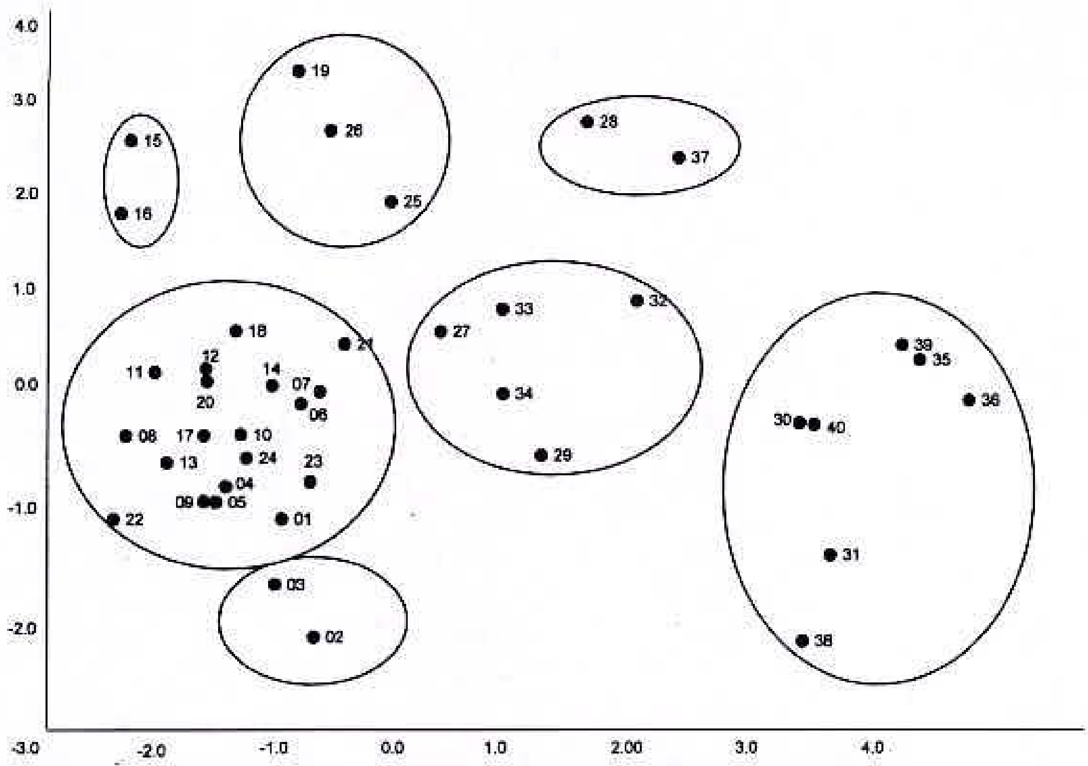

Fig 2 Scatter distribution of 40 genotypes based on their principal component scores.

4.4 Relationship between yield and yield contributing characters

Relationship between grain yield and yield contributing characters of 40 wheat genotypes are studied through genotypic and phenotypic correlation coefficients, the causes of such relations are further analyzed through path analysis

4.4.1 Correlation coefficients

Correlation studies along with path analysis provide a better understanding of the association of different characters with fruit yield. Simple correlation was partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) components. As we know yield is a complex product being influence by several inter-dependable quantitative characters. So selection may not be effective unless the other contributing components influence the yield directly or indirectly. When selection pressure is applied for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeders for making improvement through selection with a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors. Phenotypic and genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of wheat are given in Table 9.

Plant height

Plant height had non-significant positive correlation with grain yield/ plant (0.047and 0.051) at phenotypic and genotypic level (Table 9) which is supported by Shamsuddin and Ali (1989). Plant height had significant positive correlation with spikes per plant (-0.314*and -0.344*) at both levels. However, it had strong positive correlation with grains/spike (0.346* and 0.358*) at phenotypic and genotypic levels respectively.

Table 9. Coefficients of phenotypic and genotypic correlation among different yield components

Characters	correlation	Spikes /Plant	Grains/ spike	Spikes length (cm)	1000 grain weight (g)	Harvest Index (HI)	Vegetative period	Grain Filling Period	Days to Maturity	Grain yield/ plant (g)
Plant height (cm)	r_p	-0.314*	0.346*	0.098	0.294	0.181	-0.202	-0.271	-0.271	0.047
	r_g	-0.344*	0.358*	0.018	0.302	0.188	-0.237	-0.289	-0.299	0.051
Spikes/plant	r_p		0.311	0.085	-0.312*	-0.253	0.685**	0.590**	0.722**	0.263
	r_g		0.324*	0.070	-0.309	-0.251	0.776**	0.614**	0.789**	0.274
Grains/spike	r_p			0.381*	0.238	-0.024	0.407**	0.216	0.340*	0.373*
	r_g			0.395*	0.226	-0.031	0.320*	0.171	0.262	0.371*
Spikes length (cm)	r_p				0.085	0.025	0.278	0.150	0.235	0.311
	r_g				0.080	0.028	0.267	0.144	0.233	0.320*
1000 grain weight (g)	r_p					0.367*	-0.135	-0.259	-0.231	0.371*
	r_g					0.366*	-0.208	-0.287	-0.292	0.372*
Harvest index (HI)	r_p						-0.062	-0.369*	-0.278	0.415**
	r_g						-0.093	-0.385*	-0.313*	0.416**
Vegetative period	r_p							0.512**	0.817**	0.286*
	r_g							0.366*	0.538**	0.296*
Grain filling period	r_p								0.912**	0.089
	r_g								0.816**	0.092
Days to maturity	r_p									0.199
	r_g									0.207

* and ** indicate significant at 5% and 1% level of probability, respectability.

Spikes/plant

Spikes/pant had positive correlation with grain yield/ plant (0.263 and -0.274) at phenotypic and genotypic level (Table 9) which is supported by Shamsuddin and Ali (1989). Spikes/plant had significant positive correlation with grains/spike 0.324* at genotypic level. Sharma and Kaul (1986) reported that grain yield was positively and significantly correlated with spikes/plant.

Grains/spike

Grains/spike had significant and positive correlation with grain yield/ plant (0.373*and 0.371*) at phenotypic and genotypic level (Table 9). Grains/spike had significant positive correlation with vegetative period (0.407** and 0.320*) at both levels. However, it had negative correlation with harvest index (-0.024and -0.031) at phenotypic and genotypic levels respectively. Sen *et al.* (2007) observed from their study that grains/spike and 1000- grain weight showed positive and significant correlation with yield both at genotypic and phenotypic levels which support the present findings.

Spike length

Spike length had positive correlation with grain yield/ plant (0.311 and 0.320*) at phenotypic and genotypic level (Table 9). Spikes length had significant positive correlation with grains/spike (0.381* and 0.395*) at phenotypic and genotypic levels.

1000-grain weight

1000-grain weight had significant and positive correlation with grain yield/ plant (0.371* and 0.366*) at phenotypic and genotypic level (Table 9). Sen *et al.* (2007) found the similar result. 1000-grain weight had significant positive correlation with harvest index (0.367* and 0.395*) at both levels. And it had negative correlation with vegetative period (-0.135 and -0.208) at both levels. Payal *et al.*

(2007) found positive and significant correlation between harvest index and grain yield/plant which supports the present findings.

Vegetative period

Vegetative period had significant and positive correlation with grain yield/plant (0.286* and 0.296*) at phenotypic and genotypic levels. Vegetative period had significant and positive correlation with grain filling period (0.512** and 0.366**) at both levels.

Grain filling period

Grain filling period had positive correlation with grain yield/plant (0.089 and 0.092) at phenotypic and genotypic levels. Grain filling period had significant and positive correlation with days to maturity (0.912** and 0.816**) at both levels.

Days to maturity

Days to maturity had positive correlation with grain yield/plant (0.199 and 0.207) at phenotypic and genotypic levels. Days to maturity had significant and positive correlation with grain filling period (0.912**and 0.816**) at both levels. Jinbao *et al.* (2008) observed that days to maturity shows negative and significant correction with harvest index which supports these findings.

4.4.2 Path coefficient analysis

The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. ?In this study yield per plant was considered as effect (dependent variable) and plant height, spikes/plant, grains/spike, spike length, 1000-grain weight, harvest index, vegetative period, grain filling period and days to maturity were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of wheat in Table 10.

Plant height

Plant height had positive direct effect on yield/plant (0.051) (Table 10). It had negative indirect effect through spikes/plant (-0.155) and grain filling period(-0.015). On the other hand, plant height showed positive indirect effect on yield/plant via grains/spike (0.033), 1000-grain weight and days to maturity (0.005).

Spikes/plant

Spikes/plant had positive direct effect on yield/plant (0.274) (Table 10). It had positive indirect effect through grains/spike (0.030), spike length(0.016) and grain filling period(0.031). Das (1972) studied path analysis and reported that the highest direct effect was obtained for number of spikes/plant on grain yield.

Grains/spike

Grains/spike had positive direct effect on yield/plant (0.371*) (Table 10). It had positive indirect effect through spike/plant (0.146), spike length (0.089), and grain filling period(0.009). On the other hand it showed negative indirect effect on grain

Table 10. Partitioning of genotypic into direct and indirect effects of morphological characters of 40 wheat genotypes by path coefficient analysis

Characters	Plant height (cm)	Spikes /Plant	Grains/ spike	Spikes length (cm)	1000 grain weight (g)	Harvest Index (HI)	Vegetative period	Grain Filling Period	Days to Maturity	Grain yield/plant (g)
Plant height (cm)	**-0.009**	-0.155	0.033	0.004	0.097	0.079	0.011	-0.015	0.005	0.051
Spikes /plant	0.003	**0.449**	0.030	0.016	-0.099	-0.105	-0.037	0.031	-0.014	0.274
Grains/spike	-0.003	0.146	**0.092**	0.089	0.072	-0.013	-0.015	0.009	-0.005	0.371*
Spikes length (cm)	-0.0002	0.031	0.036	**0.225**	0.026	0.012	-0.013	0.007	-0.004	0.320*
1000 grain weight g	-0.003	-0.139	0.021	0.018	**0.320**	0.154	0.010	-0.014	0.005	0.371*
Harvest index	-0.002	-0.113	-0.003	0.006	0.117	**0.420**	0.004	-0.019	0.005	0.416**
Vegetative period	0.002	0.349	0.029	0.060	-0.067	-0.039	**-0.048**	0.018	-0.009	0.296
Grain filling period	0.003	0.276	0.016	0.032	-0.092	-0.162	-0.018	**0.050**	-0.014	0.092
Days to maturity	0.003	0.223	0.024	0.052	-0.093	-0.131.	-0.026	0.041	**-0.017**	0.207
Diagonally bold figures indicate the direct effect						Residual effect = 0.4913				

yield/plant via vegetative period (-0.015) and days to maturity (-0.005). Das and Mondal (1984) observed number of grains/spike and a moderate direct effect on grain yield.

Spike length

Spike length had high positive direct effect on yield/plant (0.320*) (Table 10). It had positive indirect effect through spike/plant (0.031), grains/spike (0.036) and grain filling period (0.007). On the other hand it showed negative indirect effect on grain yield/plant via vegetative period (-0.013) and days to maturity (-0.004).

1000-garin weight

1000-garin weight had high positive direct effect on yield/plant (0.371*) (Table 10). It had positive indirect effect through grains/spike (0.021) and days to maturity (0.005). On the other hand it showed negative indirect effect on grain yield/plant via spikes/plant (-0.139) and grain filling period (-0.014). Bhullar *et al.* (1985) suggested from path analysis that 1000-grain weight was one of the most important yield component in durum wheat.

Vegetative period

Vegetative period had positive direct effect on yield/plant (0.296) (Table 10). It had positive indirect effect through grains/spike (0.349), grains/spike (0.029) and grain filling period (0.018). On the other hand it showed negative indirect effect on grain yield/plant via 1000-grain weight (-0.067) and days to maturity (-0.009). Rahman *et al.* (1983) observed negative direct effects of vegetative period on yield. This disagreement with present findings might be due to environmental variation.

Grain filling period

Grain filling period had positive direct effect on yield/plant (0.092) (Table 10). It had positive indirect effect through spikes/plant (0.276), grains/spike (0.016), and grain filling period (0.018). On the other hand it showed negative indirect effect on grain yield/plant via 1000-grain weight (-0.092) and days to maturity (-0.014).

Days to maturity

Days to maturity had positive direct effect on yield/plant (0.207) (Table 10). It had positive indirect effect through spikes/plant(0.223), grains/spike (0.024), and grain filling period(0.041). On the other hand it showed negative indirect effect on grain yield/plant via 1000-grain weight (-0.093) and harvest index (-0.131).

Khan *et al.* (1994) suggested hybridization programme should include genotypes with greater number of grains/spike, high grain weight and high grain yield to obtain further improvement grain yield in bread wheat.

From this study it was observed that the characters grains/spike, 1000-grain weight and harvest index has positive and significant direct effect on grain yield. So these characters should consider for successful breeding programme.

Chapter 5
Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation was undertaken with a view to evaluating the genotypes and studying of the variation heritability and genetic advance for yield and its different contributing characters, their interrelationship and assessing genetic diversity among the 40 genotypes of wheat. The trial was conducted at the field laboratory of the Department of Genetics and Plant Breeding, Sher-E-Bangla Agricultural University, Dhaka, Bangladesh from November 2012 to April 2013. The ten characters viz. plant height, spikes/plant, spike length, grains/spike. 1000 grain weight, harvest index, vegetative period, grain filling period, days to maturity and grain yield/plant were studied.

5.1. Performance of the Genotypes

The performance of the genotypes of wheat for yield and different yield contributing characters were evaluated. It was observed that there was significant variation for all the characters. Different genotypes were performed better for different characters. The genotype G1 was exceptionally tallest variety (104.28 cm). There is significant variation among the genotypes for spikes/plant. The genotypes G30, G36, G40, G37, G31 and G39 had comparatively higher number of spikes/plant. For grain characters the genotypes G15, G19, G14, G25, G16, G18, G26, G6, G10, G20, G27 and G24 produced bold size grain. Generally varieties with early maturity time are desirable to fit the crop in our short winter season. Study of the performance of the genotypes on this point showed that the varieties G22, G11, G12, G8, G17 and G16 were early maturing required genotypes. They took 104-105 days to maturity. For harvest index, the genotypes G16, G19, G8 and G37 produced highest harvest index. Considering yield and contributing characters it appears that the genotypes G19 (6.54g) and G37 (6.65g) were promising for high yield potentiality. Both genotypes had high grain yield. G19 was also ranked a for harvest index, spike length, grains/spike and 1000-grain weight. It took 105 days to mature. The genotype G37 was best for plant height, effective tillers/plant and grains/ spike. Therefore, these two genotypes could be selected for yield improvement in spring wheat.

5.2. Variation, heritability and genetic advance

High genotypic and phenotypic coefficient of variation was observed for grains/spike, 1000-grain weight, harvest index, grain filling period and grain yield/plant. Spikes/plant exhibited high phenotypic coefficient of variation but its genotypic coefficient of variation was low. The minimum variation was observed for days to maturity.

The same characters were studied for heritability. It was observed that the characters plant height, 1000-grain weight, harvest index, vegetative period and grain yield/plant were highly heritable. Days to maturity, and grain filling period were medium heritable. Plant height was poorly heritable character.

Estimates of genetic advance in percent of mean showed that the characters spikes/plant, harvest index and grain yield/plant exhibited considerably high genetic advance. Grains/spike and 1000-grain weight showed medium genetic advance. The characters vegetative period and days to maturity showed low genetic advance.

Spikes/plant, harvest index and grain yield/plant exhibited high heritability associated with high genetic advance. These characters had also medium to high genotypic coefficient of variation. This indicates that selection on these characters would give good response for yield.

5.3 Genetic Divergence

Genetic divergence among forty genotypes of wheat were studied through Mahalanobis' D^2-statistics and principal component analysis. The genotypes were grouped into seven clusters by using Mahalanobis' D^2-statistics. The cluster I composed of nine genotypes. These were G1, G6, G18, G21, G23, G24, G27, G33 and G34. The cluster II composed of six genotypes namely G2, G3, G4, G5, G13 and G22. The cluster III contained four genotypes namely G7, G8, G10 and G29. The cluster IV consisted of six genotypes; they are G9, G11, G12, G14, G17 and G20. The cluster V contained six genotypes namely G15, G16, G19, G25, G26 and G28. This group produced the highest grain yield/plant. The cluster VI contained six genotypes namely G30, G31, G36, G38, G39 and G40. The cluster VII composed of three genotypes namely G32, G35 and G37.

The highest distance was noticed between the clusters V and VI and it was followed by the distances between clusters VI and VII, II and VI, I and VI, V and VII. The distances between clusters I and IV was the minimum preceded by the distance between clusters II and IV, I and II, I and III, and III and IV.

From this study, it was also observed that the distances among the genotypes of the cluster VII were higher than genotypes of other clusters. It suggests that cluster VII included more diverse materials.

It was observed from cluster means of 10 characters that the cluster V had the high mean values for grain yield/plant, and grains/spike. Medium mean values were for all other characters. It indicates that the high yielding genotypes were included in this cluster.

The genetic diversity of 40 genotypes were also assessed through principal component analysis. The first two components summed to give 59.46% of the total variation. From the scattered diagram revealed that the genotypes G2, G16, G19, G22, G28, G36 and G37 took positions at the periphery of the diagram suggesting that these genotypes were more diverged from the rest of the genotypes. In the first component, the eigen values tor the grain yield/plant were positive and that plant height was negative. This suggests that the first principal component distinguished those genotypes which had higher grain yield/plant but short plant height. In the second principal component the eigen values of both harvest index and grains/spike were negative suggesting these components distinguished those genotypes which had higher grains/spike with higher harvest index.

5.4. Relationship between Yield and Yield Contributing Characters

It was observed that yield/plant was positively and high significantly correlated with grains/spike and harvest index. Grain/spike was positively significant with spike length. 1000-grain weight had significantly positive correlation with harvest index. Vegetative period was positively and significantly correlated with grain filling and days to maturity.

From path coefficient analysis it was observed that among the different yield contributing characters, 1000-grain weight and harvest index contributed maximum to grain yield in positive direction. But genotypic correlation of this characters with grain yield was medium. Among other characters, grains/plant had also high positive and direct effect on yield. Although the character plant height was positively correlated with grain yield but its direct effect on grain yield was negative.

From the findings of the present study, the following conclusions could be drawn:

i. Selection procedure would be applied for desired characters such as lowest days to maturity and increase spikes/plant, number of grains/spike, grain weight, and grain yield/plant.
ii. Wide range of genetic diversity existed among the wheat genotypes. That genetic diversity could be used for future breeding programme of wheat in Bangladesh.
iii. Relatively higher value and lower differences between genotypic co-efficient of variation and phenotypic coefficient of variation of different yield contributing characters like 1000-garin weight, harvest index and yield /plant were observed which indicates high potentiality to select these traits in future which were less affected by environmental influence.

References

CHAPTER VI

REFERENCES

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Appendices

CHAPTER VIII

APPENDICES

Appendix I. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the soil before experimentation

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2012 to March 2013

Month	*Air temperature (^{0}C)		*Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
November, 2012	25.82	16.04	78	00
December, 2012	22.4	13.5	74	00
January, 2013	24.5	12.4	68	00
February, 2013	27.1	16.7	67	30
March, 2013	31.4	19.6	54	11

* Monthly average

* Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka

Appendix III. Mean performance of 40 wheat variety based on different morphological traits related to yield

Variety	Plant height (cm)	Spikes /Plant	Grains/spike	Spikes length (cm)	1000 grain weight (g)
G1	104.28a	3.887f-i	51.33m-r	14.08ghi	33.93nop
G2	78.86h-k	3.217g-l	48.55rst	14.75e-i	34.90mno
G3	79.44h-k	3.550g-j	52.33l-q	14.16ghi	36.78klm
G4	84.57d-h	4.217efg	53.00j-o	14.96d-i	35.77lmn
G5	81.86e-k	3.997fgh	48.33rst	14.18ghi	38.26ijk
G6	86.24d-h	3.443g-k	50.78n-r	16.00c-h	43.85efg
G7	81.71f-k	3.440g-k	52.67k-p	14.92d-i	40.62hi
G8	75.04i-l	3.643g-j	49.33qrs	14.14ghi	39.86hij
G9	83.21d-i	2.773jkl	54.44h-m	15.30c-hi	39.16hijk
G10	79.17h-k	3.110h-l	46.67stu	14.80e-i	44.19ef
G11	89.65c-g	3.220g-l	57.53d-h	15.56c-h	39.53hij
G12	88.71d-g	3.330g-l	60.33bcd	15.84c-h	38.80ijk
G13	85.23d-h	2.440kl	49.67p-s	15.43c-hi	32.65op
G14	85.91d-h	2.663jkl	58.89c-f	15.27c-i	49.95c
G15	98.85ab	2.773jkl	58.33d-g	13.71hi	55.98a
G16	91.35bcd	2.887i-l	51.44m-r	16.74b-f	46.00de
G17	83.40de-i	2.993h-l	55.11g-l	15.54c-h	40.89hi
G18	85.60d-h	2.997h-l	53.64i-n	17.02b-e	45.80def
G19	86.67d-h	3.107h-l	60.22bcd	17.35abc	53.25b
G20	88.68d-g	2.773jkl	58.11d-g	16.37b-g	44.16ef
G21	85.13d-h	3.497g-j	56.44f-i	16.73b-f	39.75hij
G22	86.22d-h	3.220g-l	49.99o-r	14.45f-i	34.41mnop
G23	81.83e-k	2.330l	56.11f-j	13.22i	38.98hijk
G24	82.45d-i	2.830jkl	45.33u	15.19c-i	41.59gh
G25	91.00b-e	3.330g-l	57.00e-h	17.01b-e	47.33d
G26	97.57abc	3.440g-k	60.45bcd	17.14bcd	45.71def
G27	88.77d-g	3.000h-l	60.00b-e	13.74hi	43.40fg
G28	89.16d-g	5.110cde	63.66a	15.61c-h	53.25b
G29	67.83l	5.000cde	50.66n-r	15.06c-i	44.16ef
G30	85.32d-h	8.500a	58.67c-f	16.33b-g	39.75hij
G31	73.56jkl	8.330a	54.66h-l	14.36ghi	32.48op
G32	82.93d-i	2.830jkl	58.00defg	19.18a	35.61lmn
G33	84.15d-h	4.660def	55.33g-l	16.95b-e	40.25hij
G34	90.24c-f	4.000fgh	55.67f-k	15.48c-i	32.16p
G35	84.72d-h	5.330cd	62.66ab	18.45ab	33.50nop
G36	82.17d-j	8.831a	64.66a	16.11c-g	35.60lmn
G37	83.46d-i	7.990a	61.66abc	17.12bcd	39.27hijk
G38	73.08kl	5.830bc	46.00tu	16.28b-g	37.61jkl
G39	81.32f-k	6.660b	62.33ab	15.63c-h	38.65ijk
G40	80.96g-k	8.330a	54.66h-l	14.40ghi	35.29lmn
Mean	84.76	4.19	55.12	15.61	40.58
Mini	67.83	2.33	45.33	13.22	32.16
Maxi	104.28	8.83	64.66	19.18	55.98

Appendix III. (Cont'd) : Mean performance of 40 wheat variety based on different morphological traits related to yield

Variety	Harvest Index (HI)	Vegetative period	Grain Filling Period	Days to Maturity	Grain yield/plant (g)
G1	19.18qr	64.44de	45.67defg	110.1c-i	2.16s
G2	13.18t	63.65e	45.35defgh	109.0d-i	2.82nop
G3	19.33qr	63.44e	44.56efghi	108.0f-i	2.75opq
G4	27.90hij	65.23cde	40.77lmno	106.0hi	2.93no
G5	23.49lmn	65.44bcde	40.56mno	106.3ghi	4.38jk
G6	28.44ghi	67.34abcde	41.66jklmno	109.3d-i	2.95no
G7	39.93d	64.32de	45.68defg	110.0c-i	4.70hi
G8	44.66b	63.76de	41.24klmno	105.0i	4.81h
G9	18.80qr	64.45de	41.55jklmno	106.5ghi	2.48qr
G10	26.58ijk	63.43e	44.57efghi	108.2e-i	5.95cd
G11	21.76nop	63.65e	40.35no	104.4i	4.32jkl
G12	23.58lm	64.77de	40.23no	104.8i	3.46m
G13	33.58f	65.12cde	40.88klmno	106.0hi	4.05l
G14	13.30t	66.43bcde	41.57jklmno	107.9f-i	2.58pqr
G15	37.53e	65.76bcde	41.24klmno	107.3f-i	5.69de
G16	47.34a	64.33de	41.67jklmno	105.9hi	5.40efg
G17	24.19lm	65.23cde	40.77lmno	105.9hi	3.00no
G18	29.91g	65.98bcde	41.02klmno	107.3f-i	3.47m
G19	43.65b	66.32bcde	41.68jklmno	108.3e-i	6.54b
G20	21.40op	64.54de	41.79jklmno	106.5ghi	2.44qrs
G21	26.54jk	65.21cde	42.79hijklmn	108.6ef-i	4.78h
G22	23.08mno	64.33de	39.67o	104.3i	3.56m
G23	28.49gh	66.65abcde	43.35ghijkl	110.0cd-i	3.14n
G24	34.12f	67.43abcde	41.57jklmno	109.1d-i	3.45m
G25	36.84e	65.66bcde	45.34defgh	111.3a-i	5.46efg
G26	27.17hij	64.87de	43.13ghijklm	108.1e-i	7.18a
G27	41.97c	67.12abcde	46.88cde	114.0a-g	3.45m
G28	27.53hij	68.32abcd	44.68efghi	113.5a-h	6.97a
G29	22.46mno	66.32bcde	45.68defg	112.0a-i	6.04c
G30	9.990u	67.23abcde	47.77bcd	115.0a-f	4.43ijk
G31	20.53pq	69.43abc	46.57cdef	116.0a-e	4.23jkl
G32	25.21kl	68.34abcd	45.66defg	114.1a-g	5.24g
G33	28.80gh	67.45abcde	43.55ghijk	111.1b-i	5.57ef
G34	27.49hij	67.89abcde	44.11fghij	112.2a-i	4.87h
G35	18.56r	69.61abc	49.39ab	119.0a	4.12kl
G36	17.92r	68.23abcd	49.77ab	118.4ab	4.46ij
G37	46.92a	69.79ab	42.21ijklmno	112.0a-i	6.65b
G38	14.39st	68.33abcd	50.67a	119.0a	2.33rs
G39	15.26s	69.43abc	48.57abc	117.6abc	6.40b
G40	28.33g-j	70.90a	45.13defgh	116.5a-d	5.33fg
Mean	26.98	66.25	43.73	110.12	4.36
Mini	9.99	63.43	39.67	104.33	2.16
Maxi	47.34	70.90	50.67	119.00	7.18