GENETIC ANALYSIS OF MORPHO-PHYSIOLOGICAL TRAITS OF SPRING WHEAT (*Triticum aestivum*) UNDER DROUGHT STRESS

By

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CERTIFICATE

This is to certify that thesis entitled, "GENETIC ANALYSIS OF MORPHO PHYSIOLOGICAL TRAITS OF SPRING WHEAT (Triticum aestivum) UNDER DROUGHT STRESS " *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 fide research work carried out by* ***Aysha Chowdhury****, Registration No:* **07-02538** *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 has been availed of during the course of this investigation has duly been acknowledged.

(Dr. Jamilur Rahman)
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Dated:
Place: Dhaka, Bangladesh

DEDICATED
TO
MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted during the period from November 2013 to April 2014 in rabi season in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to unravel the role of morpho-physiological characters in spring wheat under drought stress. In this experiment 30 wheat genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. During the experimental period no irrigation was provided for creating drought environment. Mean performance, variability, correlation matrix and path analysis were estimated on different yield contributing characters and yield of wheat genotypes. The longest plant (84.00 cm) was recorded in genotype Sonalika, while the shortest plant (53.33 cm) in the wheat genotype BD-489. The highest grain yield per plant (9.02 g) was recorded in Sonalika, while the lowest (5.24 g) in BD-489. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits. In correlation study, significant negative association was recorded for grain yield per plant of wheat genotypes with days to starting of heading (-0.265), days to starting of maturity (-0.267) and root number (-0.343), while the non significant negative association for number of grains/spike (-0.183), chlorophyll content (-0.097), dry matter content (-0.003) and root length (-0.058). On the other hand, significant positive association was recorded for grain yield per plant with plant height (0.688), number of spike/m^2 (0.269), number of spikelts/spike (0.630), peduncle length (0.640) and weight of 1000 grains (0.201), while non significant positive association was observed with leaf area index (0.007). Path analysis revealed that days to staring of heading, plant height, number of spike/m^2, number of spikeklets/spike, number of grains/spike, dry matter content, peduncle length and weight of 1000 grains had positive direct effect on yield per plant, on the other hand, days to starting of maturity, chlorophyll content, leaf area index, root length and root number had negative direct effect on yield per plant. In consideration of yield contributing characters and yield Sonalika performed better under drought condition followed by BD-7617, BARI Gom-25, BARI Gom-23 and BD-7650.

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- **Introduction**

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the family Graminae is an important food crop and primarily grown across the exceptionally diverse range of environments (WRC, 2009). The largest area of wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh, India and Nepal (Dubin and Ginkel, 1991). Importance of wheat crop may be understood from the fact that it covers about 42% of total cropped area in rice-wheat system in South Asia (Iqbal *et al.*, 2002). It contributes to the national economy by reducing the volume of import of cereals for fulfilling the food requirements of the country (Razzaque *et al.*, 1992). In Bangladesh, wheat occupies above 4% of the total cropped area and 11% of the area cropped in rabi and contributes 7% to the total output of food cereals (Anon., 2008). Generally wheat supplies carbohydrate (69.60%), protein (12%), fat (1.72%), and also minerals (16.20%) and also other necessary nutrients in trace amount (BARI, 1997).

In Bangladesh wheat was becoming a highly desirable food supplement to rice but our country become highly dependent on wheat imports while dietary preferences were changing. Domestic wheat production rose to more than 1 million tons per year, but was still only 7-9% of total food grain production (BARI, 2010). Wheat cultivation has been increased manifolds to meet up the food shortage in the country. But, in spite of its importance, the yield of the crop in the context of our country is low (2.2 t ha^{-1}) in comparison to other wheat growing countries of the world (FAO, 1997). At present about 706.33 thousand hectares of land in Bangladesh is covered by wheat with the annual production of 1,592 thousand tons (BBS, 2012). Although the area, production and yield of wheat have been increasing dramatically based on the demand of over increasing population of Bangladesh during the last two decades, but its present yield is too low in comparison to some developed countries like Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 tha^{-1}, respectively (FAO, 2000).

Yield of wheat are very low in Bangladesh and this low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, water availability or draught stress as delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors, seeds of high yielding varieties and water availability or draught stress are the major reasons of yield reduction. Drought is the most common factor that limits the productivity of wheat crops in Bangladesh. On an average, 44% of farmers of Bangladesh do not use irrigation in wheat production and rely entirely on rainfall (Tarafder, 2001) which is responsible for reduction of yield by 34% (Razzaque *et al.*, 1992). Fischer (1999) showed that under drought, yield reduction in spring wheat is on average of 60% of productivity. So efforts to identify drought tolerance characters among the existing varieties/lines to incorporate the tolerance character into the newly developed varieties are an important aspect to increase the yield of wheat in the climatic condition of Bangladesh.

Good quality wheat variety for producing maximum yield plays an important role and for that efforts were taken to increase the yield of wheat in Bangladesh by releasing high yielding varieties. In varietal demonstration at different districts of Bangladesh revealed that mean yield of Kanchan, Akbar, Agrani and Sonalika were 3.59, 3.29, 3.12 and 2.81 t ha^{-1}, respectively (BARI, 1993) with different prevailing environment condition during the growing season. Already BARI has released some semi-dwarf high yielding varieties which increase the popularity of wheat to farmers as they yield average 2.94 (BARI, 2012). More recently WRC of BARI has released BARI gom-27 and BARI gom-28 but still there is scope to improve the yield of wheat. Climate and weather conditions greatly influence the performance of new wheat cultivars both for yield and quality (Wajid *et al.*, 2004; Sharma *et al.*, 2006; Abdullah *et al.*, 2007). But still now information of different wheat variety to optimize the wheat production within the farmer's limited resources is inadequate in Bangladesh.

The knowledge of relationship between yield and yield contributing characters is important for planning any yield improvement program. In breeding program, correlation study provides reliable and useful information for the nature, extent and direction of selection. With the inclusion of more variables in the correlation study, indirect effect becomes complex (Nandan and Pandya, 1980). So, the path coefficient analysis helps the breeder to explain direct and indirect effects and it has been extensively used by various researchers (Green, 1980; Marinkovic, 1992 and Ali *et al.*, 2002). Path coefficient which is a partial regression coefficient specifies the importance of each variable. Relationship between yield and yield contributing characters in wheat has been studied through genotypic correlation accompanied with path coefficient analysis by many authors in different wheat genotypes (Das and Mondal, 1984 and Uddin, 1998). Findings out the selection indices which would give the most appropriate weightage to the phenotypic values of each of two or more characters are important for selection. Discriminate function for selecting simultaneously several characters, has proved to be very useful in such situation in crop improvement program.

So in the context of the above mentioned situation and in respect of wheat cultivation in Bangladesh, the present piece of work was undertaken with 30 wheat genotypes for fulfilling the following objectives-

- To assess the genetic variation among the genotypes for yield and different morpho-physiological traits in drought stress condition,
- To know the relationship among different morpho-physiologicaltraits and yield in drought stress condition,
- To assess the genetic variability of the genotypes in drought condition andp
- To select and isolate the potential drought tolerant genotype(s) for future breeding program.

chapter

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Review of Literature

CHAPTER II

REVIEW OF LITERATURE

One of the major reasons of yield reduction of wheat is that about 60% of the crop is cultivated at late sowing dry condition after harvesting the transplanted aman rice and selection of suitable variety for different agro-climatic condition. So moisture availability or drought stress and subsequently variety are the most important factors need to be considered in wheat cultivation. Some of the important and informative works and research findings related to the water availability or draught stress and variety of wheat done at home and abroad have been reviewed under the following headings:

2.1. Influence of water availability or draught stress on wheat

In Bangladesh generally, wheat is grown during Rabi (winter) season and it is dry and as such, the inadequate soil moisture in this season limits the use of fertilizers, and consequently results in decreased grain yield. Moisture as well as water is the most important agronomic factor that affects the growth and development of plants. Research works done at home and abroad showed that water availability and stress greatly influences yields of wheat. The yield and yield parameters of wheat varied due to the prevailing water availability and stress during pre-antesis and post-anthesis development. Some of the pertinent literatures regarding effect of water availability and stress in home and abroad have been presented below-

Plant height

Islam (1997) reported that plant height increased with increasing number of irrigations. The maximum plant height was obtained by three irrigations applied at 25, 50 and 70 days after sowing.

Gupta *et al.* (2001) reported that plant height decreased to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in plant height. Among the yield attributes plant height were positively correlated with grain and biological yield irrigation at the anthesis stage.

Wang *et al.* (2002) conducted a pot experiment in a green house to study the effects of water deficit and irrigation at different growing stages of winter wheat and observed that water deficiency retarded plant growth.

Wang *et al.* (2009) to investigate the effects of different irrigation and N supply levels on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farmlands with an accurate management system with irrigation regimes [0.6, 0.8 and 1.0 estimated wheat evapotranspiration (ET)] and N fertilizer application rates. Under the experimental conditions, irrigation and N has relative low effects on plant height.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al.* (2011) and found that the effect of irrigation on plant height, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better. The wheat yield was increased by 2.54%-13.61% compared to control and the treatments, irrigation of 900 m^3/ha at the elongation stage and of 450 m^3/ha at the booting stage or separate irrigation of 900 m^3/ha at the two stage were the highest.

Spike, grains and 1000-grains weight

This study was carried out by Baser *et al.* (2004) to determine the influence of water deficit on yield and yield components of winter wheat. The treatments included an unstressed control (S_0), water stress at the late vegetative stage (S_1), at the flowering stage (S_2), or at the grain formation stage (S_3) and full stress (non-irrigation S_4). The effects of water stress treatments on yield components were statistically significant compared with non-stressed conditions.

Twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in a field experiment conducted by Zarea and Ghodsi (2004) in Iran and found that number of spike/m^2 and 1000-kernel weight decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied, number of spike/m^2 were higher in cultivars C-75-14 and C-75-9.

The study was carried out by Mangan *et al.* (2008) to evaluate the performance of yield and yield components traits of wheat genotypes under water stress conditions. Four wheat varieties were screened under water stress conditions at Nuclear Institute of Agriculture (NIA) Tandojam. Different irrigation treatments (1, 2, 3 and 4) were applied during various crop growth stages. Yield contributing traits of wheat varieties were significantly affected under water stress conditions. Except spike yield, Sarsabz had significantly more 1000-grain weight, main spike yield and grains spike^{-1} as compared to other varieties over all irrigation treatments; hence more tolerant to drought. 1000-grain weight ranged between 28.1-41.8 g in four treatments.

Two field experiments with winter wheat were made by Zhao *et al.* (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Irrigation frequency and N application rate had considerable influences on total number of culms, which was significantly higher in W_1, W_2 and W_3 than in W_0, while no significant difference existed among W_1, W_2 and W_3. The effects of irrigation frequency on spike number per ha and 1000-grain-weight were statically significant, and the effects of N rate on spike number per ha and grain number per spike were significant.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during Rabi seasons. The I_2 treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. Progressive increase in number of irrigations from 1 to 4 increased various yield contributing characters viz., effective tillers m^{-2}, ear length, no. of grains ear^{-1} and test weight while three and four irrigations were found statistically at par with each other.

Field trials were conducted by Malik *et al.* (2010) to estimate the effect of number of irrigations on yield of wheat crop in the semi arid area of Pakistan. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T_2), while 1000-grains weights were not affected significantly.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al.* (2011) and found that the soil was obviously short of moisture when the irrigation was managed in the former stage, and the layer of 20-40 cm was the lowest one in all of the layers. The group dynamics, the volume of spikes per hectare and the tiller volume of single plant were improved under national compensative irrigation. The spike volume per ha, the tillers and spikes per plant were increased by 16,500-699,000, 0.12-1.16 and 0.01-0.11, respectively. For the effect of irrigation on spike length and spike grains, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better.

Grain yield

Sah *et al.* (1990) found the maximum grain yield of wheat with two irrigations but the maximum grain protein content was obtained with three irrigations. Sharma (1993) obtained higher yield with three irrigations given at CRI, tillering and milking stages of wheat than other treatments with three irrigations. They also found maximum water use efficiency with three irrigations given at CRI, tillering and milking stages.

Upadhyaya and Dubey (1991) conducted an experiment in India with three irrigation frequencies as- one irrigation (at CRI stage), two irrigations (on each at CRI and booting stage) and four irrigation (one each at CRI, booting, flowering and milking stages). Four irrigations produced the maximum grain yield, which was significantly higher than one to two irrigations. The increased yield was due to the favourable effect of treatments on yield attributing characters.

BARI (1993) reported that maximum grain yields were recorded with the application of three irrigations, applied at CRI, maximum tillering and grain filling stages. Irrigation given at CRI+ Maximum tillering (MT), CRI + Booting (BT) and CRI + Grain filling (GR) were at per in respect of number of spikes/m^2 and grains/spikes, but had higher spikes and grains over CRI + MT stages.

Yadav *et al.* (1995) reported that two irrigations scheduled at CRI (Crown Root Initiation) and milk stages gave the maximum plant height (1.026 m), maximum number of grain/ear (65) and grain yield (3158 kg/ha) of wheat.

Islam (1996) observed that irrigation significantly influenced the grain yields but it had no influence of grains per ear and 1000-grain weight. The highest grain yield (3.71 t/ha) was obtained with three irrigations (25, 45 and 60 DAS) and the lowest with no irrigations (2.61 t/ha) was obtained.

Naser (1996) reported that the effect of different irrigations on yield and yield attributing characters were statistically significant. Two irrigations at 30 and 50 DAS significantly increased grain yields over control. The highest grain yields, the maximum number of tillers per plant, the highest spike length, and the maximum number of grains per spike were recorded when two irrigations were applied. The control treatment showed the lowest result in all plant parameters.

Razi-us-Shams (1996) observed that the effect of irrigation treatments on yield and yield contributing characters (cv. Sonalika) were statistically significant. Irrigation increased the grain yields, number of tillers, panicle length, and number of grains per panicle over the control.

Meena *et al.* (1998) conducted a field experiment during 1993-95 at New Delhi on bread wheat (cv. HD 2265) with no irrigation or irrigation at flowering and/or crown root initiation stages and reported that wheat grain yield was the highest with 2 irrigations (2.57 t/ha in 1993 and 2.64 t/ha).

A field experiment was conducted by Ghodpage and Gawande (2001) in Akola, Maharashtra, India, during rabi to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations) at various physiological growth stages of late-sown wheat in Morna command area. The maximum grain yield of 2488 kg/ha was obtained in 6 irrigations treatment and it was significantly superior over all other treatments. In general, there was consistent reduction in grain yield due to missing irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, missing irrigation at tillering and milking stages resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, milking and dough stages, recording 29.30% yield reduction. Approximately 50% loss in grain was observed when irrigation was missed at tillering, flowering, milking and dough stages.

Debelo *et al.* (2001) conducted a field experiment in Ethiopia on bread wheat and reported that plant height and thousand-kernel weight showed positive and strong association with grain yield, indicating considerable direct or indirect contribution to grain yield under low moisture conditions.

Gupta *et al.* (2001) reported that grain yield and biological yield decreased to a greater extent when water stress was imposed at the anthesis stage and irrigation at the anthesis stage whereas leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

Wang *et al.* (2002) conducted a pot experiment in a green house to study the effects of water deficit and irrigation at different growing stages of winter wheat and observed that irrigation increased yield of wheat significantly than under control condition.

Zhai *et al.* (2003) conducted a pot experiment with winter wheat to determine water stress on the growth, yield contributing characters and yield of wheat and they reported that water stress significantly inhibited the yield of winter wheat.

Twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in a field experiment conducted by Zarea and Ghodsi (2004) in Iran and found that grain yield decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied grain yield were higher in cultivars C-75-14 and C-75-9.

This study was carried out by Baser *et al.* (2004) to determine the influence of water deficit on yield and yield components of winter wheat under Thrace conditions (Turkey). The treatments included an unstressed control (S_0), water stress at the late vegetative stage (S_1), at the flowering stage (S_2), or at the grain formation stage (S_3) and full stress (non-irrigation S_4). The effects of water stress treatments on grain yield were statistically significant compared with non-stressed conditions. Grain yield under non-irrigated conditions was reduced by approximately 40%.

The study was carried out by Mangan *et al.* (2008) to evaluate the performance of yield and yield components traits of wheat genotypes under water stress conditions. Four wheat varieties were screened under water stress conditions at Nuclear Institute of Agriculture (NIA) Tandojam. Different irrigation treatments (1, 2, 3 and 4) were applied during various crop growth stages. Grain yield of wheat varieties were significantly affected under water stress conditions. Grain yield ranged between 373 kg ha^{-1} in single irrigation treatment to 3931 kg ha^{-1} in four irrigations.

Gao *et al.* (2009) conducted a field experiment to determine the reasonable and effective water-saving irrigation schemes in wheat production, the commercial wheat cvs Shannong 15 and Yannong 21 were grown in in China and subjected to 3 water irrigation treatments: W_0 (with a relative water content of 60% in the 0-140 cm soil layer at the jointing stage and 55% at anthesis), W_1 (75% at the jointing stage and 65% at anthesis) and W_2 (75% at the jointing stage and 75% at anthesis). The highest irrigation water use efficiency was recorded in W_1 and the highest grain yield and water use efficiency (WUE) were achieved in W_2 for both cultivars. Under the conditions of this experiment, W_2 was the optimum water management treatment, which was beneficial to both of grain yield and WUE.

Two field experiments with winter wheat were made by Zhao *et al.* (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Irrigation frequency and N application rate had considerable influences on total number of culms, which was significantly higher in W_1, W_2 and W_3 than in W_0, while no significant difference existed among W_1, W_2 and W_3. The effects of irrigation frequency on spike number per ha and 1000-grain-weight were statically significant, and the effects of N rate on spike number per ha and grain number per spike were significant. Grain yield was the highest in W_3 and the lowest in W_0, and the highest in N_1 and the lowest in N_0.

Two field experiments with winter wheat were made by Zhao *et al.* (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Grain yield was the highest in W_3 and the lowest in W_0.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during Rabi seasons. The I_2 treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. The highest grain yield (40.65 q ha^{-1}) was credited to I_4 that was significantly superior over I_1 and I_2 but non-significant with I_3.

Field trials were conducted by Malik *et al.* (2010) to estimate the effect of number of irrigations on yield of wheat crop. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the grain yield were significantly higher when crop was irrigated with five irrigations (T_2). The highest grain yield was recorded with five irrigations at different critical growth stages of wheat crop.

In view of the importance of wheat, less available and costly P fertilizer and shortage of water a field study was conducted by Rahim *et al.* (2010) under farmer's field conditions to see the effect of phosphorus application and irrigation scheduling on wheat yield. Four irrigations i.e. 0, 2, 3, 4 were applied at critical stages of wheat and found that three irrigations at crown roots, booting, and grain development stages were sufficient to get maximum yield.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al.* (2011) and found that the wheat yield was increased by 2.54%-13.61% compared to control.

2.2 Influence of variety on wheat

Good quality wheat variety for producing maximum yield through highest yield contributing characters that plays an important and major role for wheat production. Some of the pertinent literatures regarding wheat variety/genotypes from country and abroad have been presented below-

Plant height

Islam *et al.* (1993) evaluate the performance of the existing (Sonalika) and released wheat varieties (Ananda, Kanchan, Barkat, Akbar, Aghrani) seeded from 1 November to 15 January at 15 days interval and reported that plant height were significantly affected by variety.

Litvinrnko *et al.* (1997) produced winter wheat with high grain quality for bread making in Southern Ukraine and reported that plant height itself governed by genetically.

Sulewska (2004) carried out an experiment with 22 wheat genotypes for comparing vegetation period, plant height, number of stems and spikes, yield per spike. He noticed a tallest plant due to variety. He also reported that the variety Waggershauser, Hohenh, Weisser, Kolben gave the tallest plant.

Qasim *et al.* (2008) reported the growth and yield response of three wheat varieties (Suliman-96, Chakwal-97 and Inqalab-91) to various sowing times when they studied an experiment at Karakoram Agricultural Reserch Institute, (Norther Areas) Gilgit, Pakistan and reported that plant height varied for different cultivars of wheat.

A study was undertaken by Khokhar *et al.* (2010) to determine the effects of planting dates on growth and yield of different wheat genotypes in Sindh. Four sowing dates and six wheat genotypes (V-7001, V-7002, V-7004, MPT-6, Abadgar-93, and Anmol-91) were used. Better plant growth was recorded in for wheat genotype, V-7002.

A pot experiment was carried out by Al-Musa *et al.* (2012) at Patuakhali Science and Technology University to study the performance of some BARI wheat varieties under the coastal area of Patuakhali. Four wheat varieties viz. BARI ghom-23, BARI ghom-24, BARI ghom-25 and BARI ghom-26 were planted in the field to evaluate their comparative performance. Among the BARI varieties, BARI ghom-26 produced the taller plant (47.91 cm).

A study was undertaken by Mohsen *et al.* (2013) to determine the effects of sowing dates on growth and yield components of different wheat cultivar in Iran. Five sowing dates and five wheat cultivars (Pishgam, Parsi, Bahar, Sivand and Pishtaz) were used in this experiment. Results showed that the effect of cultivars was significant on all parameters.

Iranian winter wheat cultivars and their response to delay sowing date were investigated as a field experiment by Yajam and Madani (2013). The experiment designed with four winter wheat cultivars namely B.C. Roshan, Alvand, Amirkabir and Shahriar and six sowing date from very early to very late sowing time. The results showed significant differences between cultivars the first in relation to plant height.

A field experiment was conducted by Zia-Ul-Hassan *et al.* (2014) to evaluate the response of high yielding varieties against varying sowing dates under rainfed conditions at Adaptive Research Farm, Bhaun, Chakwal. Treatments were four sowing dates and five varieties, viz. GA 2002, Chakwal 50, Farid 2006, Wafaq 2001 and Sehar 2006). The results showed that varieties remained significant in consideration of plant height.

Spike, grains and 1000-grain weight

Al-Khatib and Paulesn (1990) evaluated the yield performance of 10 wheat genotypes grown under moderate (22/17^{0}C, day/night) and high (32/7^{0}C, day/night) temperature. Yield component of 10 genotypes at maturity reacted differently to high temperature. Spike per plant significantly decreased in 3 genotypes and increased in one genotype as the temperature increased where as kernel per spike decreased in four genotypes. Kernel weight decreased significantly in all genotypes, whereas the reduction range was about 10% to 30%.

Wheat variety HD 2428 and Kalyansona were compared by Shukla *et al.* (1992) for adaptability under pot culture by exposure to high temperature treatments (8^0C above) ambient in week 1 though 4 after anthesis. Dry matter accumulation of grain in the top, middle and bottom spikelets of the spike, at 7-grain locations was recorded in weeks 2 and 3. The treatments adversely affect grain weight for HD2428 at all 3 spikelet positions, with up to 35% reduction in the first 5 grain location. Kalyansona was only marginally affected.

Islam *et al.* (1993) evaluate the performance of the existing (Sonalika) and released wheat varieties (Ananda, Kanchan, Barkat, Akbar, Aghrani) seeded from 1 November to 15 January at 15 days interval. Spike/m^2, grain/spike and 1000-grain weight were significantly affected by variety.

WRC (2003) of Bangladesh conducted an experiment in the Wheat Research Centre Nashipur, Dinajpur to examine the performance of genotypes among various tillage operations and to understand the effects of interaction between genotypes and tillage operations. Two cultivation methods were applied in the main plot and 10 wheat genotypes (Kanchan, Gourav, Shatabdi, Sourav, BAW 1008, BAW 1006, BAW 1004, BAW 969, BAW 968 and BAW 966) were tested in the sub plots. The genotypes showed a wide range of variation for yield related characters. Variety Shatabdi produced maximum grain spike^{-1} and 1000 grain weight.

Sulewska (2004) carried out an experiment with 22 wheat genotypes for comparing vegetation period, plant height, number of stems and spikes, yield per spike. He reported that the variety Waggershauser, Hohenh, Weisser, Kolben gave the longest spike.

A study was undertaken by Khokhar *et al.* (2010) to determine the effects of planting dates on growth and yield of different wheat genotypes in Sindh. Four sowing dates and six wheat genotypes (V-7001, V-7002, V-7004, MPT-6, Abadgar-93, and Anmol-91) were used. Better number of grain per unit area and grain weight were recorded in for wheat genotype, V-7002.

A pot experiment was carried out by Al-Musa *et al.* (2012) at Patuakhali Science and Technology University to study the performance of some BARI wheat varieties under the coastal area of Patuakhali. Four wheat varieties viz. BARI ghom-23, BARI ghom-24, BARI ghom-25 and BARI ghom-26 were planted in the field to evaluate their comparative performance. Among the BARI varieties, BARI ghom-26 produced the maximum grains spike^{-1} (38.52) and higher weight of 1000-grains (49.38 g).

Iranian winter wheat cultivars and their response to delay sowing date were investigated as a field experiment by Yajam and Madani (2013). The experiment designed with four winter wheat cultivars namely B.C. Roshan, Alvand, Amirkabir and Shahriar and Sub plots were six sowing date from very early to very late sowing time. The results showed significant differences between cultivars the first.

A study was undertaken by Mohsen *et al.* (2013) to determine the effects of sowing dates on growth and yield components of different wheat cultivar in Iran. Five sowing dates and five wheat cultivars (Pishgam, Parsi, Bahar, Sivand and Pishtaz) were in sub plots. Results showed that the effect of cultivars was significant on all parameters excluding 1000 grain weight. Maximum number of grain spike^{-1} related to Pishtaz cultivar.

A field experiment was conducted by Zia-Ul-Hassan *et al.* (2014) to evaluate the response of high yielding varieties against varying sowing dates under rainfed conditions at Adaptive Research Farm, Bhaun, Chakwal. Treatments were four sowing dates and five varieties, viz. GA 2002, Chakwal 50, Farid 2006, Wafaq

2001 and Sehar 2006). The results showed that varieties remained significant on spike length, spikelets per spike and grains per spike.

Field experiments were conducted by Suleiman *et al.* (2014) at the Demonstration Farm of College of Agriculture, University of Bahri to assess the performance of different wheat cultivars under different sowing dates. The experiment comprised of four dates of sowing and five wheat cultivars namely, Al Nilein, Debiera, Imam, Sasaraib, and Wad el Neil in subplots. The cultivar Imam and Wad el Neil scored the first rank in number of grains spike^{-1}.

Grain yield

Islam *et al.* (1993) evaluate the performance of the existing (Sonalika) and released wheat varieties (Ananda, Kanchan, Barkat, Akbar, Aghrani) seeded from 1 November to 15 January at 15 days interval. Grain were significantly affected by variety.

In varietal demonstration at different districts of Bangladesh BARI (1993) reported that mean yield of Kanchan, Akbar, Agrani and Sonalika were 3.59, 3.29, 3.12 and 2.81 t ha^{-1}, respectively. Variety Kanchan, Akbar, Aghrani showed 28, 17 and 12% higher grain yield over check variety Sonalika.

Samson *et al.* (1995) reported that among the different varieties the significant highest grain yield (3.5 t ha^{-1}) was produced by the variety Sowghat which was closely followed by the variety BAW-748. Other four varieties namely Sonalika, CB-84, Kanchan and Seri-82 yielded 2.70, 2.83, 3.08 and 3.15 t ha^{-1}, respectively.

Arbinda *et al.* (1994) observed that the grain yield was significantly affected by different varieties in Bangladesh. The genotypes CB-15 produced higher grain yield (3.7 t ha^{-1}) that was attributed to more number of spikes m^{-2} and grains spike^{-1}.

Litvinrnko *et al.* (1997) produced winter wheat with high grain quality for bread making in Southern Ukraine. Wheat breeding was started more than 80 years ago.

Over this time, seven wheat varieties were selected where yield potential increased from 2.73 to 6.74 t ha^{-1}.

BARI (2003) tested performance of different varieties of wheat and found Shatabdi produced the highest yield (2.72 t ha^{-1}) followed by Gourav (2.66 t ha^{-1}). The lowest yield was produced by Kanchan (2.52 t ha^{-1}).

WRC (2003) of Bangladesh conducted an experiment in the Wheat Research Centre Nashipur, Dinajpur to examine the performance of genotypes among various tillage operations and to understand the effects of interaction between genotypes and tillage operations. Two cultivation methods were applied in the main plot and 10 wheat genotypes (Kanchan, Gourav, Shatabdi, Sourav, BAW 1008, BAW 1006, BAW 1004, BAW 969, BAW 968 and BAW 966) were tested in the sub plots. The genotypes showed a wide range of variation for yield and related characters. Under bed condition, all the genotypes significantly produced higher grain yield except Gourav and Sourav.

Jalleta (2004) conducted an experiment in farmer's level with a number of improved bread wheat varieties for production in the different climatic zones. Farmers identified earliness, yield and quality as the main criteria for adaptation of wheat varieties and they found that the variety HAR-710 gave 2.56 t ha^{-1} and PAVON-76 gave 2.49 t ha^{-1} grain yield.

Sulewska (2004) carried out an experiment with 22 wheat genotypes for comparing vegetation period, plant height, number of stems and spikes, yield per spike. He noticed a greater variability of plant and spike productivity and of other morphological characters due to variety. He also reported that the variety Waggershauser, Hohenh, Weisser, Kolben gave the highest economic value among the tested genotypes as well as yield.

Maiksteniene *et al.* (2006) carried out a field experiment at the Lithuanian Institute of Agriculture's Joniskelis Experimental Station to estimate the changes in productivity and quality indicators of winter wheat varieties. The tests involved: Ada and Bussard (with very good food qualities), Lars and Tauras (with satisfactory food qualities) varieties. The higher grain yield was produced in varieties with satisfactory food qualities compared with those with very good food qualities.

Growth and yield response of three wheat varieties (Suliman-96, Chakwal-97 and Inqalab-91) to various sowing times was studied by Qasim *et al.* (2008) at Karakoram Agricultural Reserch Institute, (Norther Areas) Gilgit, Pakistan and recorded the Suliman-95 topped in grain yield (4243.75 kg ha^{-1}).

A study was undertaken by Khokhar *et al.* (2010) to determine the effects of planting dates on growth and yield of different wheat genotypes in Sindh. Four sowing dates and six wheat genotypes (V-7001, V-7002, V-7004, MPT-6, Abadgar-93, and Anmol-91) were used. Better tillering, plant growth, growth period, number of grain per unit area and grain weight were recorded in for wheat genotype, V-7002 had significantly higher grain yield of 5578 kg ha^{-1} in comparison with other genotypes, whereas V-7004 had minimum grain yield of 4716 kg ha^{-1} in comparison with other genotypes.

The study was conducted by Anwar *et al.* (2011) to determine the proper time of sowing for promising wheat genotypes and to compare their yield behavior with already approved cultivars. Four already approved varieties of wheat i.e. Inqilab-91, Uqab-2000, Shafaq-2006, Seher-2006 and eight new promising lines i.e. V-03079, V-04188, V-04189, V-03094, V-03138, V-04022, V-04112 and V-04178 were sown at six sowing dates. Most of the genotypes produced lesser yield at later sowing dates; however this response was different amongst genotypes.

Refay (2011) conducted an investigation aimed to study the influences of genotypes, sowing dates and their interaction on grain yield and yield component characters of bread wheat. Two promising lines viz., KSU-105; KSU-106 and introduce cv. Yecora Rojo, as well as two planting dates were selected. Result revealed that KSU-106 surpassed the other two genotypes by 2.0% and 11.3%.

Al-Musa *et al.* (2012) carried out a study at Patuakhali Science and Technology University to study the performance of some BARI wheat varieties under the coastal area of Patuakhali. Four wheat varieties viz. BARI ghom-23, BARI ghom-24, BARI ghom-25 and BARI ghom-26 were planted in the field to evaluate their comparative performance. Among the BARI varieties, BARI ghom-26 produced the higher grain (3.35 t ha^{-1}) yield.

A study was undertaken by Mohsen *et al.* (2013) to determine the effects of sowing dates on growth and yield components of different wheat cultivar in Iran. Five sowing dates and five wheat cultivars (Pishgam, Parsi, Bahar, Sivand and Pishtaz) were used. Results showed that Parsi cultivar has the highest seed yield (10.23 t ha^{-1}) and the Pishtaz cultivar has the lowest seed yield (8.59 t ha^{-1}).

Rita Costa *et al.* (2013) conducted a study to determine the effects of sowing date and seeding rate on grain yield and test weight of fifteen bread wheat varieties and five advanced lines from Portuguese under irrigated Mediterranean systems at two locations of Southeast Portugal. Comparing the results obtained in the two studied locations, Beja showed, for the majority of the varieties, 3.0 t ha^{-1} higher average yields than Elvas.

Field experiments were conducted by Suleiman *et al.* (2014) to assess the performance of different wheat cultivars under different sowing dates. The experiment comprised of four dates of sowing and five wheat cultivars namely, Al Nilein, Debiera, Imam, Sasaraib, and Wad el Neil in subplots. The cultivar Imam and Wad el Neil scored the first rank in grain yield t ha^{-1}.

A field experiment was conducted by Zia-Ul-Hassan *et al.* (2014) to evaluate the response of high yielding varieties against varying sowing dates. Treatments were four sowing dates and five varieties, viz. GA 2002, Chakwal 50, Farid 2006, Wafaq 2001 and Sehar 2006. The results showed yields were reduced by 19.7%, 21.5%, 12.4% and 3.2%, by wheat varieties GA 2002, Farid 2006, Wafaq 2001 and Sehar 2006, respectively, as compared with wheat variety Chakwal 50.

2.3 Genetic variability for yield contributing characters and yield of wheat

Inheritance of yield and yield contributing characters are quantitative in nature and are highly influenced by environment. So, it is necessary to separate the total phenotypic variation into its heritable and non heritable components. Genotypic coefficient of variation and heritability are the important parameters indicating the heritable nature of the characters. Both parameters are also related to response to selection. A character with high phenotypic coefficients of variation and high heritability gives high response to selection. Heritability for grain yield and its different contributing characters are reviewed here in relation to analysis the genetic advance for them.

Kadir (1997) reported high heritability accompanied by high genetic advance for number of grains per spike and 100-grain weight in wheat. Mehta *et al.* (1998) estimated moderate heritability for number of grains per spike but high for 100-grain weight.

Moderate heritable nature for plant height was also reported by Mehta *et al.* (1998). Camargo and Ferreira (1999) conducted an experiment with spring wheat genotypes and estimated moderate to high narrow sense heritability associated with high genetic advance for plant height.

Gupta and Verma (2000) found high genetic advance with heritability for plant height, number of grains per ear in bread wheat. They also observed high heritability and genetic advance for grain yield per plant. High heritability and high genetic advance were observed by Shukla *et al.* (2000) for grain yield per plant, 1000-grain weight and harvest index.

Ghimiray and Sarkar (2000) estimated high heritability coupled with high genetic advance for spikes per plant on the other hand, spikes per plant was poorly heritable character as reported by Kamboj *et al.* (2000)

Sarkar *et al.* (2001) carried out an experiment with 15 genetically diverse wheat genotypes and he observed high broad sense heritability for days to flowering, plant height, spike length and spikelets per spike.

Sharma and Garg (2002) carried out an experiment with 19 parental cultivars and 60 cross of wheat under normal and saline environments and found high heritability coupled with high genetic advance for number of days to heading, plant height, number of spikes per plant, grains per spike, 1000-grain weight and grain yield per plant.

Kumar and Shukla (2002) observed high heritability coupled with high genetic advance for plant height, number of spikelets per spike and 1000-kernel weight. They also reported that the number of spikes had low heritability coupled with low genetic advance and harvest index and grain yield per plant had low heritability coupled with high genetic advance.

Salender Kumar *et al.* (2003) found high genetic advance for number of days to 50% heading, plant height, number of spikelets per ear, 1000-grain weight in bread wheat. Mahantashivayogayya *et al.* (2003) reported high genetic advance for spikelets per spike, grains per spike and 100-seed weight.

Hamada (2003) noticed that a moderate value of heritability (broad sense and narrow sense) for number of spikes per plant. High values of heritability for spike length, number of kernels per spike, 1000-kernel weight and grain yield per plant were also reported by him. Wang *et al.* (2003) observed very high broad sense and narrow sense heritability for plant height and grain yield per plant in bread wheat.

Gupta *et al.* (2004) conducted high heritability with high genetic advance for plant height, number of spikes per plant and grain yield per plant in bread wheat. Pramad Kumar and Mishra (2004) conducted an experiment with 30 diverse bread wheat cultivars and found high heritability with high genetic advance in percentage of mean for plant height, spikes per plant, spikelets per spike and 1000-grain weight.

Hassani *et al.* (2005) carried out a study with a diallel cross of 8 bread wheat and observed high narrow sense heritability for days to flowering, spike length, spikelets per spike and grains per spike, 100-grain weight. They also observed low narrow sense heritability for grain yield per plant. Shahnaz Memon *et al.* (2005) reported the high genetic advance for plant height and spikelets per spike.

Ismail *et al.* (2006) carried out an experiment in Egypt with 15 F_1 obtained from a half diallel cross of 6 bread wheat varieties under moisture stress and non-stress conditions. They found high broad sense heritability for days to flowering, spikes per plant, spikelets per plant, number of grains per spike, 100 grain weight, harvest index and grain yield per plant in favorable soil moisture condition.

Fida Mohammed *et al.* (2006) conducted an experiment with bread wheat and found high narrow sense heritability for plant height, spike length, 1000-kernel weight and that was due to the presence of high genotypic variance.

Biju Sidharthan and Malik (2007) studied 27 wheat genotypes for important yield attributing characters and found high heritability coupled with high genetic advance for days to 50% heading, plant height, number of spikes per plant, spike length, grains/spike, 100-grain weight and grain yield per plant.

Mittal *et al.* (2008) conducted an experiment with 40 genotypes of bread wheat and found that the analysis of variability exhibited significant difference among genotypes for all the studied characters as plant height, tillers/plant, spike length, grain/spike, 100 grain weight, grain yield and harvest index.

Mukherjee *et al.* (2008) evaluated twenty genotypes of bread wheat. High magnitude of genotypic and phenotypic coefficients of variation was observed for the character tillers per meter. High heritability coupled with high genetic advance was recorded for the number of tillers per meter indicating that this character is highly heritable. Grain yield and maturity duration were also highly heritable with moderate to low genetic advance.

2.4 Relationship between yield and yield contributing characters of wheat

Grain yield in wheat is related to many yield contributing characters. The primary yield components have been identified as number of spikes per plant number of grains per spike and average grain weight. Relationship between yield and yield contributing characters are usually studied by correlation and path coefficient analysis in bread wheat.

Singh *et al.* (1998) studied the relationship between yield and yield contributing characters and stated significant and positive correlation between spikes per plant and grain yield per plant, spikelets per spike was also positively correlated with spike length and grains per spike but negatively correlated with 100-grain weight and spikes per plant.

Ismail (2001) reported that Phenotypic and genotypic correlation coefficients were negative and significant between days to heading and spikes per plant, spike length, grains per spike, 1000-grains weight, harvest index and yield per plant. Grains per spike and 1000-grain weight showed highly negative correlation as reported by Shen *et al.* (2000).

Mondal and Khajuria (2001) reported that yield per plant showed significant positive correlation with number of panicles per plant and 1000-grain weight in wheat genotypes. The direct effect of the characters under study varied from positive to negative and low to high over the period of study. They also reported that the number of panicles per plant and 1000-grain weight had significant positive correlation, as well as positive direct effect on yield. They also reported that the number of grains per spike had significant positive correlations with yield per plant.

Korkut *et al.* (2001) reported that the grain yield was significantly and positively correlated with 1000-kernel weight and the number of spikes/m_2. Simple correlation analysis by Semeena Sheikh and Iqbal Singh (2001) revealed strong positive correlation of harvest index with grain yield and significant negative association with total biomass in both the environments.

Mishra *et al.* (2001) observed a positive correlation between grain yield per plant, grain yield per spike and number of grains per spike and between grain yield per spike, harvest index and number of grain per spike in spring wheat in 3 dates of sowing they performed. They also reported that thousand grain weights was an important yield-contributing trait under rainfed condition and exhibited positive correlation with harvest index in 3 dates of sowing they performed.

Kaya *et al.* (2002) reported that grain yield in bread wheat was positively associated with plant height, spike length, kernels per spike, spikelets per spike and days to heading. Dokuyucu (2002) studied correlation coefficients, which showed that grain yield, was positivek and significantly related, with grains per spike.

Esmail (2002) conducted an experiment with bread wheat genotypes to study the association of grain yield with related traits and performed path coefficient analysis and found the largest negative phenotypic and genotypic correlation between number of spikes per plant and grain weight per spike in the 3 populations. They reported that grain yield per plant was positively correlated with number of spike per plant, plant height and days to heading but negatively correlated with grain weight per spike in the parents , F1 and F2 generations at the phenotypic and genotypic correlation levels.

Patel and Jam (2002) conducted an experiment with bread wheat and found that kernel yield had a positive and highly significant correlation with number of tillers per plant and number of kernel per spike, whereas it showed negative and non-significant correlation with days to heading, plant height and 1000-kernels weight. Sarker *et al.* (2002) found highly positive correlation of harvest index and 1000-grain weight with grain yield.

Mahak Singh *et al.* (2002) observed that genetic correlation coefficients were higher than phenotypic correlation coefficients for days to 50% flowering, plant height, number of grains per spike, length of spike, 1000-grain weight, harvest index, and grain yield per plant in bread wheat.

Gupta *et al.* (2002) reported that genotypic correlation were higher than phenotype correlations for plant height, number of grain per panicle, grain yield per plant, panicle length, number of spike per plant and 1000-grain weight. They also reported that length of main ear per plant and number of spikes per plant exhibited positive and high and significant correlation with grain yield per plant.

Kumar *et al.* (2002) reported that grain yield per plant had direct positive correlation with plant height, panicle length, number of spikes per plant and 1000-grain weight in some advanced wheat lines.

Vikram Singh *et al.* (2003) reported that days to heading had negative significant correlation with 100-grain weight. They also observed positive and significant correlation between spikes per plant and harvest index with grain yield per plant.

Jamali Singh *et al.* (2003) reported that grain yield was negatively and significantly correlated with days to heading, number of spikelet and number of grain per spike, but was positively correlated with plant height. They also reported that number of grains per spike and spikelets per spike were positively and significantly correlated with grain yield per plant.

Mahak Singh *et al.* (2003) recorded the highest genetic and phenotypic coefficients of variation for harvest index and number of grain per spike. They observed significant and positive association of grain yield with number of grain per spike, length of spike, and 1000-grain weight. They also reported negative and significant genetic correlation between days to flowering and grain yield per plant, length of spike and days to maturity and 1000-grain weight.

Golabady and Arzani (2003) reported grain yield had a positive and significant correlation with days to heading and grains per spike. Lad *et al.* (2003) observed that the grain yield exhibited highly significant and positive correlation with tillers per plant, spikelets per spike, and grains per spike both at genotypic and phenotypic levels.

Mondal and Kuljeet Kour (2004) reported that grain yield per plant was positively and significantly correlated with spikes per plant in some advanced lines of bread wheat. Safeer-ul-Hassan *et al.* (2004) conducted an experiment with twenty four bread wheat genotypes including a check variety and reported that number of spikelets per spike and plant height were significantly positive correlated with grain yield per plant.

Ihsan *et al.* (2004) conducted an experiment in 5 bread wheat cultivars and their 20 hybrids and reported that grain yield had a highly significant and positive phenotypic correlation with plant height, spikes per plant, spike length, number of spikelet per spike and 100-grain weight.

Shahnaz Memon *et al.* (2005) conducted an experiment with bread wheat progenies derived from 4×4 parent cross of spring wheat and observed the highest positive correlation for spike length and spikelet number per spike and spike length and harvest index, followed by spikelet number per spike.

Bhutta *et al.* (2005) conducted an experiment with bread wheat cultivars and showed a positive and significant correlation between number of spikelet per spike and grain yield at genotypic level but positively and non-significant at the phenotypic level. There was a positive and significant correlation for 1000-seed weight with number of spikelets per spike both at the genotypic and phenotypic level. The estimates of genotypic correlation between 1000-seed weight and grain yield were positive and significant at the genotypic level than phenotypic level.

Fida Mohammad *et al.* (2006) conducted an experiment in Pakistan on the inheritance pattern of the important yield traits viz, spikes per plant, spike length, grains per spike, 1000-grains weight, harvest index and yield per plant of 8 bread whead cultivars. They reported that yield per plant was positively correlated with number of spikes per plant, number of kernels per spike and harvest index.

Inamullah *et al.* (2006) carried out an experiment in Pakistan on the inheritance pattern of the important yield traits viz, spikes per plant, spike length, grains per spike, 1000-grains weight, harvest index and yield per plant of 8 bread wheat cultivars. They reported that yield per plant was positively correlated with number of spikes per plant, number of kernels per spike and harvest index.

Ayccek and Yldrm (2006) studied correlation coefficients between grain yield and yield components of 20 bread wheat cultivars in a field experiment conducted in Turkey and found positive and significant correlation between yield and plant height, grains number per spike, and 100-kernel weight. They also reported that grain yield was negatively and significantly correlated with time to heading.

Iqbal *et al.* (2007) conducted an experiment with a population of 130 early maturing spring wheat lines in a high latitude wheat growing region of Canada and observed positive genetic association between days to flowering and grain yield per plant. They also observed that grain yield exhibited positive genetic correlation with flowering time and harvest index.

Payal *et al.* (2007) showed that biological yield per plant, tillers per plant, harvest index, days to heading had strong positive and significant correlation with grain yield per plant. Positive direct effects of biological yield per plant, number of grains per ear, tillers per plant, 1000 kernel weight, days to heading and days to maturity on grain yield was also observed.

Sharma and Sharma (2007) studied grain yield is significantly and positively associated with tillers number, spike length, spikelets per spike, grains per spike, 100-grain weight, biological yield and harvest index. Similarly, grains per spike showed significant and positive correlation with days to maturity, spike length and spikelets per spike.

2.5 Path coefficients on yield and yield contributing characters of wheat

Study of correlation among yield and yield contributing characters is helpful for determination of the components of yields for selection for yield. However, correlations do not provide a precise picture of the relative magnitude of direct and indirect influences of each of the component characters towards yield. As a result, correlations between yield and its contributing characters are further analyzed through path coefficients.

Bhuyian *et al.* (1998) reported that harvest index had the premier direct outcome on grain yield in spring wheat. Grains per spike had direct and 100-grain weight had negative direct effects on grain yield. They also observed indirect effects of 100-grain weight through harvest index that caused the positive outcome on grain yield. Subhani and Khaliq (1994) observed high positive direct effects of spikes per plant, grains per spike and 100-grain weight on yield per plant.

Path coefficient analysis by Narwal *et al.* (1999) revealed that tillers per plant, grains per spike and spike length had positive and large direct effects on grain yield per plant at normal sown conditions and late-sown conditions. Khan *et al.* (1999) reported that the harvest index, grains per spike, plant height and spike length directly influenced on grain yield of spring wheat.

Shen *et al.* (2000) observed considerable direct effects of grains per spike. 1000-grain weight and number of spikes per plant on grain yield per plant. Tammam *et al.* (2000) showed that grain yield was affected directly by number of spkes per plant, number of kernels per spike and 1000-kernel weight in both phenotypic and genotypic levels.

Ismail (2001) conducted an experiment in Egypt during the 3 successive growing seasons of 1997/98-1999/2000 on 100 wheat F_3 families and studied path analysis. He reported that grain weight had the highest direct effects on yield followed by spikes per plant and harvest index at both phenotypic and genotypic levels.

Semeena Sheikh and Iqbal Singh (2001) observed that total biomass and harvest index accounted for the major portion of genetic variability for yield in normal and stress environments. They showed that total biomass and grains per ear accounted for the major portion of variability.

Esmail (2002) studied path coefficient analysis of some quantitative traits with grain yield in bread wheat and reported that harvest index exhibited the highest correlation to yield also had the largest direct effects on yield at phenotypic and genotypic levels. However, number of spike per plant had the highest direct effects on grain yield per plant followed by grain weight per spike and plant height in the 3 populations except plant height, which had negative direct effects in the parental lines only at the genotypic level.

Dokuyucu *et al.* (2002) reported that 100-grain weight had significantly positive direct effects on grain yield but plant height and spike length exhibited negative direct effects on grain yield. They also reported that grains per spike had positive and high direct effects on grain yield per plant.

Vikram Singh *et al.* (2003) revealed that grains per spike, 100-grain weight and spikes per plant had positive and high direct effects on grain yield per plant. Lad *et al.* (2003) observed that spikes per plant had the highest positive direct effects on yield followed by grains per spike, grain weight and spike length.

Mahak *et al.* (2003) reported that the number of grains per spike exhibited the greatest direct effect on grain yield followed by spike length and 1000-grain weight. They proposed that number of grains per spike, spike length and 1000-grain weight were the major yield contributing characters.

Gupta *et al.* (2004) conducted an experiment to evaluate path coefficients for yield and its related characters in bread wheat. They found that the number of spike per plant, number of grain per spike, plant height had negative direct effects on grain yield. They also reported that the number of spikelet per spike and length of spike showed the highest positive direct effects on grain yield. Path analysis by

Sachan and Singh (2003) showed that number of tiller per plant had the highest direct effects on grain yield.

Bhutta *et al.* (2005) conducted an experiment to evaluate path coefficient in 194 bread wheat lines showed that the direct effects of plant height on grain yield was positive, while the indirect effects of plant height through the number of spikelet per spike and 1000-seed weight were negative. The indirect effects of plant height via spike length were positive. The direct effects of spike length on grain yield were positive. The indirect effects of spike length via number of spikelet per spike and 1000-grain weight were negative. The number of spikelet per spike had negative direct effects on grain yield. The direct effects of 1000-grain weight on grain yield were positive. Its indirect effects via plant height and spike length were negative, while indirect effects via number of spikelet per spike were positive.

Shukla *et al.* (2005) conducted an experiment to investigate the association and path coefficient analysis of 25 bread wheat cultivars under rainfed and partially irrigated conditions and found that in the rain fed condition, yield per plant had positive correlations with number of grain per spike, and harvest index, but a negative correlation with days to 50% ear emergence.

Ayccek and Yldrm (2006) studied path coefficient between grain yield and yield components of 20 bread wheat cultivars in a field experiment conducted in Turkey during 1999-2001 and observed positive direct effects of plant height, grain number per spike and 1000-kernel weight and negative direct effects of time to heading on grain yield.

Saktipada *et al.* (2008) was observed that number of spikelets per panicle, days to flowering and 1000-grain weight had high direct effects on grain yield per plant. Hence direct selection for high number of spikelets per panicle, late in flowering and low 1000-grain weight might be rewarding for improvement in grain yield per plant of wheat.

chapter

3

- **Materials and methods**

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the role of morpho-physiological character in spring wheat under drought stress. The details of the materials and methods i.e. location of experimental site, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that used or followed in this experiment has been presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November 2013 to April 2014 in rabi season.

3.1.2 Site description

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February and the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and details has been presented in Appendix I.

3.1.4 Soil characteristics of the experimental plot

The soil belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix II.

3.2 Experimental details

3.2.1 Planting materials

In this experiment 30 wheat genotypes (Table 1) were used as experimental materials which were produced in the 2012-2013 cropping season, and the purity and germination percentage were leveled as 98% and 95%, respectively. These genotypes were collected from Wheat Research Centre (WRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

Table 1. Name of wheat genotypes used in the present study

#	Wheat genotypes	#	Wheat genotypes
01.	Akber	16.	BD-7544
02.	Kanchan	17.	BD-7551
03.	Sonalika	18.	BD-7552
04.	BARI Gom-20	19.	BD-7560
05.	BARI Gom-21	20.	BD-7591
06.	BARI Gom-22	21.	BD-7592
07.	BARI Gom-23	22.	BD-7599
08.	BARI Gom-24	23.	BD-7605
09.	BARI Gom-25	24.	BD-7614
10.	BARI Gom-26	25.	BD-7617
11.	BD-478	26.	BD-7618
12.	BD-479	27.	BD-7621
13.	BD-481	28.	BD-7622
14.	BD-489	29.	BD-7624
15.	BD-492	30.	BD-7650

3.2.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 535.5 m^2 with length 76.5 m and width 7.0 m. The total area was divided into three equal blocks. Each block was divided into 30 plots where 30 wheat genotypes were allotted at random. There were 90 unit plots altogether in the experiment. The size of the each plot was 2.0 m × 1.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.3. Growing of crops

3.3.1 Preparation of the main field

The piece of land selected for carried out of this experiment was opened in the 1st week of November 2013 with a power tiller, and was exposed to the sun for a week after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed from the field and finally a desirable tilth of soil was obtained for sowing of wheat seeds. Fertilizers and manures as indicated below in 3.3.3 were mixed with the soil of plot.

3.3.2 Seeds sowing

Furrows were made for sowing the wheat seeds when the land was in proper joe condition and seeds were sown at 18 November, 2013. Seeds were sown continuous with maintaining 20 cm line to line distance and plant to plant 5 cm. After sowing, seeds were covered with soil and slightly pressed by hand.

3.3.3 Application of fertilizers and manure

The fertilizers N, P, K and S in the form of Urea, TSP, MP and Gypsum, respectively were applied. Cowdung was applied @ 10 t ha^{-1} during 15 days before seeds sowing in the field. The entire amount of TSP, MP and Gypsum, 2/3rd of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation (BARI, 2011). The dose and method of application of fertilizer are presented below in Table 2.

Table 2. Doses and method of application of fertilizers in wheat field

Fertilizers	Dose (per ha)	Application (%)	
		Basal	1st installment
Urea	220 kg	66.66	33.33
TSP	180 kg	100	--
MP	50 kg	100	--
Gypsum	120 kg	100	--
Cowdung	10 ton	100	--

Source: BARI, 2011, Krishi Projukti Hatboi, Joydebpur, Gazipur

3.3.4 After care

After the germination of seeds, various intercultural operations such as weeding, top dressing of fertilizer and plant protection measures were accomplished for better growth and development of the wheat seedlings as per the recommendation of BARI. No irrigation was provided as per drought stress.

3.3.4.1 Weeding

Weedings were done to keep the plots free from weeds which ultimately ensured better growth and development of wheat seedlings. The newly emerged weeds were uprooted carefully. One manual weeding was taken up once at peak tillering stage to remove weeds around the clumps.

3.3.4.2 Plant protection

The crop was attacked by different kinds of insects during the growing period. Triel-20 ml was applied on 12 January and sumithion-40 ml/20 litre of water was applied on 30 January as plant protection measure. During the entire growing period the crop was observed carefully as protection measures.

3.3.4.3 Soil moisture and field capacity determination:

The moisture content of the experimental field soil was determined by gravimetric method. Soil sample was collected randomly from all the 3 replications at 12 days interval starting from 50 days after sowing and continued up to grain filling. The following formulas were used to calculate soil moisture content and water at field capacity.

$$\% \text{ Soil moisture (weight basis): } \frac{\text{Weight of soil moisture}}{\text{Weight of oven dry soil}} \times 100$$

Soil moisture contents were 23%, 21.16%, 19.42% and 19.00% after 51, 63, 73 and 87 days after sowing (DAS), respectively. The water at field capacity of the experimental field soil was 37.8%. At the time of crown root initiation stage in early December'2013 no rainfall was recorded in the experimental field area (Appendix I). No supplementary irrigation was provided to create drought condition and the experiment was conducted under rain-fed condition only.

3.4 Harvesting, threshing and cleaning

The crop was harvested manually depending upon the maturity and bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning of wheat grain. Fresh weight of grain was recorded plot wise from 1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. Yields of wheat grain was recorded and converted into per plant.

3.5 Data collection

3.5.1 Days to staring of heading

Days to starting of heading was recorded by calculating the number of days from sowing to starting of heading by keen observation of the experimental plots.

3.5.2 Days to starting of maturity

Days to starting of maturity was recorded by calculating the number of days from sowing to starting of maturity as spikes become brown color by keen observation of the experimental plot.

3.5.3 Plant height

The height of plant was recorded in centimeter during at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot that were tagged earlier. The height was measured from the ground level to the tip of the plant by a meter scale.

3.5.4 Number of spikes/m^2

The total number of spikes/m^2 was counted as the number of spike per square meter value was recorded.

3.5.5 Number of spikelets/spike

The total number of spikelets/spike was counted as the number of spikelets from 10 randomly selected spikes from each plot and average value was recorded.

3.5.6 Number of grains/spike

The total number of grains/spike was counted by adding the number of filled and unfilled grains from 10 randomly selected spikes from each plot and average value was recorded.

3.5.7 Chlorophyll content

Chlorophyll content of 10 selected leaves was determined from plant samples by using an automatic machine immediately after removal of leaves from plants to avoid rolling and shrinkage.

3.5.8 Dry matter content

Data from ten sample fresh plants from each plot were collected and gently washed with tap water, thereafter soaked with paper towel. Then fresh weight was taken immediately after soaking by paper towel. After taking fresh weight, the sample was oven dried at 70^{0}C for 72 hours. Then oven-dried samples were transferred into a desiccator and allowed to cool down to room temperature, thereafter dry weight was taken. Dry matter content was calculated using the following formula:

$$\text{Dry matter content} = \frac{\text{Dry weight of stem (g)}}{\text{Fresh weight of stem (g)}} \times 100$$

3.5.9 Leaf area index

Leaf area (LA) was determined from plant samples by using an automatic leaf area meter immediately after removal of leaves from plants to avoid rolling and shrinkage. After that leaf area index was calculated by dividing leaf area into the area for each plant and value was recorded.

3.5.10 Peduncle length

The length of peduncle was measured as the average of 10 plants selected at random from the inner rows of each plot. The length was measured from the base to tip of the peduncle.

3.5.11 Root length

The length of root was measured with a meter scale from roots of 10 selected plant and the average value was recorded.

3.5.12 Root number

The total number of roots per plant was counted as the number of roots from 10 randomly selected plants from each plot and average value was recorded.

3.5.13 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested grain of each individual plot and then weighed in grams and recorded.

3.5.14 Grain yield per plant

Grains obtained from m^{-2} from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area used to record grain yield m^{-2} and converted this into per plant yield.

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the morpho-physiological character in spring wheat under drought stress. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.7 Estimation of variability

Genotypic and phenotypic coefficient of variation and heritability were estimated by using the following formulae:

3.7.1 Estimation of components of variance from individual environment

Genotypic and phenotypic variances were estimated with the help of the following formula suggested by Johnson *et al.* (1955). The genotypic variance (σ^2_g) was estimated by subtracting error mean square (σ^2_e) from the genotypic mean square and dividing it by the number of replication (r). This is given by the following formula -

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MS_V - MS_E}{r}$$

Where,

MS_V = genotype mean square

MS_E = error mean square

r = number of replication

The phenotypic variance (σ^2_p), was derived by adding genotypic variances with the error variance, as given by the following formula –

Phenotypic variance (σ^2_{ph}) = $\sigma^2_g + \sigma^2_e$

Where,

σ^2_{ph} = phenotypic variance

σ^2_g = genotypic variance

σ^2_e = error variance

3.7.2 Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following formula as suggested by Burton (1952):

$$\% \text{ Genotypic coefficient of variance} = \frac{\sigma_g}{\overline{x}} \times 100$$

Where,

σ_g = genotypic standard deviation

$\overline{x}$ = population mean

$$\% \text{ Phenotypic coefficient of variance} = \frac{\sigma_{ph}}{\overline{x}} \times 100$$

Where,

σ_{ph} = phenotypic standard deviation

$\overline{x}$ = population mean

3.7.3 Estimation of heritability

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

$$\text{Heritability } (\%) = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

3.7.4 Estimation of genetic advance

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960):

$$GA = \frac{\sigma^2_g}{\sigma^2_p} \times K.\ \sigma_p$$

Where,

GA = Genetic advance

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

σ_{ph} = phenotypic standard deviation

K = Selection differential which is equal to 2.64 at 5% selection intensity

3.7.5 Estimation of genetic advance in percentage of mean

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952):

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

3.8 Estimation of correlation

Simple correlation was estimated of the 14 traits with the following formula (Singh and Chaudhary, 1985):

$$r = \frac{\sum xy - \frac{\sum x.\ \sum y}{N}}{[\{\sum x^2 - \frac{(\sum x)^2}{N}\}\{\sum y^2 - \frac{(\sum y)^2}{N}\}]^{1/2}}$$

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.9 Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect of independent variables on the dependent variable.

In order to estimate direct and indirect effect of the correlated characters, say x_1, x_2, x_3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as given below:

$$ryx_1 = Pyx_1 + Pyx_2rx_1x_2 + Pyx_3rx_1x_3$$

$$ryx_2 = Pyx_1rx_1x_2 + Pyx_2 + Pyx_3rx_2x_3$$

$$ryx_3 = Pyx_1rx_1x_3 + Pyx_2\,rx_2x_3 + Pyx_3$$

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (unknown). P's in the above equations may be conveniently solved by arranging them in matrix form. Total correlation, say between x_1 and y is thus partitioned as follows:

Pyx_1 = The direct effect of x_1 on y

$Pyx_1rx_1x_2$ = The indirect effect of x_1 via x_2 on y

$Pyx_1rx_1x_3$ = The indirect effect of x_1 via x_3 on y

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985):

$$P^2RY = 1 - \sum Piy.riy$$

Where,

$P^2RY = (R^2)$; and hence residual effect, $R = (P^2RY)^{1/2}$

Piy = Direct effect of the character on yield

riy = Correlation of the character with yield

chapter

4

- **Resuts and Discussion**

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the role of morpho-physiological character in spring wheat under drought stress. Mean performance, variability, correlation matrix and path analysis were done on different yield contributing characters and yield of wheat genotypes was estimated. The experimental results obtained have been presented under the following heads:

4.1 Evaluation of mean performance of different yield contributing characters and yield of wheat under draught stress

Mean performance and analysis of variance was estimated and presented in Table 3 and 4. 'F' test revealed highly significant variation among 30 wheat genotypes in terms of all the studied characters.

Significantly high level of variation for different yield contributing characters and yield revealed the indicative possibilities of improving the genetic yield potential of wheat genotypes under drought stress.

4.1.1 Days to staring of heading

Statistically significant variation was recorded for different wheat genotypes on days to starting of heading under the present trial (Table 3). Data revealed that the average days to starting of heading was around 53.00 days with a range from 45.00 to 66.33 days and more than 50% genotypes have required more than that average day required for staring of heading. The highest days to starting of heading (66.33) was observed in the genotype of BD-7624 which was statistically similar (65.00, 61.67) with the wheat genotypes of BD-7650, BD-7621 and BD-7622, while the lowest days (45.00) from BARI Gom-25. Qasim *et al.* (2008) reported that days to heading varied for different cultivars of wheat. Mohsen *et al.* (2013) reported that the effect of cultivars was significant for days to starting of heading in wheat. Sulewska (2004) also reported that days to starting of heading in wheat varied from genotype to genotype.

Table 3. Mean performance of yield contributing characters and yield of spring wheat under drought condition

Wheat genotypes	Days to starting heading	Days to starting maturity	Plant height (cm)	Number of spikes/m^2	Number of spikelets /spike	Number of grains/ spike	Dry matter content (%)	Leaf area index	Peduncle length (cm)	Weight of 1000-grains (g)
Akber	47.33 d-h	112.00 d	71.10 b-g	257.00 de	42.00 b-e	57.00 f	5.33 a-d	2.32 e-k	15.67 f-i	31.10 l
Kanchan	46.33 e-h	114.67 b-d	68.67c-g	320.00 a	39.33 b-i	60.00 ef	5.33 a-d	3.23 a-c	16.27 d-h	33.20 j-l
Sonalika	46.33 e-h	111.67 d	84.00 a	240.00 ef	42.33 b-d	66.00 c-f	5.33 a-d	2.66 c-f	18.67 a	51.47 a
BARI Gom-20	47.00 e-h	114.67 b-d	69.67 b-g	282.67 b-d	37.33 c-j	59.67 ef	4.67 cd	3.70 a	16.50 c-g	46.83 bc
BARI Gom-21	45.33 gh	111.33 d	67.60 c-g	318.67 a	34.67 g-j	62.00 d-f	5.33 a-d	2.16 e-k	15.63 f-i	43.53 cd
BARI Gom-22	47.00 e-h	114.00 b-d	75.97 a-d	105.33 k	40.00 b-h	64.67 c-f	5.00 b-d	1.40 lm	17.00 b-e	30.50 l
BARI Gom-23	45.33 gh	111.33 d	82.67 a	311.67 ab	38.67 b-i	65.33 c-f	4.67 cd	2.08 f-k	18.00 ab	49.10 ab
BARI Gom-24	45.67 f-h	112.00 d	76.00 a-d	278.67 cd	39.00 b-i	61.33 d-f	6.67 a	2.59 d-g	17.73 a-c	40.00 d-h
BARI Gom-25	45.00 h	110.33 d	81.00 ab	307.00 a-c	40.00 b-h	64.00 c-f	6.33 ab	3.42 ab	17.67 a-c	46.80 bc
BARI Gom-26	45.67 f-h	110.33 d	83.33 a	324.00 a	36.00 d-j	64.67 c-f	4.67 cd	3.13 a-d	17.43 a-d	42.17 de
BD-478	56.00 bc	110.33 d	71.00 b-g	159.33 gh	35.33 f-j	66.00 c-f	6.00 a-c	2.81 b-e	17.00 b-e	36.17 g-k
BD-479	55.00 bc	112.67 cd	61.33 gh	180.00 g	44.00 b	65.33 c-f	5.67 a-c	2.51 d-i	15.00 h-j	46.40 bc
BD-481	53.00 c-f	119.00 a-d	61.83 f-h	181.67 g	44.00 b	68.67 a-f	6.00 a-c	1.76 j-l	18.00 ab	37.33 f-j
BD-489	53.00 c-f	119.33 a-d	53.33 h	145.67 h-j	34.67 g-j	70.00 a-f	6.33 ab	3.24 a-c	15.33 g-i	41.90 de
BD-492	56.00 bc	126.00 a-c	64.33 d-g	122.67 i-k	34.00 h-j	72.00 a-e	4.00 d	2.53 d-h	14.13 j	36.33 g-k
BD-7544	54.67 b-d	127.00 ab	68.33 c-g	215.33 f	38.67 b-i	69.67 a-f	6.00 a-c	2.41 e-j	17.27 b-e	36.50 g-k
BD-7551	53.67 c-e	121.33 a-d	60.67 gh	131.67 h-k	42.33 b-d	70.33 a-f	5.00 b-d	1.83 j-l	14.00 j	38.17 e-i
BD-7552	52.00 c-h	119.33 a-d	68.00 c-g	105.67 k	35.33 f-j	66.67 b-f	6.33 ab	1.86 h-l	16.07 e-h	32.27 kl
BD-7560	54.67 b-d	116.00 a-d	73.33 a-f	178.00 g	34.67 g-j	69.33 a-f	4.67 cd	1.96 g-l	15.47 f-i	47.07 bc
BD-7591	53.33 c-e	118.67 a-d	74.00 a-e	127.33 h-k	43.00 bc	65.00 c-f	5.33 a-d	1.98 g-l	16.67 c-f	47.33 bc
BD-7592	53.33 c-e	117.33 a-d	68.67 c-g	118.67 jk	33.33 ij	80.00 ab	5.33 a-d	1.89 h-l	17.43 a-d	40.37 d-g
BD-7599	52.00 c-h	115.33 b-d	66.00 d-g	117.00 jk	39.33 b-i	64.00 c-f	5.67 a-c	1.73 kl	15.70 f-i	35.70 h-k
BD-7605	53.00 c-f	116.00 a-d	73.00 a-f	135.67 h-k	41.00 b-g	76.67 a-c	6.33 ab	1.85 i-l	18.00 ab	32.97 j-l
BD-7614	53.00 c-f	114.67 b-d	70.33 b-g	123.00 i-k	42.67 bc	69.33 a-f	4.67 cd	1.40 lm	17.10 b-e	37.37 f-j
BD-7617	52.67 c-g	122.00 a-d	78.33 a-c	158.67 gh	51.00 a	68.33 a-f	6.33 ab	1.99 g-l	16.07 e-h	41.67 d-f
BD-7618	55.00 bc	123.00 a-d	67.33 c-g	114.33 jk	41.33 b-f	70.33 a-f	5.67 a-c	1.04 m	16.73 b-f	34.13 i-l
BD-7621	61.67 ab	129.33 a	65.67 d-g	104.33 k	32.00 j	72.33 a-e	6.33 ab	2.11 f-k	14.67 ij	38.00 e-i
BD-7622	61.67 ab	120.00 a-d	76.00 a-d	151.67 g-i	44.67 b	74.67 a-d	6.67 a	2.52 d-h	14.07 j	30.33 l
BD-7624	66.33 a	123.33 a-d	63.33 e-h	106.33 k	35.67 e-j	81.33 a	5.00 b-d	1.05 m	16.00 e-h	37.00 g-j
BD-7650	65.00 a	119.67 a-d	70.67 b-g	107.00 k	44.33 b	74.00 a-d	5.00 b-d	1.76 j-l	17.67 a-c	37.33 f-j
Mean	52.53	117.09	70.52	184.30	39.36	67.96	5.52	2.23	16.43	39.30
Range	45.00-66.33	110.3-129.3	53.33-84.00	104.3-324.0	32.00-51.00	57.00-81.33	4.00-6.67	1.04-3.70	14.00-18.67	30.33-51.47
CV(%)	7.25	5.91	8.30	9.38	8.50	10.18	12.70	15.50	4.08	6.06

Table 4. Analysis of variance (ANOVA) for yield contributing characters and yield of spring wheat under drought condition

Characters	Degrees of freedom (df)			Mean Sum of Squares (MSS)		
	Replication	Genotypes	Error	Replication	Genotypes	Error
Days to starting of heading	2	29	58	1.233	101.577**	14.521
Days to starting of maturity	2	29	58	4.744	83.952*	47.882
Plant height (cm)	2	29	58	28.588	155.636**	34.223
Number of spikes/m^2	2	29	58	62.633	18582.88**	299.001
Number of spikelets/spike	2	29	58	2.211	55.401**	11.200
Number of grains/spike	2	29	58	4.311	98.890**	47.886
Chlorophyll content	2	29	58	14.925	60.522**	15.867
Dry matter content (%)	2	29	58	0.078	1.510**	0.492
Leaf area index	2	29	58	0.084	1.351**	0.119
Peduncle length (cm)	2	29	58	0.371	4.903**	0.448
Root length (cm)	2	29	58	0.300	9.614**	0.519
Root number	2	29	58	0.078	9.534**	0.308
Weight of 1000-grains (g)	2	29	58	1.247	104.502**	5.678
Grain yield per plant (g)	2	29	58	0.030	2.712**	0.231

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

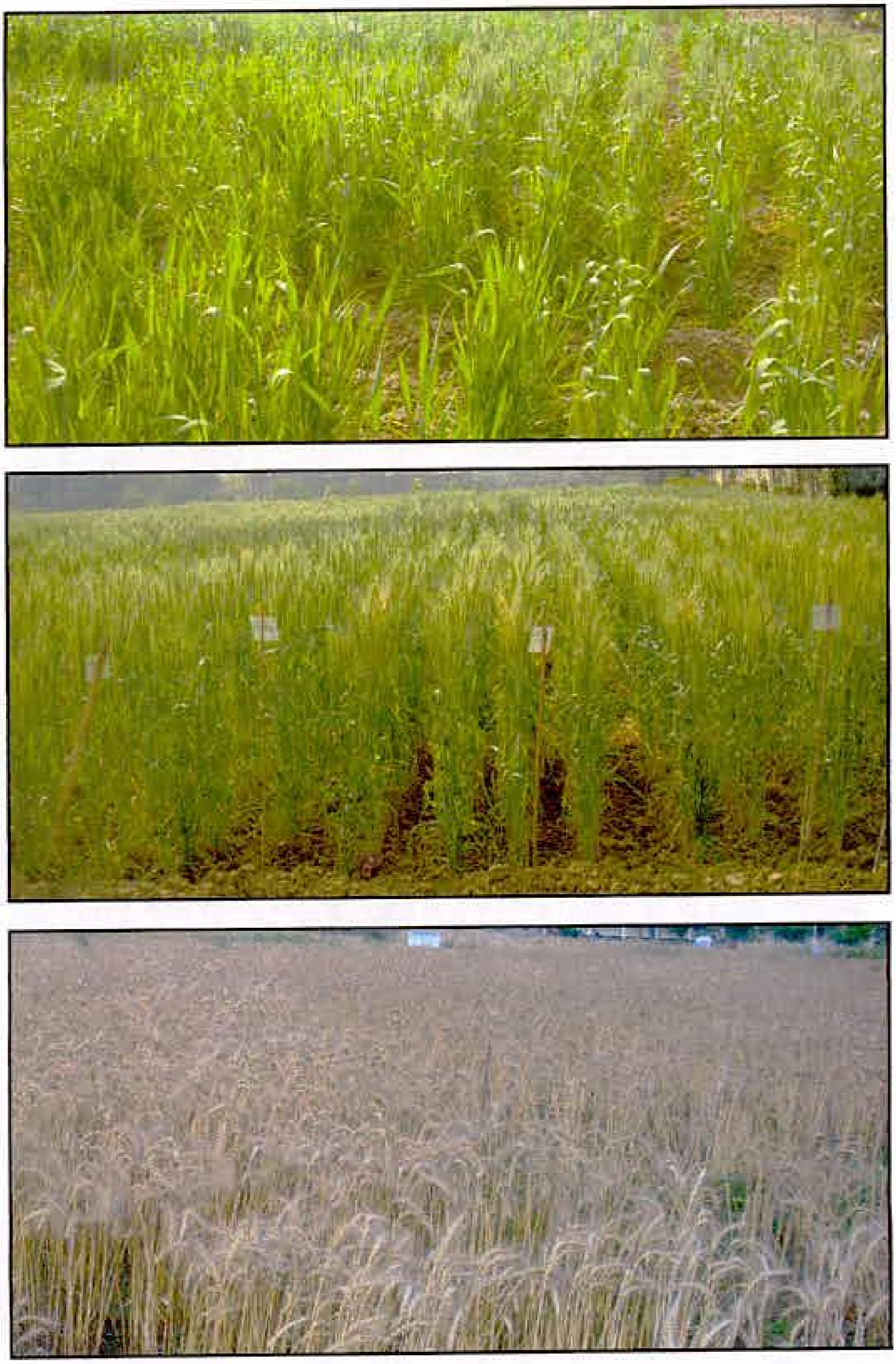

Plate 1. Photograph showing different stage of wheat variety

a)Floweringstage b)Milkingstage c)Maturitystage b

4.1.2 Days to starting of maturity

Days to starting of maturity varied significantly due to different wheat genotypes (Table 3). Data revealed that the average days to starting of maturity was around 117 days with a range from 110.33 to 129.33 days and in an average 50% genotypes had required less than that average day required for staring of heading. The highest days to starting of maturity (129.33) was found in genotype BD-7621 which was statistically similar (127.00) with BD-7544, whereas the lowest days (110.33) were attained in the wheat genotypes BARI Gom-25, BARI Gom-26 and BD-478.

4.1.3 Plant height

Different wheat genotypes showed statistically significant variation in terms of plant height (Table 3). The average plant height was around 70.52 cm with a range from 53.33 cm to 84.00 cm but for plant height most of the genotypes within 60-70 cm in height. The longest plant (84.00 cm) was recorded in genotype Sonalika which was statistically similar (83.33 cm and 82.67 cm) with BARI Gom-26 and BARI Gom-23, again the shortest plant (53.33 cm) was found in wheat genotype BD-489. Gupta *et al.* (2001) reported that plant height decreased to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in plant height. Islam *et al.* (1993) reported that plant height significantly affected by variety. Litvinrnko *et al.* (1997) reported that plant height itself governed by genetically.

4.1.4 Number of spikes/m^2

Number of spikes/m^2 showed statistically significant variation for different wheat genotypes under the present trial (Table 3). The average number of spikes/m^2 was around 184.30 with a range from 104.33 to 324.00. The maximum number of spikes/m^2 (324.00) was attained in BARI Gom-26 which was statistically similar (320.00, 318.67, 311.67 and 307.00) with Kanchan, BARI Gom-21, BARI Gom-23 and BARI Gom-25, whereas the minimum number (104.33) was observed in the wheat genotype BD-7621. Baser *et al.* (2004) reported that the effects of water stress treatments on yield components were statistically significant compared with non-stressed conditions. Zarea and Ghodsi (2004) reported that number of spike/m^2 decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied, number of spike/m^2 were higher in cultivars C-75-14 and C-75-9.

4.1.5 Number of spikelets/spike

Statistically significant difference was observed for different wheat genotypes in terms of number of spikelets/spike (Table 3). The average number of spiklets/spike was around 39.36 with a range from 32.00 to 51.00. The maximum number of spikelets/spikes (51.00) was found in BD-7617 which was followed (44.67, 44.33 and 44.00) by BD-7622, BD-7650, BD-479 and BD-481, while the minimum number (32.00) was observed in the wheat genotype BD-7621.

4.1.6 Number of grains/spike

Different wheat genotypes showed statistically significant differences in terms of number of grains/spike (Table 3). The average number of grains/spike was around 67.96 with a range from 57.00 to 81.33. The maximum number of grains/spikes (81.33) was recorded in BD-7624 which was statistically similar (80.00) with BD-7592, again the minimum number (57.00) in wheat genotype Akber. Good quality wheat variety for producing maximum yield through the highest yield contributing characters that plays an important and major role for wheat production. Islam *et al.* (1993) reported that grain/spike was significantly affected by variety.

4.1.7 Chlorophyll content

Statistically significant variation was recorded for different wheat genotypes in terms of chlorophyll content (Figure 1). Data revealed that the average chlorophyll was around 48.62 with a range from 40.37 to 58.37. The highest chlorophyll content (58.37) was attained in BARI Gom-24 which was statistically similar (56.80) with BD-7591, whereas the lowest chlorophyll content (40.37) was found in the wheat genotype BARI Gom-23. Zarea and Ghodsi (2004) reported also reported similar findings earlier.

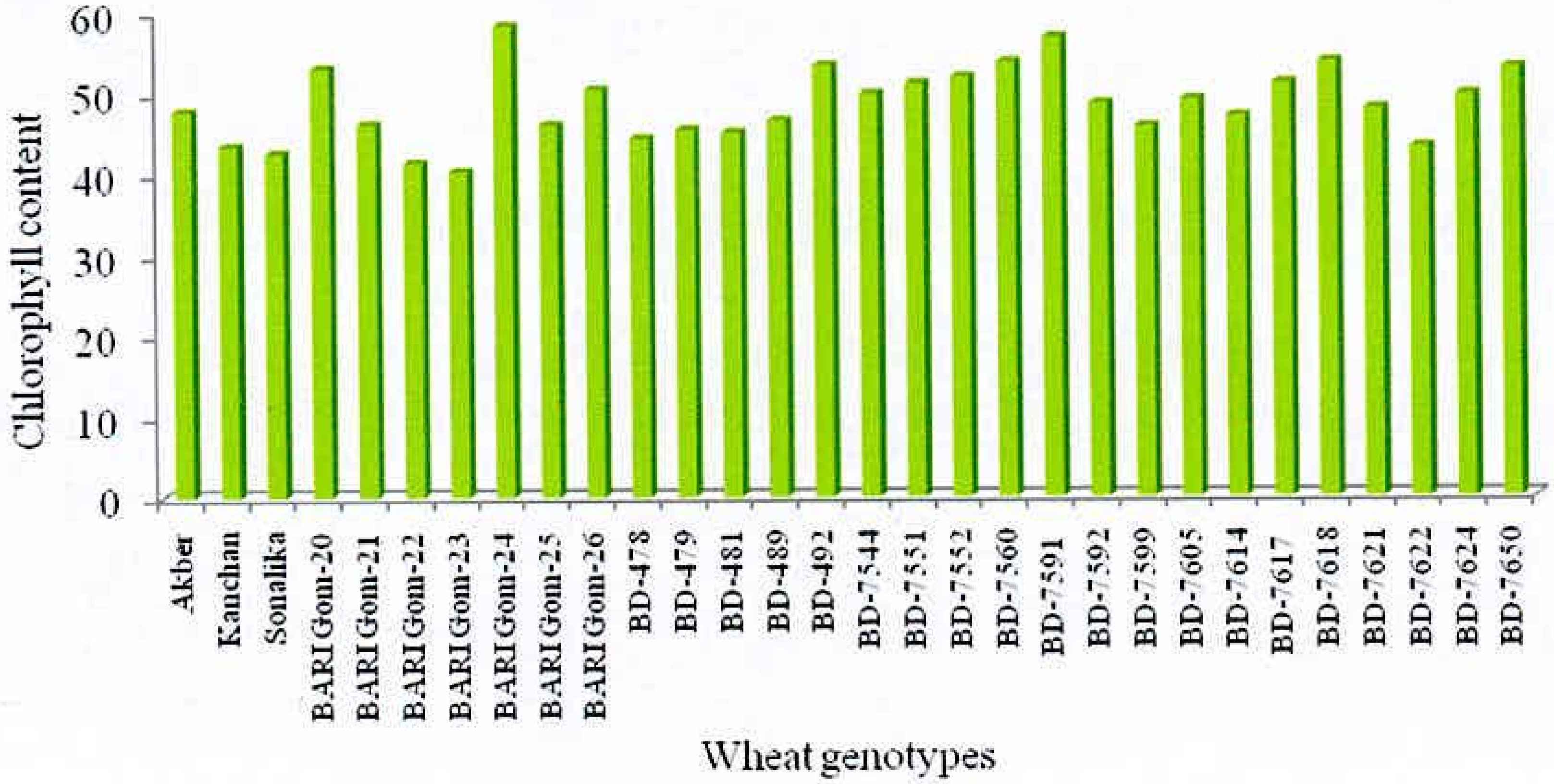

Figure 1. Chlorophyll content for different wheat genotypes

4.1.8 Dry matter content

Dry matter content varied significantly for different wheat genotypes under the present trial (Table 3). The average dry matter content was 5.52% with a range from 4.00% to 6.67%. The highest dry matter content (6.67%) was observed in BARI Gom-24 and BD-7622 which was statistically similar (6.33%) with BARI Gom-25, BD-489, BD-7552, BD-7605 and BD-7621, while the lowest dry matter content (4.00%) was found in the wheat genotype BD-492.

4.1.9 Leaf area index

Different wheat genotypes showed statistically significant variation in terms of leaf area index (Table 3). The average leaf area index was 2.23 with a range from 1.04 to 3.70. The highest leaf area index (3.70) was attained in BARI Gom-20 which was statistically similar (3.42) with BARI Gom-25. On the other hand, the lowest dry matter content (1.04) was recorded in the wheat genotype BD-7618 which was statistically similar (1.05) with BD-7624.

4.1.10 Peduncle length

Statistically significant variation was observed for different wheat genotypes in terms of peduncle length (Table 3). The average peduncle length was 16.43 cm with a range from 14.00 cm to 18.67 cm. The longest peduncle (18.67 cm) was found in Sonalika which was statistically similar (18.00 cm) with BARI Gom-23, BD-481 and BD-7605, whereas the shortest peduncle (14.00 cm) was observed in the wheat genotype BD-7551 which was statistically similar (14.07 cm and 14.13 cm) with BD-7622 and BD-492.

4.1.11 Root length

Root length varied significantly for different wheat genotypes (Figure 2). The average root length was 5.34 cm with a range from 3.00 cm to 9.07 cm. The longest root (9.07 cm) was recorded in BD-7552 which was statistically similar (9.00 cm) with Kanchan. On the other hand, the shortest root (3.00 cm) was recorded in the wheat genotype BARI Gom-23 and BARI Gom-26 which was statistically similar (3.33 cm) with BD-7605 and BD-7622.

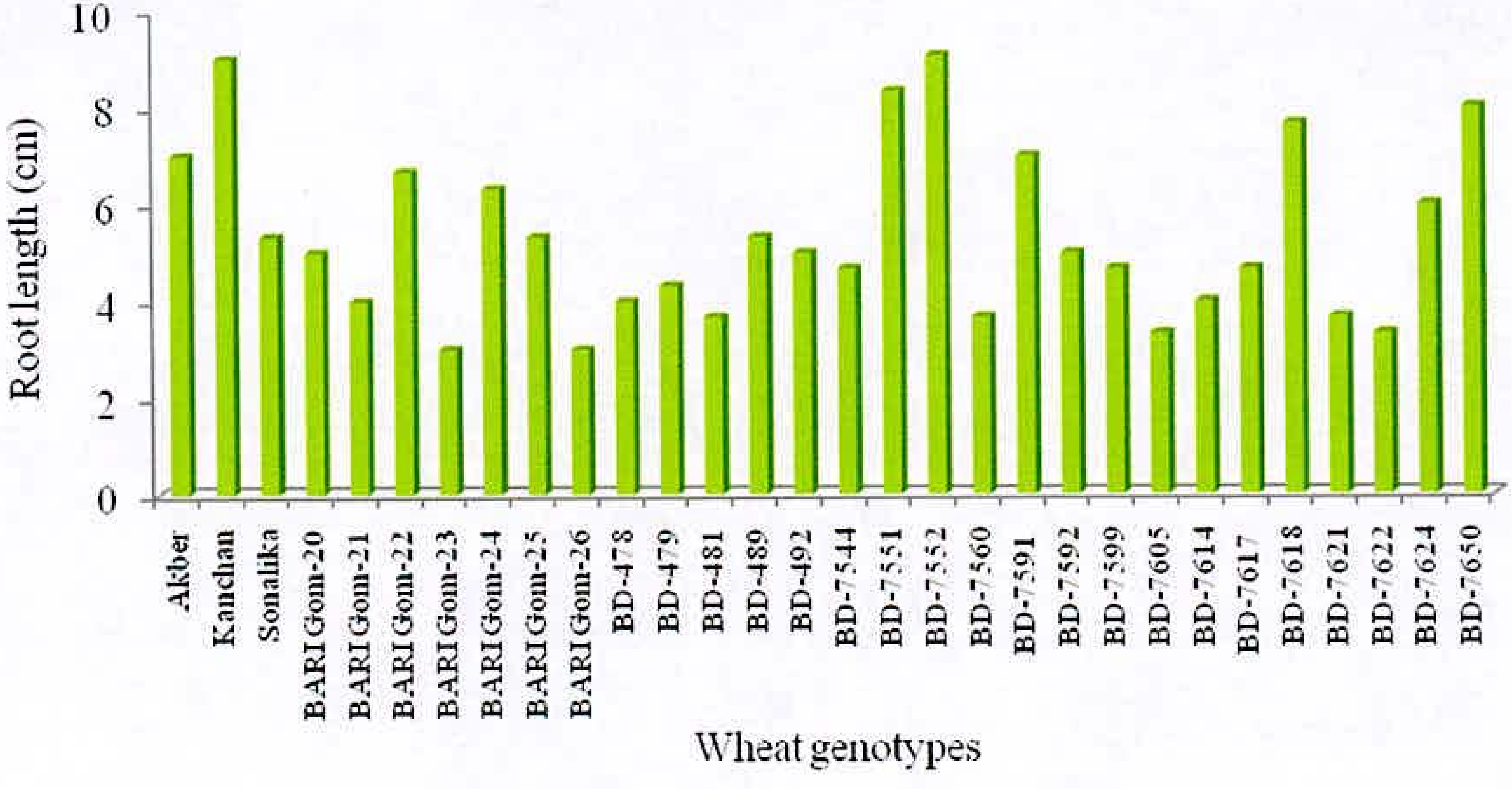

Figure 2. Root length for different wheat genotypes

4.1.12 Root number

A statistically significant variation was observed for different wheat genotypes in terms of root number (Figure 3). The average root number was 12.71 with a range from 10.00 to 15.00. The maximum root number (15.00) was observed in BD-489, BD-7614 and BD-7618 which was statistically similar (14.67) with BARI Gom-24, BD-492, BD-7552, BD-7599 and BD-7621, whereas the minimum root number (10.00) was recorded in the wheat genotype Sonalika, BD-7560, BD-7605 and BD-7624 which was statistically similar (10.33) with BARI Gom-23 and BD-7622.

4.1.13 Weight of 1000 grains

Weight of 1000 grains showed statistically significant variation for different wheat genotypes under the present trial (Table 3). The average weight of 1000 grains was 39.30 g with a range from 30.33 g to 51.47 g. The highest weight of 1000 grains (51.47 g) was found in Sonalika which was statistically similar (49.10 g) with BARI Gom-23. On the other hand, the lowest weight of 1000 grains (30.33 g) was attained in the wheat genotype BD-7622 which was statistically similar (30.50 g and 31.10 g) with BARI Gom-22 and Akbar. Malik *et al.* (2010) reported that that the yield contributing parameters were significantly higher when crop was irrigated with five irrigations, while 1000-grains weights were not affected significantly. Islam *et al.* (1993) reported that 1000-grain weight was significantly affected by variety.

4.1.14 Grain yield per plant

Different wheat genotypes showed statistically significant differences in terms of grain yield per plant (Figure 4). The average grain yield per plant was 6.99 g with a range from 5.24 g to 9.02 g. The highest grain yield per plant (9.02 g) was recorded in Sonalika which was statistically similar (8.84 g) with BD-7617, while the lowest grain yield per plant (5.24 g) was observed in the wheat genotype BD-489. Razi-us-Shams (1996) observed that the effect of irrigation treatments on yield and yield contributing characters (cv. Sonalika) were statistically significant. Irrigation increased the grain yields.

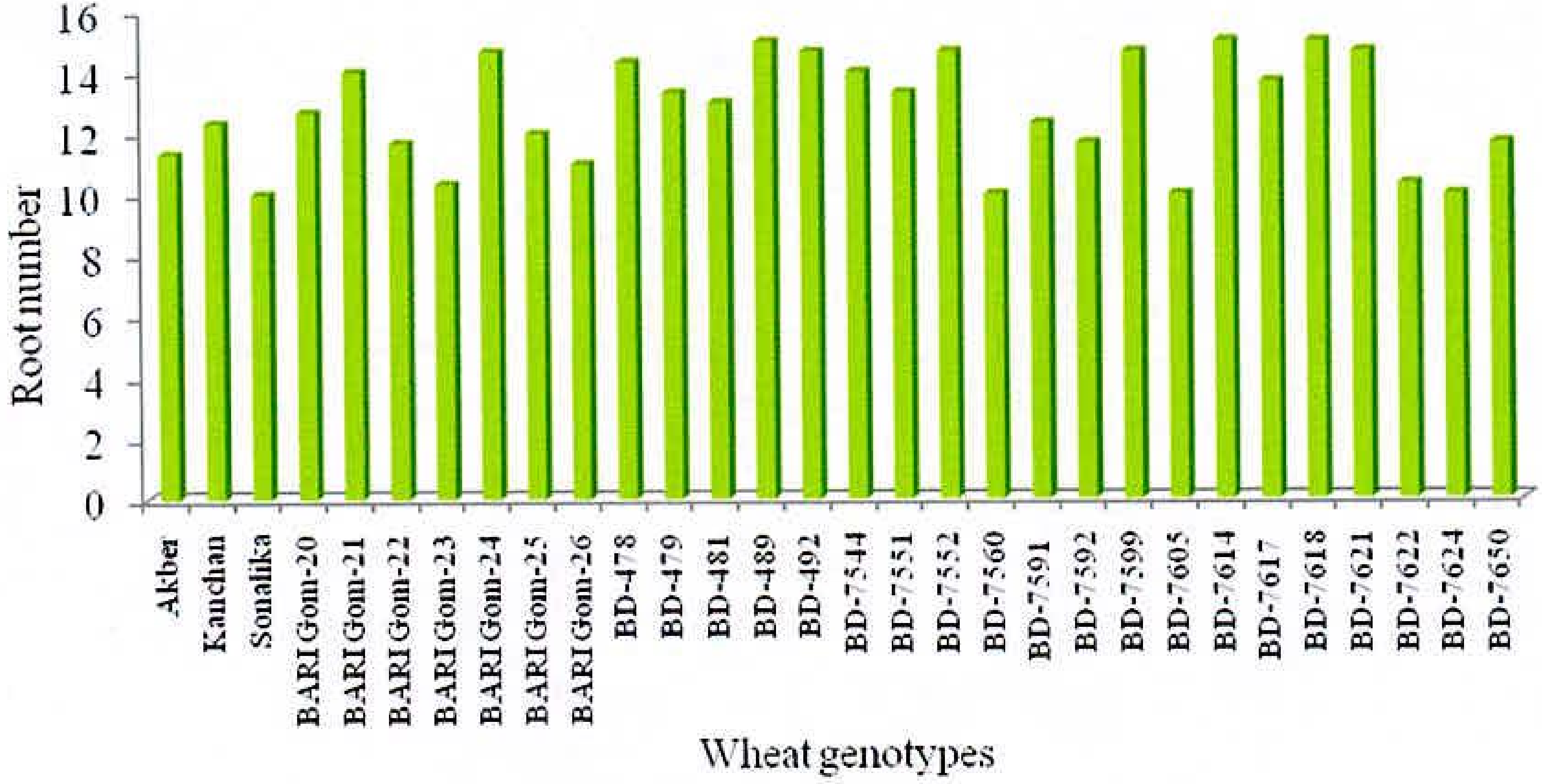

Figure 3. Root number for different wheat genotypes

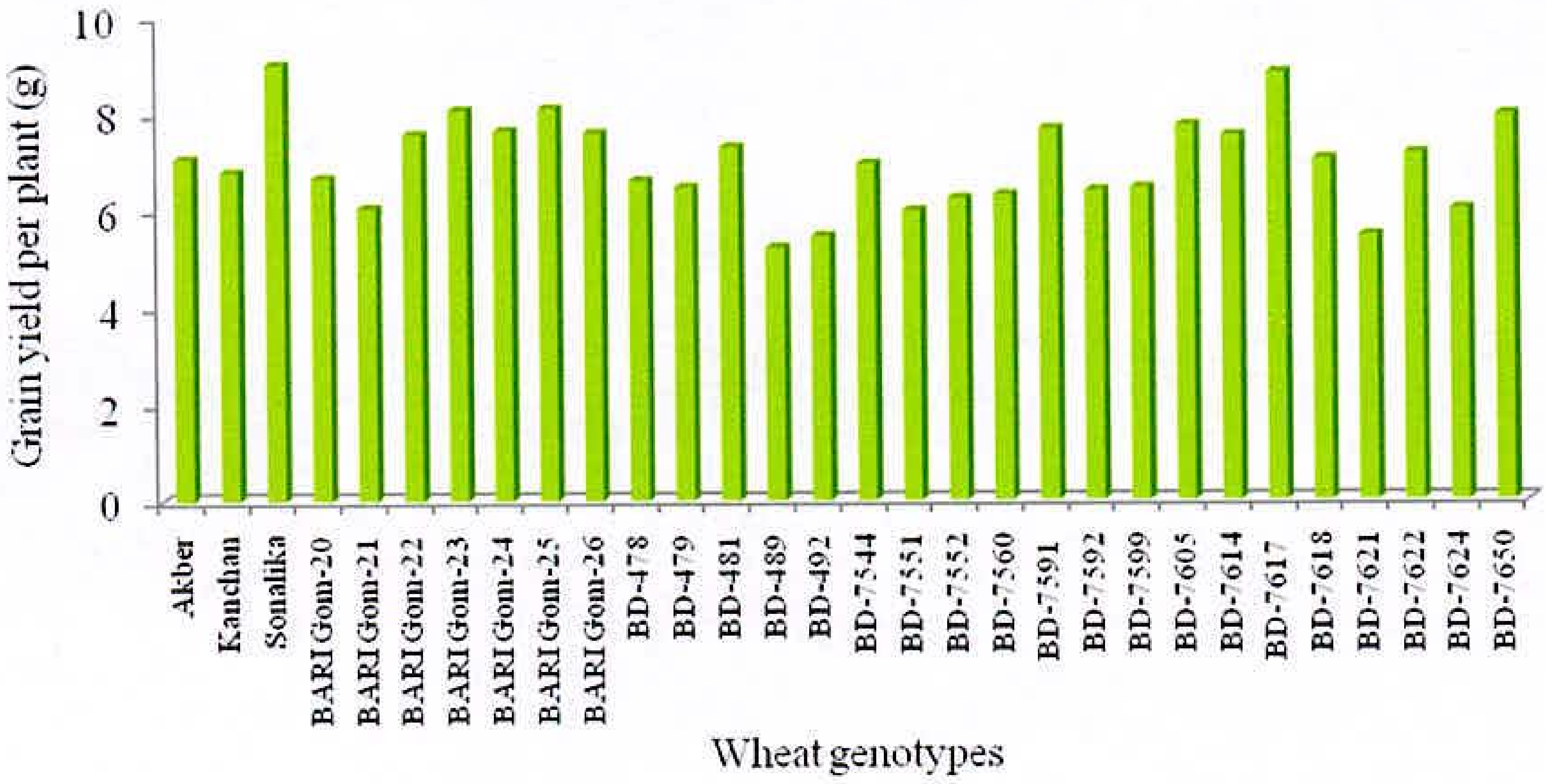

Figure 4. Grain yield per plant for different wheat genotypes

4.2 Variability study for 11 traits of wheat

Genotypic and phenotypic variance, heritability, genetic advance and genetic advance in percentage of mean was estimated for 14 traits in 30 collected genotypes of wheat and presented in Table 5.

4.2.1 Days to starting of heading

Days to starting of heading refers to phenotypic variation (43.54) was higher than the genotypic variance (29.02) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (12.56%) and genotypic (10.25%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment. High heritability (66.65%) in days to starting of heading attached with moderate genetic advance (11.61) and moderate genetic advance in percentage of mean (22.10). The high heritability along with moderate genetic advance in percentage of mean of days to starting of heading indicated the possible scope for improvement through selection of the character. Sharma and Garg (2002) found high heritability coupled with high genetic advance for number of days to heading.

4.2.2 Days to starting of maturity

Phenotypic variation (59.91) was higher than the genotypic variance (12.02) in terms of days to starting of maturity, that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (6.61%) and genotypic (2.96%) co-efficient of variation. The difference between phenotypic and genotypic variation was high indicated great influence of the environment for the expression of this character. Therefore, the breeder must have to simultaneous consideration of genetic work predicted environment for improving the trait. Low heritability (20.07%) in days to starting of maturity attached with low genetic advance (4.10) and low genetic advance in percentage of mean (3.50). The low heritability along with low genetic advance in percentage of mean of days to starting of maturity indicated the less possible scope for improvement through selection of the character.

Table 5. Genetic parameters of different yield contributing characters and yield of spring wheat under drought condition

Characters	Genotypic variance (σ^2g)	Phenotypic variance (σ^2p)	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (%)	Genetic Advance (GA)	GA in percentage of mean
Days to starting heading	29.02	43.54	10.25	12.56	66.65	11.61	22.10
Days to starting maturity	12.02	59.91	2.96	6.61	20.07	4.10	3.50
Plant height (cm)	40.47	74.69	9.02	12.26	54.18	12.36	17.53
Number of spikes/m^2	6094.63	6393.63	42.36	43.39	95.32	201.22	109.18
Number of spikelets/spike	14.73	25.93	9.75	12.94	56.81	7.64	19.41
Number of grains/spike	17.00	64.89	6.07	11.85	26.20	5.57	8.20
Chlorophyll content	14.89	30.75	7.94	11.41	48.40	7.09	14.57
Dry matter content (%)	0.34	0.83	10.55	16.52	40.82	0.98	17.80
Leaf area index	0.41	0.53	28.74	32.64	77.53	1.49	66.80
Peduncle length (cm)	1.49	1.93	7.42	8.46	76.82	2.82	17.16
Root length (cm)	3.03	3.55	32.61	35.29	85.38	4.25	79.54
Root number	3.08	3.38	13.80	14.47	90.90	4.41	34.73
Weight of 1000-grains (g)	32.94	38.62	14.60	15.81	85.30	13.99	35.61
Grain yield per plant (g)	0.83	1.06	13.01	14.72	78.17	2.12	30.37

4.2.3 Plant height

In terms of plant height, phenotypic variation (74.69) was higher than the genotypic variance (40.47) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (12.26%) and genotypic (9.02%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of plant height. High heritability (54.18%) in plant height attached with moderate genetic advance (12.36) and moderate genetic advance in percentage of mean (17.53). The high heritability along with moderate genetic advance in percentage of mean of plant height indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait. Kumar and Shukla (2002) observed high heritability coupled with high genetic advance for plant height. Wang *et al.* (2003) observed very high broad sense and narrow sense heritability for plant height

4.2.4 Number of spikes/m^2

Number of spikes/m^2 refers that phenotypic variation (6393.63) was higher than the genotypic variance (6094.63) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (43.39%) and genotypic (42.36%) co-efficient of variation. That mean the very close to phenotypic and genotypic variance which indicated that environment had played a little role with little genetic variation among the genotypes of this trait i.e. environmental influence was minimum. High heritability (95.32%) in number of spikes/m^2 attached with high genetic advance (201.22) and high genetic advance in percentage of mean (109.18). The high heritability along with high genetic advance in percentage of mean of number of spikes/m^2 this trait possessed high variation, it was potential for effective selection for further genetic improvement without minimum consideration of environmental effect. Ghimiray and Sarkar (2000) estimated high heritability coupled with high genetic advance for spikes per plant

4.2.5 Number of spikelets/spike

Phenotypic variation (25.93) was higher than the genotypic variance (14.73) in consideration of number of spikelets/spike, that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (12.94%) and genotypic (9.75%) co-efficient of variation. The difference between phenotypic and genotypic variation was high indicated great influence of the environment for the expression of this character. Therefore, the breeder must have to simultaneous consideration of genetic work predicted environment for improving the trait. High heritability (56.81%) in number of spikelets/spike attached with low genetic advance (7.64) and moderate genetic advance in percentage of mean (19.41). The high heritability along with low genetic advance in percentage of mean of number of spikelets/spike indicated that this trait possessed high variation. Sarkar *et al.* (2001) observed high broad sense heritability for spikelets per spike. Pramad Kumar and Mishra (2004) found high heritability with high genetic advance in percentage of mean for spikelets per spike of wheat.

4.2.6 Number of grains/spike

Number of grains/spike refers that phenotypic variation (64.89) was higher than the genotypic variance (17.00) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (11.85%) and genotypic (6.07%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of number of grains/spike. Low heritability (26.20%) in number of grains/spike attached with low genetic advance (5.57) and low genetic advance in percentage of mean (8.20). The high heritability along with moderate genetic advance in percentage of mean of number of grains/spike indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait. Sharma and Garg (2002) found high heritability coupled with high genetic advance for number of grains per spike.

4.2.7 Chlorophyll content

In terms of chlorophyll content, phenotypic variation (30.75) was higher than the genotypic variance (14.89) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (11.41%) and genotypic (7.94%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of chlorophyll content. Moderate heritability (48.40%) in chlorophyll content attached with moderate genetic advance (7.09) and moderate genetic advance in percentage of mean (14.57). Moderate estimate of heritability and low genetic advance were found for chlorophyll content suggested that this character was not predominantly controlled by environment with complex gene interaction.

4.2.8 Dry matter content

Phenotypic variation (0.83) was higher than the genotypic variance (0.34) for dry matter content indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (16.52%) and genotypic (10.55%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of dry matter content. Moderate heritability (40.82%) in dry matter content attached with low genetic advance (0.98) and low genetic advance in percentage of mean (17.80). Moderate high estimate of heritability and low genetic advance were registered for days to flowering of male suggested that this character was predominantly controlled by environment with complex gene interaction.

4.2.9 Leaf area index

In terms of leaf area index, phenotypic variation (0.53) was higher than the genotypic variance (0.41) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (32.64%) and genotypic (28.74%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of leaf area index. High heritability (77.53%) in leaf area index attached with low genetic advance (1.49) and high genetic advance in percentage of mean (66.80). The high heritability along with moderate genetic advance in percentage of mean of leaf area index indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait.

4.2.10 Peduncle length

Peduncle length in consideration of phenotypic variation (1.93) was higher than the genotypic variance (1.49) indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (8.46%) and genotypic (7.42%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of peduncle length. High heritability (76.82%) in peduncle length attached with low genetic advance (2.82) and high genetic advance in percentage of mean (17.16). The high heritability along with moderate genetic advance in percentage of mean of peduncle length indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait.

4.2.11 Root length

Root length in refers to phenotypic variation (3.55) was higher than the genotypic variance (3.03) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (35.29%) and genotypic (32.61%) co-efficient of variation. That mean the very close to phenotypic and genotypic variance which indicated that environment had played a little role with little genetic variation among the genotypes of this trait i.e. environmental influence was minimum. High heritability (85.38%) in root length attached with low genetic advance (4.25) and high genetic advance in percentage of mean (79.54). The high heritability estimate coupled with low expected genetic advance for this trait indicated the less importance of both additive and non additive genetic effects for the controlling the character.

4.2.12 Root number

Phenotypic variation (3.38) was higher than the genotypic variance (3.08) in terms of root number indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (14.47%) and genotypic (13.80%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of root number. High heritability (90.90%) in root number attached with low genetic advance (4.41) and high genetic advance in percentage of mean (34.73). The high heritability along with moderate genetic advance in percentage of mean of root number indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait.

4.2.13 Weight of 1000 grains

Weight of 1000 grains in consideration of phenotypic variation (38.62) was higher than the genotypic variance (32.94) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (15.81%) and genotypic (14.60%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of weight of 1000 grains. High heritability (85.30%) in weight of 1000 grains attached with high genetic advance (13.99) and high genetic advance in percentage of mean (35.61). The high heritability along with moderate genetic advance in percentage of mean of weight of 1000 grains indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in consideration of this trait. Kumar and Shukla (2002) observed high heritability coupled with high genetic advance for 1000-kernel weight.

4.2.14 Grain yield per plant

For grain yield per plant in context of phenotypic variation (1.06) was higher than the genotypic variance (0.83) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic

(14.72%) and genotypic (13.01%) co-efficient of variation. The moderate difference for this parameter was also suggested a considerable influence of environment for the expression of grain yield per plant. High heritability (78.17%) in grain yield per plant attached with low genetic advance (2.12) and high genetic advance in percentage of mean (30.37). The high heritability estimate coupled with moderate expected genetic advance for this trait indicated the importance of both additive and non additive genetic effects for the controlling the character. The heritability estimates provides the basis for selection on the phenotypic performance. Gupta and Verma (2000) observed high heritability and genetic advance for grain yield per plant. Sharma and Garg (2002) found high heritability coupled with high genetic advance for grain yield per plant.

4.3 Correlation Matrix

To measure the mutual relationship among yield and yield contributing characters of wheat genotypes correlation matrix analysis was done and also to determine the component characters on which selection could be based for improvement in yield of 30 genotypes of wheat (Table 6).

4.3.1 Days to starting of heading

Significant positive association was recorded for days to starting of heading of wheat genotypes with days to starting maturity (0.434) and number of grains/spike (0.493), while the non significant positive association for number of spikelets/spike (0.033), chlorophyll content (0.183), dry matter content (0.074) and root number (0.023). On the other hand, significant negative association was recorded for days to starting of heading with plant height (-0.334), number of spikes/m^2 (-0.641), leaf area index (-0.365), peduncle length (-0.253), weight of 1000 grains (-0.258) and grain yield per plant (-0.265) and non significant negative association was observed with root length (-0.009). The results revealed that increase of days to 50% flowering decreases most of yield contributing characters and yield in wheat. Patel and Jam (2002) found that kernel yield had a positive and highly significant correlation with days to heading.

Table 6. Correlation matrix of different yield contributing characters and yield of spring wheat under drought condition

Characters	Days to starting heading	Days to starting maturity	Plant height (cm)	Number of spikes/m^2	Number of spikelets/spike	Number of grains/spike	Chlorophyll content	Dry matter content (%)	Leaf area index	Peduncle length (cm)	Root length (cm)	Root number	Weight of 1000-grains	Grain yield per plant (g)
Days to starting heading	1.00													
Days to starting maturity	0.434**	1.00												
Plant height (cm)	-0.334**	-0.342**	1.00											
Number of spikes/m^2	-0.641**	-0.436**	0.361**	1.00										
Number of spikelets/spike	0.033	0.003	0.163	-0.035	1.00									
Number of grains/spike	0.493**	0.300**	-0.186	-0.473**	-0.148	1.00								
Chlorophyll content	0.183	0.159	-0.014	-0.159	-0.079	0.083	1.00							
Dry matter content (%)	0.074	0.084	-0.070	-0.064	0.067	-0.014	0.022	1.00						
Leaf area index	-0.365**	-0.295**	0.143	0.591**	-0.134	-0.345**	-0.052	0.042	1.00					
Peduncle length (cm)	-0.253*	-0.192	0.397**	0.276**	0.120	-0.059	-0.069	0.037	-0.019	1.00				
Root length (cm)	-0.009	0.074	-0.165	-0.158	0.070	-0.092	0.242*	-0.037	-0.105	-0.062	1.00			
Root number	0.023	0.203*	-0.404**	-0.218*	-0.083	-0.160	0.185	0.168	-0.005	-0.205*	0.162	1.00		
Weight of 1000-grains (g)	-0.258**	-0.239**	0.242*	0.399**	-0.047	-0.131	0.021	-0.143	0.333**	0.183	-0.266**	-0.183	1.00	
Grain yield per plant (g)	-0.265**	-0.267**	0.688**	0.269**	0.630**	-0.183	-0.097	-0.003	0.007	0.640**	-0.058	-0.343**	0.201*	1.00

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

4.3.2 Days to starting of maturity

Days to starting of maturity of wheat genotypes showed a significant negative association with plant height (-0.342), number of spikes/m^2 (-0.436), leaf area index (-0.295) weight of 1000-grains (-0.239), grain yield per plant (-0.267), while the non significant negative association for peduncle length (-0.192). On the other hand, significant positive association was recorded for days to starting of maturity with days to starting heading (0.434), number of grains/spike (0.300) and root number (0.203), whereas non significant positive association was observed with number of spikelets/spike (0.003), chlorophyll content (0.159), dry matter content (0.084) and root length (0.074).

4.3.3 Plant height

Data revealed a significant positive association was recorded for plant height of wheat genotypes with number of spikes/m^2 (0.361), peduncle length (0.397), weight of 1000 grains (0.242) and grain yield per plant (0.688), while the non significant positive association for number of spikelets/spike (0.163) and leaf area index (0.143). On the other hand, significant negative association was recorded for plant height with days to starting of heading (-0.334), days to starting of maturity (-0.342) and root number (-0.404) and non significant negative association was observed with number of grains/spike (-0.186), chlorophyll content (-0.014), dry matter content (-0.070) and root length (-0.165). The results revealed that plant height increase considerably with highest yield and yield contributing characters. This suggested that plant height for different genotypes were more potential to allocate their photosynthesis towards highest yield. Kumar *et al.* (2002) reported that grain yield per plant had direct positive correlation with plant height.

4.3.4 Number of spikes/m^2

Number of spikes/m^2 of wheat genotypes showed significant negative association with days to starting of heading (-0.641), days to starting of maturity (-0.436), number of grains/spike (-0.473) and root number (-0.218), whereas the non significant negative association for number of spikelets/spike (-0.035), chlorophyll content (-0.159), day matter content (-0.064) and root length (-0.158). On the other hand, significant positive association was recorded for number of spikes/m^2 with plant height (0.361), leaf area index (0.591), peduncle length (0.276), weight of 1000 grains (0.399) and grain yield per plant (0.269). Kumar *et al.* (2002) reported that grain yield per plant had direct positive correlation with number of spikes per plant and 1000-grain weight in some advanced wheat lines.

4.3.5 Number of spikelets/spike

Significant positive association was recorded for number of spikelets/spike of wheat genotypes with grain yield per plant (0.630), again the non significant positive association for dry matter content (0.067), peduncle length (0.120), root length (0.070), days to starting of heading (0.033), days to starting of maturity (0.003) and plant height (0.0163). On the other hand, non significant negative association was recorded for number of spikelets/spike with number of grains/spike (-0.148), chlorophyll content (-0.079), leaf area index (-0.134), root number (-0.083), weight of 1000 grains (-0.047) and number of spikes/m^2 (-0.035). Lad *et al.* (2003) observed that the grain yield exhibited highly significant and positive correlation with spikelets per spike.

4.3.6 Number of grains/spike

Number of grains/spike of wheat genotypes showed significant negative association with leaf area index (-0.345) and number of spikes/m^2 (-0.473), whereas the non significant negative association for dry matter content (-0.014), peduncle length (-0.059), root length (-0.092), root number (-0.160), weight of 1000 grains (-0.131), grain yield per plant (-0.183), plant height (-0.186) and number of spikelets/spike (-0.148). On the other hand, significant positive association was recorded for number of grains/spike with days to starting of heading (0.493), days to starting of maturity (0.300) and non significant positive association was observed with chlorophyll content (0.083). Dokuyucu (2002) studied correlation coefficients, which showed that grain yield, was positive and significantly related, with grains per spike.

4.3.7 Chlorophyll content

Statistically significant positive association was recorded for chlorophyll content of wheat genotypes with root length (0.242), while the non significant positive association for day matter content (0.022), root number (0.185), weight of 1000 grains (0.021), days to starting of heading (0.183), days to starting of maturity (0.159) and number of grains/spike (0.083). On the other hand, non significant negative association was recorded for chlorophyll content with leaf area index (-0.052), peduncle length (-0.069), grain yield per plant (-0.097), plant height (-0.014), number of spikes/m^2 (-0.159) and number of spikelets/spike (-0.079).

4.3.8 Dry matter content

Data revealed insignificant positive association was recorded for dry matter content of wheat genotypes with leaf area index (0.042), peduncle length (0.037), root number (0.168), days to starting of heading (0.074), days to starting of maturity (0.084), number of spikelets/spike (0.067) and chlorophyll content (0.022) whereas the non significant negative association for dry matter content with root length (-0.037), weight of 1000 grains (-0.143), grain yield per plant (-0.003), plant height (-0.070), number of spikes/m^2 (0.064) and number of grains/spike (-0.014).

4.3.9 Leaf area index

Significant positive association was recorded for leaf area index of wheat genotypes with weight of 1000 grains (0.333), number of spikes/m^2 (0.591), while the non significant positive association for grain yield per plant (0.007), plant height (0.143) and dry matter content (0.042). On the other hand, significant negative association was recorded for leaf area index with days to starting of heading (-0.365), days to starting of maturity (-0.295) and number of grains/spike (-0.345), whereas non significant negative association was observed with peduncle length (-0.019), root length (-0.105), root number (-0.005), number of spikelts/spike (-0.134) and chlorophyll content (-0.052).

4.3.10 Peduncle length

Peduncle length of wheat genotypes showed significant positive association with grain yield per plant (0.640), plant height (0.397) and number of spikes/m^2 (0.276), again the non significant positive association for weight of 1000 grains (0.183), number of spikelts/spike (0.120) and dry matter content (0.037). On the other hand, significant negative association was recorded for peduncle length with root number (-0.205) and days to starting of heading (-0.253) and non significant negative association was observed with root length (-0.062), days to starting of maturity (-0.192), number of grains/spike (-0.059), chlorophyll content (-0.069) and leaf area index (-0.019).

4.3.11 Root length

Significant negative association was recorded for root length of wheat genotypes with weight of 1000 grains (-0.266), whereas the non significant negative association for grain yield per plant (-0.058), days to starting of heading (-0.009), plant height (-0.165), number of spike/m^2 (-0.158), number of grains/spike (-0.092), dry matter content (-0.037), leaf area index (-0.105) and peduncle length (-0.062). On the other hand, significant positive association was recorded for root length with chlorophyll content (0.242) and non significant positive association was observed with root number (0.162), days to starting of maturity (0.074) and number of spikelts/spike (0.070).

4.3.12 Root number

Statistically significant negative association was recorded for root number of wheat genotypes with grain yield per plant (-0.343), plant height (-0.404), number of spike/m^2 (-0.218) and peduncle length (-0.205), again the non significant negative association for weight of 1000 grains (-0.183), number of spikelts/spike (-0.083), number of grains/spike (-0.160) and leaf area index (-0.005). On the other hand, significant positive association was recorded for root number with days to starting of maturity (0.203), whereas non significant positive association was observed with days to starting of heading (0.023), chlorophyll content (0.185), dry matter content (0.168) and root length (0.162).

4.3.13 Weight of 1000 grains

Weight of 1000 grains of wheat genotypes showed significant positive association with grain yield per plant (0.201), plant height (0.0242), number of spikes/m^2 (0.399) and leaf area index (0.333), whereas the non significant positive association for chlorophyll content (0.021) and peduncle length (0.183). On the other hand, significant negative association was recorded for weight of 1000 grains with days to starting heading (-0.258), days to starting of maturity (-0.239) and root length (-0.266), whereas non significant negative association was observed with number of spikelts/spike (-0.047), number of grains/spike (-0.131), dry matter content (-0.143) and root number (-0.183). Sarker *et al.* (2002) found highly positive correlation of 1000-grain weight with grain yield. Arun Kumar *et al.* (2002) reported that grain yield per plant had direct positive correlation with 1000-grain weight in some advanced wheat lines.

4.3.14 Grain yield per plant

Significant negative association was recorded for grain yield per plant of wheat genotypes with days to starting of heading (-0.265), days to starting of maturity (-0.267) and root number (-0.343), while the non significant negative association for number of grains/spike (-0.183), chlorophyll content (-0.097), dry matter content (-0.003) and root length (-0.058). On the other hand, significant positive association was recorded for grain yield per plant with plant height (0.688), number of spike/m^2 (0.269), number of spikelts/spike (0.630), peduncle length (0.640) and weight of 1000 grains (0.201), while non significant positive association was observed with leaf area index (0.007). Ayccek and Yldrm (2006) reported that grain yield was negatively and significantly correlated with time to heading. Inamullah *et al.* (2006) reported that yield per plant was positively correlated with number of spikes per plant, number of kernels per spike. Payal *et al.* (2007) observed Positive direct effects of biological yield per plant, number of grains per ear, tillers per plant, 1000 kernel weight, days to heading and days to maturity on grain yield.

4.4 Path Co-efficient Analysis

Path co-efficient analysis denotes the components of correlation co-efficient within different traits into the direct and indirect effects and indicates the relationship in more meaningful way. Path co-efficient were analyzed using the genotypic correlation only. The results of the path co-efficient using genotypic correlation presented in Table 7.

4.4.1 Yield per plant *vs* days to starting of heading

Path analysis revealed that days to staring of heading had positive direct effect (0.205) on yield per plant. It showed negligible positive indirect effect through days to starting maturity, number of spikes/m^2, number of spikelets/spike, number of grains/spike, dry matter content, leaf area index, peduncle length and weight of 1000-grains, whereas days to starting of heading showed negative indirect effect through plant height, chlorophyll content, root length and root number.

4.4.2 Yield per plant *vs* days to starting of maturity

Days to staring of maturity had negative direct effect (-0.134) on yield per plant through path analysis. It showed negligible positive indirect effect through plant height, number of spikelets/spike, chlorophyll content, dry matter content and root number whereas days to starting of maturity showed negative indirect effect through days to starting heading, number of spikes/m^2, number of grains/spike, leaf area index, peduncle length, root length and weight of 1000-grains.

4.4.3 Yield per plant *vs* plant height

Path analysis revealed that plant height had positive direct effect (0.163) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, number of spikes/m^2, chlorophyll content, dry matter content, peduncle length and root number, whereas plant height showed negative indirect effect through days to starting maturity, number of spikelets/spike, number of grains/spike, leaf area index and weight of 1000-grains. Khan *et al.* (1999) reported that plant height and spike length directly influenced on grain yield of spring wheat. Dokuyucu *et al.* (2002) reported that 100-grain weight had significantly positive direct effects on grain yield but plant height exhibited negative direct effects on grain yield.

Table 7. Path coefficients of different yield contributing characters and yield of spring wheat under drought condition

Characters	Days to starting heading	Days to starting maturity	Plant height (cm)	Number of spikes/m^2	Number of spikelets/spike	Number of grains/spike	Chlorophyll content	Dry matter content (%)	Leaf area index	Peduncle length (cm)	Root length (cm)	Root number	Weight of 1000-grains	Yield (g/plant)
Days to starting heading	**0.205**	0.129	-0.456	0.038	0.104	0.122	-0.298	0.186	0.025	0.106	-0.145	-0.345	0.064	-0.265
Days to starting maturity	-0.133	**-0.134**	0.155	-0.168	0.214	-0.207	0.133	0.265	-0.097	-0.159	-0.139	0.142	-0.139	-0.267
Plant height (cm)	0.243	-0.148	**0.163**	0.255	-0.169	-0.146	0.348	0.136	-0.161	0.168	-0.078	0.169	-0.092	0.688
Number of spikes/m^2	0.105	0.054	0.134	**0.113**	-0.168	0.137	-0.111	0.201	-0.156	-0.075	0.161	0.087	-0.213	0.269
Number of spikelets/spike	-0.233	-0.059	0.227	-0.165	**0.243**	0.135	-0.132	0.275	-0.095	0.356	-0.046	0.266	-0.142	0.630
Number of grains/spike	0.128	-0.344	-0.016	0.138	-0.072	**0.056**	-0.165	0.123	-0.078	0.121	-0.295	0.167	0.054	-0.183
Chlorophyll content	-0.133	0.092	-0.145	0.236	-0.123	0.045	**-0.119**	0.008	0.032	0.175	0.134	-0.431	0.132	-0.097
Dry matter content (%)	0.118	-0.135	-0.469	0.048	-0.088	0.075	0.143	**0.138**	-0.032	0.296	0.181	-0.305	0.033	0.003
Leaf area index	0.194	0.182	0.067	-0.202	0.299	-0.133	0.108	0.097	**-0.218**	0.117	-0.309	0.015	-0.210	0.007
Peduncle length (cm)	-0.058	0.104	-0.281	0.054	0.398	-0.221	-0.156	0.365	0.142	**0.157**	0.106	0.068	-0.038	0.640
Root length (cm)	0.161	0.117	-0.209	0.155	-0.078	0.021	-0.289	0.145	-0.178	0.143	**-0.246**	-0.034	0.234	-0.058
Root number	-0.275	0.033	0.114	0.089	-0.234	0.033	-0.265	-0.199	0.032	0.175	0.134	**-0.078**	0.098	-0.343
Weight of 1000-grains (g)	0.151	-0.038	0.234	-0.265	0.044	-0.213	-0.145	0.195	0.056	-0.246	0.066	0.178	**0.184**	0.201

Residual effect = 0.2514

4.4.4 Yield per plant *vs* number of spikes/m^2

From path analysis it was revealed that number of spikes/m^2 had positive direct effect (0.113) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, days to starting maturity, plant height, number of grains/spike, dry matter content, root length and root number, whereas number of spikes/m^2 showed negative indirect effect through number of spikelets/spike, chlorophyll content, leaf area index, peduncle length and weight of 1000-grains. Subhani and Khaliq (1994) observed high positive direct effects of spikes per plant, grains per spike and 100-grain weight on yield per plant. Esmail (2002) reported that number of spike per plant had the highest direct effects on grain yield per plant followed by grain weight per spike and plant height.

4.4.5 Yield per plant *vs* number of spikelets/spike

Number of spikelts/spike had positive direct effect (0.243) on yield per plant through path analysis. It showed negligible positive indirect effect through plant height, number of grains/spike, dry matter content, peduncle length and root number, whereas number of spikelts/spike showed negative indirect effect through days to starting of heading, days to starting maturity, number of spikes/m^2, chlorophyll content, leaf area index, root length and weight of 1000-grains.

4.4.6 Yield per plant *vs* number of grains/spike

In consideration of path analysis it was revealed that number of grains/spike had positive direct effect (0.056) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, number of spikes/m^2, dry matter content, peduncle length, root number and weight of 1000-grains whereas number of grains/spike showed negative indirect effect through days to starting maturity, plant height, number of spikelets/spike, chlorophyll content, leaf area index and root length. Mahak *et al.* (2003) reported that the number of grains per spike exhibited the greatest direct effect on grain yield followed by spike length and 1000-grain weight and they proposed that number of grains per spike, spike length and 1000-grain weight were the major yield contributing characters.

4.4.7 Yield per plant *vs* chlorophyll content

For path analysis revealed that chlorophyll content had negative direct effect (-0.119) on yield per plant. It showed negligible positive indirect effect through days to starting maturity, number of spikes/m^2, number of grains/spike, dry matter content, leaf area index, peduncle length, root length and weight of 1000-grains whereas chlorophyll content showed negative indirect effect through days to starting of heading, plant height, number of spikelets/spike and root number.

4.4.8 Yield per plant *vs* dry matter content

Dry matter content had positive direct effect (0.138) on yield per plant in path analysis. It showed negligible positive indirect effect through days to starting of heading, number of spikes/m^2, number of grains/spike, chlorophyll content, peduncle length, root length and weight of 1000-grains whereas dry matter content showed negative indirect effect through days to starting maturity, plant height, number of spikelets/spike, leaf area index and root number.

4.4.9 Yield per plant *vs* leaf area index

In consideration of path analysis revealed that leaf area index had negative direct effect (-0.218) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, days to starting maturity, plant height, number of spikelets/spike, chlorophyll content, dry matter content, peduncle length and root number, whereas leaf area index showed negative indirect effect through number of spikes/m^2, number of grains/spike, root length and weight of 1000-grains.

4.4.10 Yield per plant *vs* peduncle length

Path analysis revealed that peduncle length had positive direct effect (0.157) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, number of spikes/m^2, number of spikelets/spike, dry matter content, leaf area index, root length and root number whereas peduncle length showed negative indirect effect through days to starting of heading, plant height, number of grains/spike, chlorophyll content and weight of 1000-grains.

4.4.11 Yield per plant *vs* root length

It was revealed from path analysis revealed that root length had negative direct effect (-0.246) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, days to starting maturity, number of spikes/m^2, number of grains/spike, dry matter content, peduncle length and weight of 1000-grains whereas root length showed negative indirect effect through plant height, number of spikelets/spike, chlorophyll content, leaf area index and root number.

4.4.12 Yield per plant *vs* root number

Root number had negative direct effect (-0.078) on yield per plant through path analysis. It showed negligible positive indirect effect through days to starting maturity, plant height, number of spikes/m^2, number of grains/spike, leaf area index, peduncle length, root length and weight of 1000-grains whereas root number showed negative indirect effect through days to starting of heading, number of spikelets/spike, chlorophyll content and dry matter content.

4.4.13 Yield per plant *vs* weight of 1000 grains

Path analysis revealed that weight of 1000 grains had positive direct effect (0.184) on yield per plant. It showed negligible positive indirect effect through days to starting of heading, plant height, number of spikelets/spike, dry matter content, leaf area index, root length and root number whereas weight of 1000 grains showed negative indirect effect through days to starting maturity, number of spikes/m^2, number of grains/spike, chlorophyll content and peduncle length. Ayccek and Yldrm (2006) recorded positive direct effects of plant height, grain number per spike and 1000-kernel weight and negative direct effects of time to heading on grain yield. Saktipada *et al.* (2008) was observed that number of spikelets per panicle, days to flowering and 1000-grain weight had high direct effects on grain yield per plant.

chapter

5

• Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November 2013 to April 2014 in rabi season in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the role of morpho-physiological character in spring wheat under drought stress. In this experiment 30 wheat genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. During the experimental period no irrigation was provided for creating drought environment. Mean performance, variability, correlation matrix, path analysis was done on different yield contributing characters and yield of wheat genotypes.

The highest days to starting of heading (66.33) was observed in the genotype of BD-7624, while the lowest days (45.00) from BARI Gom-25. The highest days to starting of maturity (129.33) was found in genotype BD-7621, whereas the lowest days (110.33) were attained in the wheat genotypes BARI Gom-25, BARI Gom-26 and BD-478. The longest plant (84.00 cm) was recorded in genotype Sonalika, again the shortest plant (53.33 cm) was found in the wheat genotype BD-489. The maximum number of spikes/m^2 (324.00) was attained in BARI Gom-26, whereas the minimum number (104.33) was observed in the wheat genotype BD-7621. The maximum number of spikelets/spikes (51.00) was found in BD-7617, while the minimum number (32.00) was observed in the wheat genotype BD-7621. The maximum number of grains/spikes (81.33) was recorded in BD-7624, again the minimum number (57.00) was recorded in the wheat genotype Akber. The highest chlorophyll content (58.37) was attained in BARI Gom-24, whereas the lowest chlorophyll content (40.37) was found in the wheat genotype BARI Gom-23. The highest dry matter content (6.67%) was observed in BARI Gom-24 and BD-7622, while the lowest dry matter content (4.00%) was found in the wheat genotype BD-492. The highest leaf area index (3.70) was attained in BARI Gom-20 and, the lowest dry matter content (1.04) was recorded in the wheat genotype BD-7618.

The longest peduncle (18.67 cm) was found in Sonalika, whereas the shortest peduncle (14.00 cm) was observed in the wheat genotype BD-7551. The longest root (9.07 cm) was recorded in BD-7552 and the shortest root (3.00 cm) was recorded in the wheat genotype BARI Gom-23 and BARI Gom-26. The maximum root number (15.00) was observed in BD-489, BD-7614 and BD-7618, whereas the minimum root number (10.00) was recorded in the wheat genotype Sonalika, BD-7560, BD-7605 and BD-7624. The highest weight of 1000 grains (51.47 g) was found in Sonalika and the lowest weight of 1000 grains (30.33 g) was attained in the wheat genotype BD-7622. The highest grain yield per plant (9.02 g) was recorded in Sonalika, while the lowest grain yield per plant (5.24 g) was observed in the wheat genotype BD-489.

In consideration of days to starting of heading refers to phenotypic variation (43.54) was higher than the genotypic variance (29.02) supported by narrow difference between phenotypic (12.56%) and genotypic (10.25%) co-efficient of variation with high heritability (66.65%) in days to starting of heading attached with moderate genetic advance (11.61) and moderate genetic advance in percentage of mean (22.10). Phenotypic variation (59.91) was higher than the genotypic variance (12.02) in terms of days to starting of maturity, supported by narrow difference between phenotypic (6.61%) and genotypic (2.96%) co-efficient of variation with low heritability (20.07%) in days to starting of maturity attached with low genetic advance (4.10) and low genetic advance in percentage of mean (3.50). In terms of plant height, phenotypic variation (74.69) was higher than the genotypic variance (40.47) supported by narrow difference between phenotypic (12.26%) and genotypic (9.02%) co-efficient of variation with high heritability (54.18%) in plant height attached with moderate genetic advance (12.36) and moderate genetic advance in percentage of mean (17.53). Number of spikes/m^2 refers that phenotypic variation (6393.63) was higher than the genotypic variance (6094.63) supported by narrow difference between phenotypic (43.39%) and genotypic (42.36%) co-efficient of variation with high heritability (95.32%) in number of spikes/m^2 attached with high genetic advance (201.22) and high genetic advance in percentage of mean (109.18). Phenotypic variation (25.93) was higher than the genotypic variance (14.73) in consideration of number of spikelets/spike, supported by narrow difference between phenotypic (12.94%) and genotypic (9.75%) co-efficient of variation with high heritability (56.81%) in number of spikelets/spike attached with low genetic advance (7.64) and moderate genetic advance in percentage of mean (19.41). Number of grains/spike refers that phenotypic variation (64.89) was higher than the genotypic variance (17.00) supported by narrow difference between phenotypic (11.85%) and genotypic (6.07%) co-efficient of variation with low heritability (26.20%) in number of grains/spike attached with low genetic advance (5.57) and low genetic advance in percentage of mean (8.20). In terms of chlorophyll content, phenotypic variation (30.75) was higher than the genotypic variance (14.89) supported by narrow difference between phenotypic (11.41%) and genotypic (7.94%) co-efficient of variation with moderate heritability (48.40%) in chlorophyll content attached with moderate genetic advance (7.09) and moderate genetic advance in percentage of mean (14.57). Phenotypic variation (0.83) was higher than the genotypic variance (0.34) for dry matter content supported by narrow difference between phenotypic (16.52%) and genotypic (10.55%) co-efficient of variation with moderate heritability (40.82%) in dry matter content attached with low genetic advance (0.98) and low genetic advance in percentage of mean (17.80). In terms of leaf area index, phenotypic variation (0.53) was higher than the genotypic variance (0.41) supported by narrow difference between phenotypic (32.64%) and genotypic (28.74%) co-efficient of variation with high heritability (77.53%) in leaf area index attached with low genetic advance (1.49) and high genetic advance in percentage of mean (66.80). Peduncle length in consideration of phenotypic variation (1.93) was higher than the genotypic variance (1.49) supported by narrow difference between phenotypic (8.46%) and genotypic (7.42%) co-efficient of variation with high heritability (76.82%) in peduncle length attached with low genetic advance (2.82) and high genetic advance in percentage of mean (17.16). Root length in refers to phenotypic variation (3.55) was higher than the genotypic variance (3.03) supported by narrow difference between phenotypic

(35.29%) and genotypic (32.61%) co-efficient of variation with high heritability (85.38%) in root length attached with low genetic advance (4.25) and high genetic advance in percentage of mean (79.54). Phenotypic variation (3.38) was higher than the genotypic variance (3.08) in terms of root number indicating supported by narrow difference between phenotypic (14.47%) and genotypic (13.80%) co-efficient of variation with high heritability (90.90%) in root number attached with low genetic advance (4.41) and high genetic advance in percentage of mean (34.73). Weight of 1000 grains in consideration of phenotypic variation (38.62) was higher than the genotypic variance (32.94) supported by narrow difference between phenotypic (15.81%) and genotypic (14.60%) co-efficient of variation with high heritability (85.30%) in weight of 1000 grains attached with high genetic advance (13.99) and high genetic advance in percentage of mean (35.61). For grain yield per plant in context of phenotypic variation (1.06) was higher than the genotypic variance (0.83) supported by narrow difference between phenotypic (14.72%) and genotypic (13.01%) co-efficient of variation with high heritability (78.17%) in grain yield per plant attached with low genetic advance (2.12) and high genetic advance in percentage of mean (30.37).

In correlation study, significant negative association was recorded for grain yield per plant of wheat genotypes with days to starting of heading (-0.265), days to starting of maturity (-0.267) and root number (-0.343), while the non significant negative association for number of grains/spike (-0.183), chlorophyll content (-0.097), dry matter content (-0.003) and root length (-0.058). On the other hand, significant positive association was recorded for grain yield per plant with plant height (0.688), number of spike/m^2 (0.269), number of spikelts/spike (0.630), peduncle length (0.640) and weight of 1000 grains (0.201), while non significant positive association was observed with leaf area index (0.007).

Path analysis revealed that days to staring of heading had positive direct effect (0.205) on yield per plant. Days to staring of maturity had negative direct effect (-0.134) on yield per plant through path analysis. Path analysis revealed that plant height had positive direct effect (0.163) on yield per plant. From path analysis it was revealed that number of spikes/m^2 had positive direct effect (0.113) on yield per plant. Number of spikelts/spike had positive direct effect (0.243) on yield per plant through path analysis. In consideration of path analysis it was revealed that number of grains/spike had positive direct effect (0.056) on yield per plant. For path analysis revealed that chlorophyll content had negative direct effect (-0.119) on yield per plant. Dry matter content had positive direct effect (0.138) on yield per plant in path analysis. In consideration of path analysis revealed that leaf area index had negative direct effect (-0.218) on yield per plant. Path analysis revealed that peduncle length had positive direct effect (0.157) on yield per plant. It was revealed from path analysis revealed that root length had negative direct effect (-0.246) on yield per plant. Root number had negative direct effect (-0.078) on yield per plant through path analysis. Path analysis revealed that weight of 1000 grains had positive direct effect (0.184) on yield per plant.

In consideration of yield contributing characters and yield Sonalika perform better under drought condition followed by BD-7617, BARI Gom-25, BARI Gom-23 and BD-7650. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits indicating that high environmental influence on the studied characters. Correlation analysis revealed that the characters plant height, number of spike/m^2, number of spikelts/spike, peduncle length and weight of 1000 grains had highly positive correlation with yield per plant.

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APPENDICES

Appendix I. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2013 to April, 2014

Month	*Air temperature (°C)		*Relative humidity (%)	*Total rainfall (mm)
	Maximum	Minimum		
November, 2013	25.8	16.0	78	00
December, 2013	22.4	13.5	74	00
January, 2014	25.2	12.8	69	00
February, 2014	27.3	16.9	66	39
March, 2014	31.7	19.2	57	23
April, 2014	34.2	23.4	61	112

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy 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 initial soil

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

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka