GROWTH AND YIELD PERFORMANCE OF SELECTED WHEAT GENOTYPES AT VARIABLE IRRIGATION MANAGEMENT

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CERTIFICATE

This is to certify that the thesis entitled, ***"GROWTH AND YIELD PERFORMANCE OF SELECTED WHEAT GENOTYPES AT VARIABLE IRRIGATION MANAGEMENT*** *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* ***SOIL SCIENCE,*** *embodies the result of a piece of bona fide research work carried out by* ***MD. ABDUR RAHMAN*** *Registration No.* ***11-04653*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Place: Dhaka, Bangladesh

(Prof. Mst. Afrose Jahan)
Supervisor

DEDICATED TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the Agronomy Field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period of November 17, 2016 to March 290, 2017 to Growth and yield performance of selected wheat genotypes at variable irrigation management as influenced by different varieties and different irrigated and non irrigated condition. In this experiment, the treatment consisted of three varieties viz. V_1 = BARI Gom 26, V_2 = BARI Gom 28, V_3 = BARI Gom 30, and four different irrigations condition viz. I_0 = No Irrigation throughout the growing season, I_1 = One irrigation (Irrigate at CRI stage), I_2= Two irrigation (Irrigate at CRI and grain filling), I_3= Three irrigation (irrigate at CRI, booting and grain filling stages). The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters. Results showed significant variation in almost every parameter of treatments. The highest Plant height, number of effective tillers hill^{-1}, spike length number of grain spike^{-1} was obtained from BARI Gom-30. The highest grain weight hectare^{-1} (1.37 ton) was found from wheat variety BARI Gom-30. All parameter of wheat showed statistically significant variation due to amount of irrigation. The maximum value of growth, yield contributing characters, seed yield was observed with three irrigation (irrigate at CRI, booting and grain filling stages). The interaction between different levels of variety and irrigation was significantly influenced on almost all growth and yield contributing characters, seed yield. The highest grain yield (1.93 t ha^{-1}) was obtained from BARI Gom-30 with three irrigation (irrigate at CRI, booting and grain filling stages). The optimum growth and higher yield of wheat cv. BARI Gom-30 could be obtained by applying three irrigations at irrigate at CRI, booting and grain filling stages.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops cultivated all over the world. Wheat production was increased from 585,691 thousand tons in 2000 to 713,183 thousand tons in 2013 which was ranked below rice and maize in case of production (FAO, 2015). In the developing world, need for wheat will be increased 60 % by 2050 (Rosegrant and Agcaoili, 2010). The International Food Policy Research Institute projections revealed that world demand for wheat will increase from 552 million tons in 1993 to 775 million tons by 2020 (Rosegrant *et al.*,1997). Wheat grain is the main staple food for about two third of the total population of the world. (Hanson *et al.,* 1982).

It supplies more nutrients compared with other food crops. Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006). It is the second most important cereal crop after rice in Bangladesh. So, it is imperative to increase the production of wheat to meet the food requirement of vast population of Bangladesh that will secure food security. During 2013-14 the cultivated area of wheat was 429607 ha having a total production of 1302998 metric tons with an average yield of 3.033 metric tons ha^{-1}whereas during 2012-13 the cultivated area of wheat was 416522 ha having a total production of 1254778 metric tons with an average yield of 3.013 tons ha^{-1} (BBS, 2014).

Current demand of wheat in the country is 3.0-3.5 million tons. Increasing rate of consumption of wheat is 3% per year (Roy and Pandit, 2007). Wheat production is about 1.0 milllion from 0.40 million hectares of land. Bangaladesh has to import about 2.0-2.5 million ton wheat every year. Wheat is grown all over Bangladesh but wheat grows more in Dhaka, Faridpur, Mymensingh, Rangpur, Dinajpur, Comilla districts. Wheat has the umpteen potentialities in yield among other crops grown in Bangladesh. However, yield per hectare of wheat in Bangladesh is lower than other wheat growing countries in the world due to various problems. World wheat production will reduce owing to global warming and developing countries like Bangladesh will be adversely affected (CIMMYT- IPCC, 2007; ICARDA, 2011; CGIAR, 2009 and OECD, 2003). But major problems are delayed sowing after the harvest of transplanted aman rice and no or limited irrigation facilities.

Increasing food production of the country in the next 20 years to much population growth is a big challenge in Bangladesh. It is more difficult because, land area devoted to agriculture will decline and better quality land and water resources will be divided to the other sector of national economy. In order to grow more food from marginal and good quality lands, the quality of natural resources like seed, water, varieties and fuel must be improved and sustained. Variety plays an important role in producing high yield of wheat because different varieties responded differently for their genotypic characters, input requirement, growth process and the prevailing environment during growing season.

According to the researchers, variety is an important factor affecting farmers" yields and is also among the factors given the highest priority for immediate technology transfer. The speed with which new varieties are released and diffused to the farming population is an important factor influencing the benefits realized from plant breeding. Diffusion of new varieties ensures continuing increase in productivity through the increased yield potential of new varieties; it reduces the time lapse from the investment in research to the time the benefits are realized, thereby increasing the returns to research; and it helps to maintain genetic resistance to diseases and pests (Heisey, 1990).

Irrigation plays an imperative role for optimum growth and development of wheat. Idris *et al.* (1983) stated that uneven distribution is responsible for foiling synchronization with water requirement of wheat in the entire plain of the country. The germination of seed and uptake of nutrients from the soil are negatively affected by insufficient soil moisture. Water requirement for a crop depends on the variation in crop cover and climatic conditions all over the growing season (Doorenbos and Pruitt, 1977). The moisture available in a soil is the difference of moisture contents at the PWP (Permanent wilting point) and FC (Field capacity), levels which is available to the plant in the root zone. The field capacity is the amount of water remaining in the soil after having been wetted and after free drainage has ceased. The matric potential at this soil moisture condition is around - 1/10 to – 1/3 bar. The permanent wilting point is the water content of a soil when most plants (wheat, corn, sunflowers etc.) growing in that soil wilt and fail to recover their turgor upon rewetting. The matric potential at this soil moisture condition is commonly estimated at -15 bar. Irrigation requirement is the quantity of water needed above the existing moisture level. The difference between available moisture and irrigation requirements lies in the losses in conveyance, evaporation and seepage, which must be considered when reckoning the irrigation requirements. Prasad *et al*., 1988 observed that water use efficiency (WUE) was generally higher in lower frequencies of irrigation. They reported that maximum WUE when two irrigations were applied at crown-root initiation and flowering because these are the most critical stages of irrigation, and therefore, water utilization was most efficient leading to high WUE. During crop-growth period total evapotranspiration was higher when more irrigation was given.

In Bangladesh the wheat growing season (November-March) is in the driest period of the year. Wheat yield was declined by 50% owing to soil moisture stress(Islam and Islam,1991). Irrigation water should be applied in different critical stages of wheat for successful wheat production. Shoot dry weight, number of grains, grain yield, biological yield and harvest index decreased to a greater extent when water stress was imposed at the anthesis stage while water stress was imposed at booting stage caused a greater reduction in plant height and number of tillers (Gupta *et al*., 2001). Determination of accurate amount of water reduces irrigation cost as well as checks ground water waste. Water requirements vary depending on the stages of development. The pick requirement is at crown root initiation stage(CRI). In wheat, irrigation has been recommended at CRI, flowering and grain filling stages. However, the amount of irrigation water is shrinking day by day in Bangladesh which may be attributed to filling of pond river bottom. Moreover, global climate change scenarios are also responsible for their scarcity of irrigation water. So, it is essential to estimate water saving technique to have an economic estimate of irrigation water.

Information on the amount of irrigation water as well as the precise sowing time of wheat with change in climate to expedite wheat production within the farmer's limited resources is inadequate in Bangladesh. The need of water requirement also varies with sowing times as the soil moisture depletes with the days after sowing in Bangladesh as there is scanty rainfall after sowing season of wheat in general in the month of November.

With above considerations, the present research work was conducted with the following objectives:

1. To evaluate yield performance of selected wheat genotypes*(s)* at variable irrigation management.
2. To identify the suitable genotype (s) of wheat giving higher yield under moisture stress condition.

CHAPTER II

REVIEW OF LITERATURE

Wheat is an important cereal crop in Bangladesh which can contribute to a large rent in the national economy. But the research works done on this crop with respect to agronomic practices are inadequate. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the irrigation and varieties of wheat, so far been done at home and abroad on this crop, have been reviewed in this chapter under the following heads-

2.1. Effect of variety on growth and yield of wheat

Uddin et al (2015) conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during November 2012 to April 2013to evaluate the influence of variety and sowing date on grain growth and yield of wheat. The experiment consisted of four wheat variety viz., BARI Gom -21, BARI Gom-24, BARI Gom-25and BARI Gom-26 and three sowing date viz., 20 November, 01December and 12 December. Grain growth, yield contributing characters and yield of wheat were significantly influenced by different variety and sowing date. Among the variety, BARI Gom-24 and BARI Gom-25 showed initial lower lag phase duration of 8 days after anthesis (DAA) and 12 DAA, respectively than BARI Gom -21 (16 DAA) sown at 01 December. The maximum grain growth rate whole over the period was maintained by BARI

Gom-26 sown at 01 December. It reached peak at 20 DAA (1.17 mg /grain/day). The minimum growth rate was maintained by BARI Gom-21 and BARI Gom-24 sown at 12 December (0.15 mg /grain/day). BARI Gom -25 sown at 01December gave the highest yield (4.6 t ha^{-1}) whereas BARI Gom-21 sown at 20 November gave the lowest (2.67 t ha^{-1}). All the wheat varieties sown at 01 December yielded better than 20 November and 12 December sowing.

Rahman *et al.* (2013) carried out a field trail at South-Surma, Sylhet, in 2009-10 and at FSRD site Jalalpur, Sylhet in 2010-11 in collaboration with WRC and OFRD, BARI to examine the response of 7 wheat varieties at two levels of lime in split-plot design where lime was applied in main plots and different wheat varieties were grown in sub-plots. The seeds were sown on 05 December 2009 and 30 November 2010 for the growing season of 2009-10 and 2010-11, respectively. The wheat varieties used in this study were Shatabdi, Sufi, Sourav, Bijoy, Prodip, BARI Gom-25 and BARI Gom-26. The index of relative performance of each variety in comparison to mean yield of all varieties under the contrast conditions of liming and non-liming was estimated to determine relative adaptability of wheat variety under experimental soil conditions. The result indicated that most of the yield components viz., spikes/m^2, 100-grain weight, and grain yield of wheat were significantly improved by liming for both the years and locations. There were variations in lime response among the wheat varieties. The index of relative adaptability (IRA %) for yield of BARI Gom-26 and Bijoy was more than 100% for both the years. The results indicated that these two wheat varieties are relatively tolerant to low pH and could be adapted in acidic soil of Sylhet.

Alam (2013) conducted an experiment to study growth and yield potentials of wheat as affected by agronomic practices. The experiment consisted of three factors such as (1) two methods of planting viz. conventional and bed planting (2) four wheat varieties namely Protiva, Sourav, Shatabdi and Prodip and (3) four levels of nitrogen viz. 0, 60, 110 and 160 kg N ha^{-1}. A splitsplit plot design was used for the experiment with three applications. The highest total dry matter, leaf area index and crop growth rate were observed in bed planting method with 160 kg N ha^{-1}. Prodip produced the highest total dry matter up to grain filling stage with the application of 160 kg N ha^{-1} . Leaf area index and crop growth rate were higher at booting and tillering stages respectively. Grain yield was higher in bed planting system than conventional one due to improvement in yield components. Grain yield was increased with increasing levels of nitrogen application. Prodip produced the highest grain yield with 160 Kg N ha^{-1}. The highest grain yield was found with the combination of bed planting method and 160 Kg N ha^{-1} and the lowest was recorded from conventional method at control treatment. The overall results indicate that Prodip showed better performance in bed planting system with 160 Kg N ha^{-1}.

Ahamed and Farooq (2013) accumulated photo thermal units, growth attributes and phenology of three wheat varieties (Chakwal-50, Wafaq-2001 and an advance line NR-268) were studied in four planting windows from 20th October-5th December at 15 days interval during 2008-09 in Randomized

Complete Block Design with factorial arrangements. Delayed sowing puts adverse effects with respect to growth characteristics of tested varieties like Crop growth rate (CGR), Net assimilation rate (NAR), Leaf area index (LAI) and growing degree days and photo thermal units but the intensity varied among varieties. The late sown conditions induced the maximum epicuticular wax deposition (0.0071 g cm^{-2}) and synthesis of proline contents (37.08 µg g^{-1}) in leaf tissues at flag leaf stage and it was typically related to Chakwal -50 (44.45 µg g^{-1}). TheWafaq-2001 did well with respect to stomatal conductance and photosynthetic rates over tested NR-268 even in delayed sowing. Sustaining the growth in late sown conditions of Wafaq-2001 was clear indication of its adoptability measures to terminal heat stress. On overall basis, the Chakwal-50 was the best performer and seeding at 5th November must be ensured to maintain desirable growth pattern. The growing degree days and Photo thermal units were growth drivers and early sowing time might need to be changed based on concept for better understanding of phenophases and other growth aspects of crop in context of climate variability.

Khakwani *et al.* (2012) conducted an experiment of 6 bread wheat varieties (Damani, Hashim -8, Gomal-8, DN-73, Zam-04 and Dera-98) were subjected to 2 treatments i.e., control treatment (100% field capacity) and stressed treatment (20 days water stress was given during booting stage and 20 days water stress after anthesis). The findings revealed highly significant differences among means of wheat varieties in all physiological and yield traits. Almost all varieties showed their best adaptation under stressed environment however Hashim-8 and Zam-04 behaved exclusively and indicated higher relative water content (RWC), mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) whereas stress susceptibility index (SSI) and tolerance (TOL) estimated at its lowest, as these traits are recognized beneficial drought tolerance indicators for selection of a stress tolerant variety. Similarly, total grain yield per plant, biological yield per plant and harvest index was also higher in the same wheat varieties that put them as good candidates for selection criteria in wheat breeding program for drought resistant.

Nadim *et al*. (2012) evaluated growth and yield response of wheat variety Gomal -8 using micronutrients and their application methods. The trial was laid out in a randomized complete block design with split-plot arrangements. Five different micronutrients were placed in main plot while their three application methods were assigned to sub-plots. Results revealed that application of boron @ 2 kg ha^{-1} produced higher crop growth rate (23.58 g m^{-2} day^{-1}), net assimilation rate (2.82 mg $m^{-2}day^{-1}$), number of tillers (234.5 m^{-2}), number of grains (52.92 $spike^{-1}$) and grain yield (3.14 t ha^{-1}). The use of iron @ 12 kg ha^{-1}also showed encouraging results similar to boron. Among various application methods, side dressing at 4 weeks after sowing (WAS) showed the best results as compared to soil application and foliar spray. Higher leaf area index and crop growth rate was obtained with the application of zinc @ 10 kg ha^{-1}. Also, different micronutrients had significant interaction with application methods for physiological and agronomic traits including number of tillers, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) and grain yield. Side dressing best interacted with boron for producing higher number of tillers, grains spike^{-1} , net assimilation rate and grain yield. This method showed better combination with iron for higher number of tillers, LAI and grain yield.

Al-Musa *et al.* (2012) conducted a pot experiment which was carried 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 in respect of germination percentage, growth, yield and yield attributing characters. Among the four varieties, BARI ghom-26 showed superior performance irrespective of all parameters studied except total dry matter content (TDM) and yield reduction percentage. Among the BARI varieties, BARI ghom-26 produced greater germination (61.00%) at 13 days judge against to other varieties. The taller plant (47.91 cm), higher LAI (1.84), maximum TDM (17.37 g plant^{-1}) and effective tillers plant $^{-1}$ (18.08) were also obtained with the similar variety. BARI ghom-26 was also most effective to produce the maximum grains spike^{-1}(38.52), higher weight of 1000-grains (49.38 g), higher grain (3.35 t ha^{-1}) and straw (8.50 g plant^{-1}) yield and greater HI (4.03%). So, the variety BARI ghom-26 produced the outstanding superiority among the varieties.

Hussain *et al*. (2012) evaluated phenology, growth and yield of three elite varieties of wheat („Gourab‟, „BARI Gom-25‟ and „BARI Gom-26‟) under two sowing conditions: optimum (sown on November 15) and late heat stress condition (sown on December 27). All wheat varieties, when sown late, faced severe temperature stress that significantly affected phenology, growth and finally yield. Taking into consideration phenological variation, dry matter (fresh and dry weight) partitioning and grain yield, variety „BARI Gom-26‟ performed better both in optimum and late heat stress, followed by „BARI Gom-25‟; „Gourab‟ performed the least. On the basis of heat tolerance parameters [relative performance (RP) and heat susceptibility index (HSI)], „BARI Gom-25‟ (RP-79%; HSI-0.7) was the best performing variety followed by „BARI Gom-26‟ (RP-74%; HSI-0.9) under heat stress while „Gourab‟ (RP-61%; HSI-1.3) was sensitive to heat.

Hussain et al. (2012) conducted an experiment to evaluate the growth and yield response of different wheat varieties sown on different dates. Five wheat varieties viz. Sahar-2006 (SH-06), Faisalabad-2008 (FSD-08), Lassani-2008 (LS-08), Abdul Staar-2002 (AS-02) and Tripe Dwarf-1 (TD-1) were sown, at fortnightly interval, on 25 Oct, 10 and 25 Nov, and 10 and 25 Dec. Delayed wheat planting after 10th Nov decreased the tiller number per plant.

Rahman *et al.* (2009) conducted in research farm of Wheat Research Centre , Dinajpur (25°38´ N, 88°41´ E and 38.20 m above sea level), Bangladesh, during wheat season of 2003-04 with 10 wheat genotypes

(Gen/3/Gov, PB 81/PVN, Fang 60, Kanchan, Sari 82, HI 977, HAR 424, PF 70354, Opata and Fyn/Pvn) sown on optimum (November 17) and late (December 21) condition in a randomized complete block design with three replications to evaluate the performance of these genotypes under optimum and late sown condition and to find out the suitable time of sowing for a specific genotypes. Under optimum sown condition, differences among the genotypes were found to be significant in respect of grain yield, biomas at anthesis, ground cover at 4 -5 leaf stage, days to anthesis, maturity and flag leaf emergence, plant height, grain filling duration and 1000-grain weight, and insignificant for biomass at final harvest, ground cover at anthesis, chlorophyll content of the flag leaf and differences in temperature between canopy and ambient. They reported that the highest number of effective tillers plant^{-1}was obtained by 17 November sowing.

Mohsen *et al*. (2013) conducted a field experiment and the study was undertaken to determine the effects of sowing dates on growth and yield components of different wheat cultivar in Iran. The trial was laid out in RCBD (randomized complete block design) with split plot arrangement having three replications during 2011-12 and at Boroujerd, Iran. Five sowing dates i.e. October 31, November 15 and 30, December 15 and 30 were in main plots, whereas five wheat cultivars (Pishgam, Parsi, Bahar, Sivand and Pishtaz) were in sub plots. Results showed that the effect of sowing date was significant on all parameters. The highest tiller number for sowing date gave highest tiller in November 15.

Kabir *et al.* (2009) carried out a field experiment in Bangladesh to determine the effect of seed rate and irrigation level on the performance of wheat cv. Gourab was studied. The experiment comprises of two factors namely (1) four seed rate viz. 100, 120, 140 and 160 kg ha^{-1} and (2) four levels of irrigation namely (i) no irrigation i.e. control, (ii) one irrigation given at Crown root initiation (CRI) stage, (iii) two irrigations given at CRI and Panicle initiation stages and (iv) three irrigation given at CRI, panicle initiation and grain filling stages. The highest number of total tillers $plant^{-1}$ (9.07) was recorded by two irrigations given at CRI and panicle initiation stage which was statistically identical with one irrigation given at CRI stage and the lowest (8.18) observed when no irrigation was given. The highest effective tillers $plant^{-1}$ (3.31) was obtained by one irrigation applied was at CRI stage which is statistically similar to two irrigations applied at CRI and panicle initiation stages, the lowest (2.43) was recorded when no irrigation was applied. The highest number of non-effective tillers $plant^{-1}$ (1.42) was obtained by no irrigation application and the lowest (0.61) was found in one irrigation applied at CRI stage.

In a trial with wheat in Joydebpur and Jessore, BARI (1984) reported that the highest number of effective tillers $plant^{-1}$ was obtained by 20 November sowing similar finding were reported by Sarker *et al*. (1999).

Abdelmulaa (2011) concluded that the induced terminal heat stress during both years was severe enough to cause a reduction in yield of the tested genotypes. The observed significant effect of sowing date and its interaction with years on yield entails the crucial impact of the onset and duration of winter season on wheat productivity in the non-traditional central areas of Sudan. The determined differential genotypic variability to terminal heat stress and the estimated correlation between yield and its components could be exploited in breeding programs to identify and develop new heat tolerant widely adapted cultivars. Such cultivars could be suitable for optimum sowing date as well as for terminal heat stress, for example, genotype OASIS/ KAUZ//3BCN. Moreover, the genotype KAUZ"S"657C1-3-6-2-2-1-2, which exhibited a specific adaption and high yielding only under late sowing, could be identified and selected for improving tolerance to terminal heat stress prevailing in the central areas of Sudan.

Hussain *et al*. (2010) investigated to assess the growth and yield response of three wheat varieties (Inqalab-91, Kharchia and Parwaz-94) to different seeding densities i.e. 100, 125 and 150 kg ha-1

were carried out on a sandy loam soil. The results indicated that seeding densities significantly affected various growth and yield parameters like germination count, total number of tillers m-2, number of grains spike^{-1}and grain yield, but total leaf area plant^{-1}, straw yield and harvest index were not affected significantly. The varieties differed significantly from one another with respect to the yield and yield contributing parameters. Wheat variety Inqalab-91 when sown @ 150 kg ha^{-1}gave the highest yield.

Tariq (2011) carried out an experiment at Research Area, College of Agriculture, Dera Ghazi Khan. The experiment was laid out in Completely Randomized Design (CRD) with factorial arrangements having three replications during Rabi season 2009-10. Two wheat genotypes V_1 : Mairaj-2008 and V2: Fareed-2006 were used to evaluate the effect of drought introduced at different crop growth stages according to the given irrigation schedules i.e. (i): Control (no drought), ii: Irrigation skip at tillering (20-40 DAS), iii: Irrigation skip at jointing (40 -75 DAS), iv: Irrigation skip at spike emergence (75-90 DAS), and v: Irrigation skip at grain formation (105-115 DAS). It was found that Miraj-2008 produced significantly higher plant height, number of productive tillers per pot, number of spikelets per spike, spike length, weight of spike per pot, biological yield, harvest index, moisture contents, and relative leaf water contents than that of Fareed-2006. No irrigation skipping resulted in maximum grain yield and yield contributing parameters. Both of the wheat varieties have no genetic potential to withstand against drought. However, skipping irrigation at grain formation crop growth stage abruptly reduced the grain yield followed by skipping irrigation at tillering stage as compared to rest of the crop growth stages. It is therefore suggested that irrigation at grain formation and tillering stage should never be missed in successful crop husbandry.

Ahamed *et al.* (2010) evaluated the effect of high temperature stress in Bijoy ad Shatabdi wheat varieties under the late sown condition and found that the ear weight and seed weight per stem were highest in Bijoy and husk weight was found to be the highest in Shatabdi. Grain weight of variety Bijoy (34.94 g) and Shatabdi (33.30 g) were higher in late sowing, whereas Sufi had lowest 1000 grain weight (23.81 g) and finally Bijoy produced the highest grain yield both under normal sowing and late sown mediated heat stressed condition. Considering all Bijoy was said to be the best performing variety amongst all and Sufi the worst one considering specially the yield components and yield.

Alam and Rahman (2008) carried out a research work with twenty wheat varieties/lines to study the effect of source-sink manipulation on grain yield in wheat. Significant variations among the genotypes were observed for grains spike, 100-grain weight and grain yield main spike. Removal of flag leaf caused decreased in grain spike, 100-grain weight and grain yield main spike by 9.94%, 7.65% and 16.88%, respectively. Similarly removal of all leaves caused reduction of grains spike, 100-grain weight and grain yield main spike by 17.17%, 13.27% and 27.92%, respectively. On the other hand, removal of 50%spikelets decreased 41.03% and 37.01% in grains spike and grain yield main spike and increased 9.44% in 100-grain weight. Similarly, 25% spikelets removal reduced grains spike and grain yield main spikeby 25.13% and 23.38%, respectively but increased 4.08% in 100-grain weight. The variety/lines BL-1020, Ananda and Akbar showed high decrease in grains spikes, 100-grain weight and grain yield main spike by defoliation treatment.

Mehmet and Telat (2006) conducted an experiment in two locations over two years. The adaptation and stability statistics of 20 bread wheat genotypes were estimated for yield performances. Regression coefficient, mean squares of deviation from regression and determination coefficients were estimated. All the genotypes were found stable for their traits of plant density and days to heading. There were differences in stability performances among the genotypes for the traits of plant height, grain numbers spike-1, grain weight spike-1, 1000 kernels weight and grain yield. The instability for plant height and grain weight spike-1 among the genotypes were originated from the mean squares of deviation from regression; for the other traits it was resulted from not only the mean squares of deviation from regression but also from the differences among regression coefficients of genotypes.

Jalleta (2004) conducted an experiment in farmers' 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 also found that the variety HAR-710 gave yield of 2.56 t ha-1 and PAVON-76 gave 2.49 t ha-1.

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

BARI (2003) conducted an experiment in Wheat Research Centre at Nashipur, Dinajpur with some varietal performance in Rajshahi and found that Shatabdi produced highest (3.2 t ha-1) followed by Gourab (3.13 t ha-1) and lowest yield produced by Kanchan (2.96 t ha-1).

WRC (2003) conducted an experiment in Heat Tolerant Screening Nursery in Barisal region with 50 advance lines/varieties. The used lines/ varieties were E50-(3.94 t ha^{-1}), BAW 1048 (3.85 t ha-1, BAW 1021 3.64 t ha-1), BAW 1024(3.6 t ha-1), E 45 (3.58 t ha-1) and WRC (2.97 t ha-1). Among the varieties produced by E 50 (3.94 t ha-1) produced the highest yield.

WRC (2003) conducted an experiment in the Wheat Research Centre Nashipur, Dinajpur to see the performance of genotypes among various tillage operations and to understand the effects of interaction between genotypes and tillage operations. Two cultivation methods; bed and conventionally tilled flat were in the main plot and 10 wheat genotypes (Kanchan, Gourab, Shatabdi, Shourav, BAW 1008, BAW 1006, BAW 1004, BAW 969, BAW 968 and BAW 96)were tested in 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 Gourab and Shourav. Variety Shatabdi produced maximum grain spike-1and 1000-grain weight under bothtillage operations. Among the varieties Shatabdi showed good stability for grain yields (5.40 t ha-1in bed 5.0 t ha-1in conventional methods).

Sikder *et al.* (2001) conducted an experiment with ten recommended wheat (*Triticum aestivum* L.) Varieties and two sowing conditions i.e. optimum sowing (November 30) and late sowing (December 30). By late sowing, the varieties were given high temperature stress during reproductive growth phase. The experiment was conducted to determine the relative heat tolerance of the wheat varieties and to evaluate the relative yield performance of heat tolerant and heat sensitive wheat varieties under late seeded conditions. Based on membrane thermo stability (MT) test, four varieties (Ananda, Pavon, Aghrani, and Barkat) took maximum heat killing time and were classified as relative heat tolerant, three varieties (Akbar, Kanchan and Protiva) as moderately tolerant and the rest three varieties (Balaka, Sawgat and Sonora) took the shortest heat killing time and considered as heat sensitive. The grain number per ear, 1000 grain weight and main shoot grain weight of tolerant and moderately tolerant varieties showed higher relative performance compared to sensitive varieties, But the relative ear number per plant and relative grain yield were found to range low to high in heat tolerant and moderately tolerant varieties. In heat sensitive varieties the relative ear number per plant and relative grain yield were moderate to high. Thus the results suggest in addition to membrane thermo stability test, the high relative grain number per ear, 1000 grain weight and main shoot grain weight can be used to determine the heat tolerance of wheat varieties under late seeded warmer conditions.

Litvinchko *et al.* (1997) reported that winter wheat with high grain quality for bread making was produced in Southern Ukraine. Wheat breeding began 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}. This increase was due to a decrease in photoperiodic sensitivity and the introduction of semi dwarf genes. Genes for photoperiodic sensitivity and vernalization requirement were combined and the effect of these genes on grain yield, frost and drought resistance and growth and development rate of plant in autumn and early spring were studied.

2.2. Influence of irrigation on growth and yield of wheat

Islam *et al.* (2015) carried out an experiment with four irrigation stages viz. I_0: No irrigation; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at preflowering stage (45 DAS) and I_3: Irrigation at both CRI and pre-flowering stage. Maximum number of tiller $hill^{-1}$(5.2), CGR (6.7gm-2day^{-1}), RGR (0.03gg-1day^{-1}), dry matter content (28.7%), number of spikes $hill^{-1}$(4.5), number of spikelets $spike^{-1}$ (19.0), ear length (17.5), filled grains spike-1 (30.8), total grains $spike^{-1}$(32.9), weight of 1000-grains (47.1 g), grain yield (3.9 tha^{-1}), straw yield (4.9 t ha^{-1}), biological yield (8.8 t ha^{-1}) and harvest index (45.9%) were obtained from I_3 whereas lowest occurred in I_0. They also stated that early flowering (70.6 days), maturity (107.2 days) and minimum number of unfilled grains $spike^{-1}$ (2.1) were also obtained from I_3.

Chouhan *et. al.* (2015) observed that water saving of about 28.42% higher when drip irrigation was applied rather than the border irrigation system. They also stated that water productivity of drip irrigated wheat was 24.24% higher compared with the border irrigated wheat. But, there was slightly reduction of 10.8% in the grain yield because of severe water deficit during the growing stages.

Shirazi *et al.* (2014) observed that maximum grain yield of 2.27 t $ha^{-1}$by the application of 200mm irrigation treatment.

Atikullah, et *al*. (2014) showed that maximum dry matter content (18.8g/plant), crop growth rate (CGR) (13.5 g m-2 day^{-1}), relative growth rate (RGR) (0.024 g m^{-2} day-^{1}) were obtained from I_1 which was statistically same as I_2 whereas lowest obtained from $I_{0.}$ They also reported that Plant height (80.7 cm), number of tiller (4.9/hill), number of spike (4.7/hill), number of spikelets (18.5/spike), spike length (19.2 cm), filled grains (29.3/spike), total grains (31.3/spike), 1000-grains weight (44.4 g), yield (grain 3.4 t/ha, straw 5.7 t/ha and biological 9.1 t/ha) and harvest index were observed better in I_1

Atikulla (2013) observed that each of the 3 different dated irrigated plots showed better performance than that of the non-irrigated plot in all the parameters studied. Among the 3 different dates of irrigation, irrigation at crown root initiation stage (I_1), recorded the highest values in all the parameters studied but it was statistically similar with irrigation at flowering (I_2) and irrigation at grain filling stage of wheat (I_3).

Khan *et al.* (2013) reported that for the maximum yield of wheat the crop may be irrigated after five weeks interval. Excessive and earlier irrigation interval can be harmful for the optimum yield of wheat if seasonal rainfall is >330mm.

Sultana (2013) stated that increasing water stress declined the plant height, nos. of effective tillers per hill, grain yield and straw yield and maximum grain yield was obtained for the variety BARI Gam-26 that was 2.96t ha-1.

Tomic *et al*. (2012) stated that the irrigation and drainage are essential f or grain yield. Grain yield increases with the increase of irrigation levels at different critical levels.

The field experiment was conducted by Vinod *et al.* (2011) during winter seasons to study the effect of irrigation and fertilizer management on yield and economics of simultaneous planting of winter sugarcane + wheat. The experiment was carried out in split plot design, keeping four irrigation options in main plot, viz. irrigation scheduled at 0.8 (I1), 1.0 (I2), 1.2 (I3) IW/CPE ratio and critical stages i.e. crown root initiation, tillering, late jointing, flowering, milk and dough stages of wheat (I4), and four nutrient levels, with four replications. The maximum gain of gross return (Rs 126,992.0/ha), net return (Rs 75,882.5/ha) and B:C ratio (1.49) was obtained with irrigation at physiological stages of wheat followed by irrigation at 1.2 IW/CPE ratio over the irrigation at 0.8 and 1.0 IW/CPE ratio whereas, least net returns (Rs 48,687.4/ha) and B:C ratio (1.34) was under 0.8 IW/CPE ratio.

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 plant height, spike length and spike grains, 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 m3/ha at the elongation stage and of 450 m3/ha at the booting stage or separate irrigation of 900 m3/ha at the two stage were the highest.

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 (T1) at crown root development, booting, milking and grain development; five irrigations (T2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the grain yield and yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T2), while 1000-grain weight, germination count m-2and number of tillers m-2were not affected significantly. The highest grain yield was recorded with five irrigations at different critical growth stages of wheat crop.The possible reason might be availability of more moisture. The results revealed that the application of irrigation at tillering stage played a vital role to increase wheat yield and contrarily the application of irrigation at maturity caused decrease in wheat yield.

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 and phosphorus use efficiency. ertilizer P doses 0, 47, 81 and 111 kg P2O5ha-1were calculated by using adsorption isotherms and applied by broadcast and band placement. Four irrigations i.e. 0, 2, 3, 4 were applied at critical stages of wheat. Basal N:K=130:65 kg ha-1were applied. Wheat grain yield increased from 1.58 Mg ha-1 to 3.94 Mg ha-1with the use of P @ 81 kg P_2O_5 ha^{-1}. Band placement of P proved better over broadcast, whilst three irrigations at crown roots, booting, and grain development stages were sufficient to get maximum yield and improve phosphorus use efficiency.

Naeem *et al.* (2010) conducted a field study pertaining to the effect of different levels of irrigation on yield and yield components of wheat cultivars at Agronomic Research Area, University of Agriculture, Faisalabad. Treatments were three cultivars and five irrigation levels I1(irrigation at crown root stage), I2(irrigation at crown root + tillering), I3(irrigation at crown root + tillering +booting), I4(irrigation at crown root + tillering + booting + anthesis), and I5(irrigation at crown root + tillering + booting + anthesis + milking). Wheat crop supplied with five irrigations at crown root + tillering + booting + earing +milking recorded the highest grain yield (5696.8 kg ha-1) which was significantly higher than all the other irrigation levels.

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 I2treatment combinations comprised of four irrigation levels viz., I1(one irrigation at CRI stage), I2(two irrigations: one each at CRI and flowering stages), I3(three irrigations: one each at CRI, LT and flowering stages) and I4(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. The highest grain yield (40.65 q ha^{-1}) was credited to I_4 that 7was significantly superior over I_1 and I_2 but non-significant with I_3. Consumptive use of water increased while water use efficiency gradually decreased with increase in number of irrigations.

Using semi-winter wheat Yumai 49-198 as experiment material, a field experiment was conducted by Li *et al.* (2010) to investigate the leaf area index, dry matter accumulation, photosynthetic characteristics and yield of winter wheat under different irrigation stages and amounts. The results showed that, before the jointing stage, the leaf area index increased with the increase of irrigation amount. After jointing stage, all the indexes were good when the field water capacity maintained at 65%, while too much irrigation amount was unfavourable to the dry matter accumulation, especially to the photosynthetic rate of flag leaf and yield formation after anthesis.

Excessive nitrogen (N) and high irrigation in local agricultural systems are raising concern owing to water quality and water quantity in the middle reach of the Heihe River basin. Consequently, a controlled study of irrigation and N was conducted by 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. A complete randomized block split-plot design was employed, with irrigation regimes [0.6, 0.8 and 1.0 estimated wheat evapotranspiration (ET)] and N fertilizer application rates [0, 140, 221, 300 kg/hm^2] as the main-plot and split-plot respectively. Under the experimental conditions, irrigation and N had relative low effects on plant height. Water consumption was increased with irrigation, water consumption in high irrigation treatment was increased by 16.68% and 36.88% compared with intermediate irrigation treatment and low irrigation treatment, respectively. The low irrigation (378 mm during spring wheat growth), accompanied by 221 kg N/hm2 was the best management system for the relative high economic yield and high WUE in this region.

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: W0 (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 W2for 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 and one in Baoding in 2006-2007 and the other in Gaocheng in 2007-2008. Four irrigation treatments (W0, 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. In 2006-2007, 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 W0, and the highest in N1 and the lowest in N_0.

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 and grain yield contributing traits of wheat varieties were significantly affected under water stress conditions. Except spike yield, Sarsabz had significantly more 1000-9 grain weight, grain yield, main spike yield and grains spike^{-1} as compared to other varieties over all irrigation treatments; hence more tolerant to drought. Grain yield ranged between 373 kg ha^{-1} in single irrigation treatment to 3931 kg ha^{-1} in four irrigations, whereas 1000-grain weight ranged between 28.1-41.8 in four treatments.

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. Grain yield, total biomass, number of spike/m^2, harvest index and 1000-kernel weight decreased with increasing irrigation intervals. Water use efficiency was highest with irrigation at 20-day intervals. When a 20 and 30-day irrigation interval were applied, grain yield, number of spike/m2, harvest index and water use efficiency 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). Four wheat genotypes were grown under five different water stress treatments. The treatments included an unstressed control (S0), water stress at the late vegetative stage (S1), at the flowering stage (S2), or at the grain formation stage (S3) and full stress (non-irrigation S4). The effects of water stress treatments on grain yield and yield components were statistically significant compared with non-stressed conditions. Grain yield under non-irrigated conditions was reduced by approximately 40%. Among the genotypes, MV-17 gave the highest grain yield.

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 growth and yield of winter wheat.

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. Irrigation increased yield of wheat significantly than under control condition.

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 shoot dry weight, number of grains, grain yield, biological yield and harvest index 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 and number of tillers. Among the yield attributes, number of leaves and number of tillers were positively correlated at the anthesis stage whereas leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

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.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Research field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the period of November 2016 to March 2017. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

The experiment was conducted in the Research Field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period of November, 2016 to March, 2017 to observe the growth and yield performance of selected wheat genotypes at variable irrigation management. The experimental field is located at 23041´ N latitude and 90º 22´ E longitude at a height of 8.6 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2013). The location of the experimental site has been shown in Appendix I.

3. 2 Soil characteristics

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The experimental plot was also high land, having pH 5.56.

The physicochemical properties and nutrient status of soil of the experimental plots are given in Appendix II.

3. 3 Climate condition

The experimental field was situated under sub-tropical climate; usually the rainfall is heavy during *Kharif* season, (April to September) and scanty in *Rabi* season (October to March). In *Rabi* season temperature is generally low and there is plenty of sunshine. The temperature tends to increase from February as the season proceeds towards *kharif*. Rainfall was almost nil during the period from November 2016 to March 2017 and scanty from February to September.

3.4 Planting material

The test crop was wheat (*Triticum aestivum*). Three wheat varieties BARI Gom-26, BARI Gom-28 and BARI Gom-30 were used as test crop and were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatments

The experiment consisted of two factors and those were the wheat genotypes and irrigation. Three wheat genotypes and four irrigations were used under the present study. The treatments of the experiment were as follows:

Factor A: three wheat varieties

1. V_1 = BARI Gom-26

2. V_2 = BARI Gom-28

3. V_3 = BARI Gom-30

Factor B: four irrigations

1. I_0 = No Irrigation throughout the growing season

2. I_1 = One irrigation (Irrigate at CRI stage)

3. I_2= Two irrigation (Irrigate at CRI and grain filling)

4. I_3= Three irrigation (Irrigate at CRI, booting and grain filling stages)

3.6 Land preparation

Repeated ploughing with power tiller and country plough was done on 9 November and final land was prepared on 15 November, 2016. Ploughing was followed by laddering in order to break clods as well as level the land. All weeds, stubbles and crop residues were removed from the experimental field. The layout of the experiment was done as per statistical design.

3.7 Experimental design

The experiment was laid out in a split plot design with three replications having irrigation application in the main plots, verities in the sub plots. There were 12 treatments combinations. The total numbers of unit plots were 36. The size of unit plot was 2 m x 2 m = 4.00 m^2. The distances between sub-plot to sub-plot, main plot to main plot and replication to replication were, 0.75, 0.75 and 1.5 m, respectively.

3.8 Fertilizer application

The following doses of fertilizers were used:

Urea : 120 kg ha^{-1}

TSP : 180 kg ha^{-1}

MoP : 55 kg ha^{-1}

Gypsum : 110 kg ha^{-1}

Total Urea was spilited into 2 doses which first dose was applied at sowing time and second dose at 21 DAS (CRI). The whole amount of triple super phosphate (TSP), muriate of potash (MoP), and gypsum was incorporated in each plot at the time of final land preparation.

3.9 Collection and Sowing of seeds

As per treatment seeds of different wheat varieties were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, and Gazipur. At a good tilth condition, furrows were made with hand rakes for sowing. Before sowing, seeds were treated with Provax 200-Ec @ 2.5 g powder for kg^{-1} seed. Seeds were sown continuously in line on 1st sowing, 19 November 2016 @ 120 kg ha^{-1}. The line to line distance was maintained 20 cm. After sowing, the seeds were covered with soil and lightly pressed by hand. Two guards were appointed from early morning to evening to protect the wheat seeds from birds.

3.10 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. The following intercultural operations were followed:

3.10.1 Irrigation

Four levels of irrigation treatment were applied. In irrigated plots three irrigations were applied, the first irrigation after 30 days of sowing at crown root initiation (CRI), the second after 45 days at heading stage and the third irrigation after 62 days at grain filling stage.

3.10.2 Weeding

Weeding was done twice during the whole growing period, the first weeding after 20 days of sowing and the second other after 40 days of sowing. During the irrigation care was taken so that water could not flow from one plot to another or overflow the boundary of the plot. Excess water of the field was drained out.

3.10.3 Insect and pest control

The crop was attacked by different kinds of insects (cereal aphid and grass hopper) during the growing period. The experimental plots were sprayed at 35 days with appropriate insecticides to control the insects. Insecticide was applied to the plots after irrigation at afternoon. Two guards were appointed to protect the wheat grain from birds especially pigeons from mid February to harvest.

3.10.4 General Observation of experimental field

The plots under experiment were frequently observed to notice any change in plant growth, other characters were noted down immediately to make necessary measures.

3.4.6 Harvesting and sampling

Maturity of crop was determined when 90% of the grains became golden yellow in color. Ten plants per plot were preselected randomly from which different growth and yield attributes data were collected and 1 m^2 areas from middle portion of each plot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. For recording yield components data, ten plants from each plot were collected randomly. Threshing, cleaning and drying of grains were done separately for each treatment. Properly dried grain and straw were weighed and converted in to ton ha^{-1} basis.

3.12 Data collection

Data were collected on the following growth components:

1. Plant height
2. Number of effective tillers $plant^{-1}$
3. Number of non effective tillers $plant^{-1}$
4. Length of spike
5. Number of grain per spike
6. Thousand seed weight
7. Grain yield (t/ha)
8. Straw yield (t/ha)
9. Biological yield

3.12.1 Plant height (cm)

The plant height was measured from the ground level to top of the plant 75 and 90 DAS. From each plot, plants of 10 plants were measured and averaged. The mean plant height was determined in cm.

3.12.2 Number of effective tillers $plant^{-1}$

Ten plants were selected from each plot randomly. The number of total effective tillers from 10 plants was counted and averaged then to have number of effective tillers $plant^{-1}$.

3.12.3 Number of non effective tillers plant^{-1}

Ten plants were selected from each plot randomly. The number of non effective tillers from 10 plants was counted and averaged then to have number of non effective tillers plant^{-1}.

3.124 Spike length (cm)

Spike length were counted from five plants from basal node of the rachis to apex of each spike and then averaged. This was taken at different days after sowing (DAS) separately.

3.12.5 Number of grains spike^{-1}

The number of grains spike^{-1} was counted from 10 spike and number of grains spike^{-1} was measured by the following formula

Number of grains spike^{-1}=$\frac{\text{Total number of grains}}{\text{Number of spike}}$

3.12.6 Weight of 1000 grains

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram**.**

3.12.7 Grain yield

Grain yield was determined from each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.12.8 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.12.9 Biological yield

Biological yield was calculated from the following formula

Biological yield = Grain yield + Stover yield

3.13 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.14 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter contents. The soil samples were analyzed by the following standard methods as follows:

3.14.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.14.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.15 Statistical analysis

The collected data on each plot were statistically analyzed to obtain the level of significance using the computer based software MSTAT-C developed by Russel (1986). Mean difference among the treatments were tested with the least significant difference (LSD) test at 5 % level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprised with presentation and discussion of the results obtained from the study to observe the growth and yield performance of selected wheat genotypes at variable irrigation management have been presented in Table and Figure.

4.1 Plant height

4.1.1 Effect of variety

Plant height varied significantly among the tested three varieties (Fig. 1). At, 75 DAS, BARI Gom 30 showed the tallest plant height (34.72 cm) and BARI Gom 26 recorded the shortest plant height (32.32 cm). At, 90 DAS, BARI Gom 30 recorded the highest plant height (76.13 cm) was observed from BARI Gom 26. However, BARI Gom 26 recorded the shortest plant height (75.01 cm) which was also statistically similar with BARI Gom 28. Islam and Jahiruddin (2008) also concluded that plant height varied significantly due to various wheat varieties.

4.1.2. Effect of irrigation

Plant height of wheat showed statistically significant variation due to amount of irrigation at 75, 90 DAS under the present trial (Figure 2). At 75 DAS, the tallest plant (34.78 cm) was recorded from I_3 (Three irrigation) while the shortest plant

(32.02 cm) was observed from I_0 (No Irrigation throughout the growing season) treatment. At 60 DAS, the tallest plant (77.51 cm) was found from I_3, which was statistically similar with I_2 (Two irrigation) and I_1 (One irrigation). The shortest plant (71.29 cm) was observed from I_0. Plant height was likely increased due to applying higher amount of irrigation compared to less amount of irrigation. Sultana (2013) stated that increasing water stress declined the plant height.

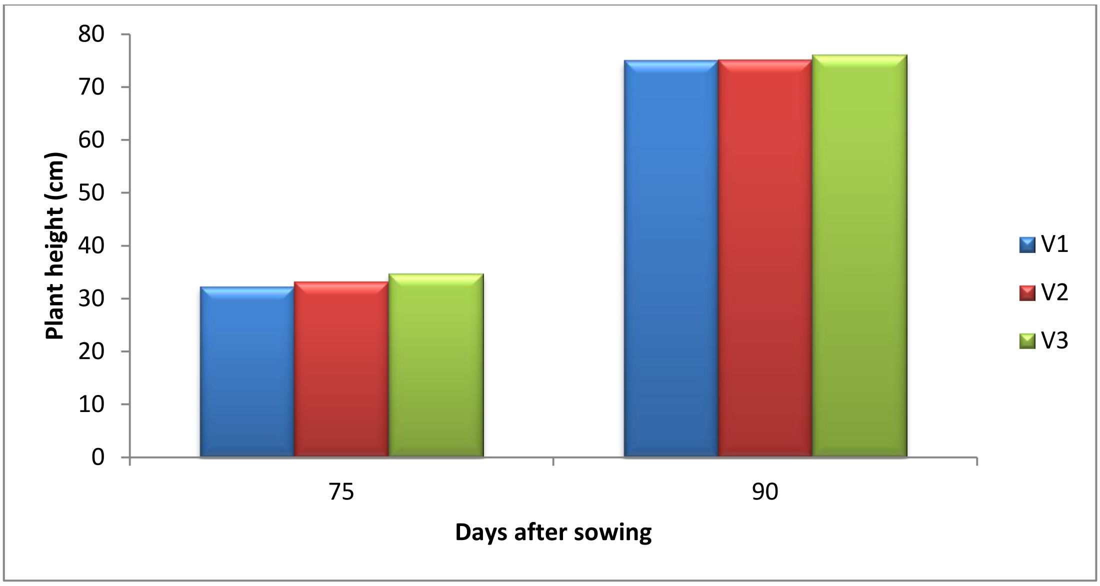
4.1.3 Interaction effect of variety and irrigation

Interaction effect of variety and different amount of irrigation showed significant differences on plant height of wheat at 75 and 90 DAS (Table 1). The highest plant height at 30 was 38.00 cm obtained from V_3I_3 treatment combination. The shortest plant height at 30 was 30.67 cm obtained from V_1I_0 treatment combination. At 60 DAS, plant height was 78.50 cm obtained from V_3I_3 and lowest was 69.83 cm obtained from V_1I_0 treatment combination, which was statistically similar with V_2I_0 and $_3I_0$ treatment combination.

4.2 Number of effective tiller hill^{-1}

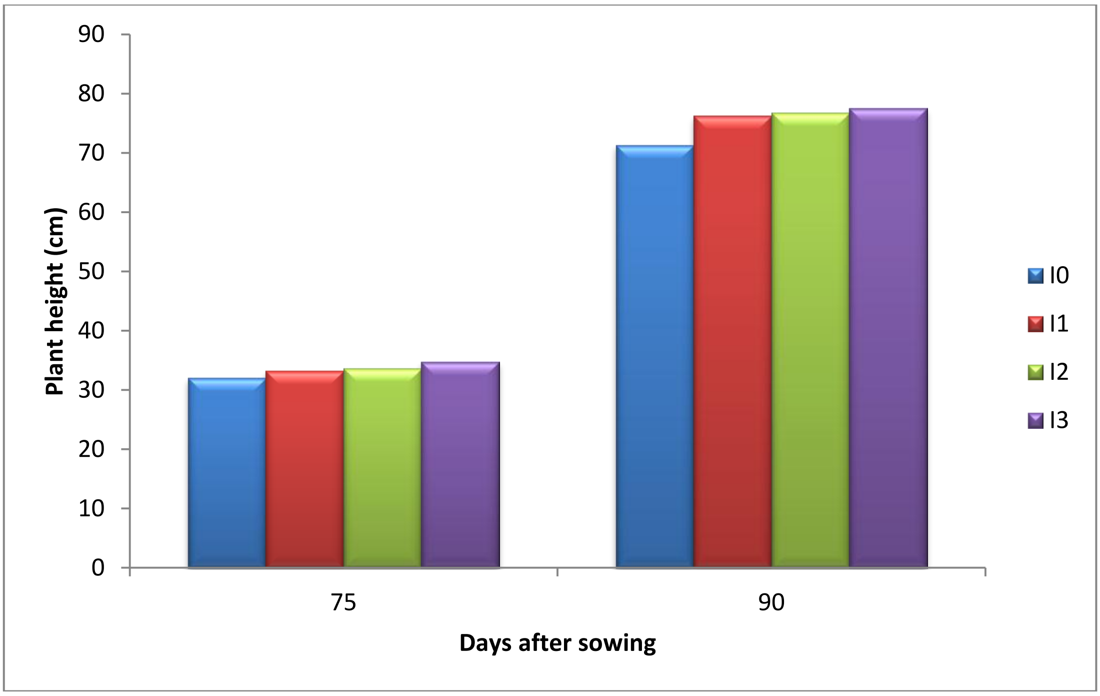
4.2.1 Effect of variety

Number of effective tillers hill^{-1} of wheat was not varied significantly due to varieties (Table 2). BARI Gom 30 produced the highest number of effective tillers hill^{-1} **(**9.33) and the lowest number of effective tillers hill^{-1} (8.58) was observed in BARI Gom 26.



V_1 = BARI Gom 26, V_2 = BARI Gom 28, V_3 = BARI Gom 30

Fig. 1. Effect of variety on plant height of wheat at different days after sowing



I_0 = No Irrigation throughout the growing season, I_1 = One irrigation (Irrigate at CRI stage), I_2= Two irrigation (Irrigate at CRI and grain filling), I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

Fig. 2. Effect of irrigation on plant height of wheat at different days after sowing

Table 1. Interaction effect of variety and irrigation on plant height of wheat

Treatment	Plant height (cm)	
	75 DAS	90 DAS
V_1I_0	30.67 e	69.83 c
V_1I_1	33.50 bcd	76.67 ab
V_1I_2	34.00 bcd	77.00 ab
V_1I_3	34.67 bc	76.90 ab
V_2I_0	32.50 cde	71.83 c
V_2I_1	33.27 bcd	75.40 b
V_2I_2	31.83 de	76.43 ab
V_2I_3	31.67 de	77.13 ab
V_3I_0	32.90 bcde	72.20 c
V_3I_1	32.93 bcde	76.73 ab
V_3I_2	35.07 b	77.07 ab
V_3I_3	38.00 a	78.50 a
$LSD_{(0.05)}$	2.11	2.26
CV(%)	3.73	5.00

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

V_1 = BARI Gom 26 I_0 = No Irrigation throughout the growing season
V_2 = BARI Gom 28 I_1 = One irrigation (Irrigate at CRI stage)
I_2= Two irrigation (Irrigate at CRI and grain filling)
V_3 = BARI Gom 30 I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

4.2.2 Effect of irrigation

Different levels of irrigation varied significantly in terms of number of effective tillers $hill^{-1}$ of wheat at harvest under the present trial (Table 3). The highest number of effective tillers $hill^{-1}$ 9.89 was recorded from I_3 treatment, while the corresponding lowest number of effective tillers $hill^{-1}$ were 7.89 observed in I_0 treatment. Sultana (2013) stated that increasing water stress reduced the number of tillers per hill.

4.2.3 Interaction of variety and irrigation

Variety and irrigation showed significant differences on number of effective tillers $hill^{-1}$ of wheat due to interaction effect (Table 4). The highest number of effective tillers $hill^{-1}$ 10.33 were observed from V_3I_3 treatment combination, while the corresponding lowest number of effective tillers $hill^{-1}$ as 7.33 were recorded from V_1I_0 treatment combination.

4.3 Number of non effective tiller $hill^{-1}$

4.3.1 Effect of variety

Number of non effective tillers $hill^{-1}$ of wheat was not varied significantly due to varieties (Table 2). BARI Gom 26 produced the highest number of non effective tillers $hill^{-1}$ **(**1.33) and the lowest number of non effective tillers $hill^{-1}$ (1.00) was observed in BARI Gom 30.

Table 2. Effect of variety on yield and yield contributing characters of wheat

Treatment	Number of effective tiller per plant	Number of non effective tiller per plant	Length of spike (cm)	Number of grain per spike
V_1	8.58	1.33	8.08	36.92 b
V_2	8.83	1.08	8.13	37.25 b
V_3	9.33	1.00	8.46	37.75 a
LSD $_{(0.05)}$	NS	NS	NS	0.50
CV(%)	9.81	5.22	8.66	5.73

V_1 = BARI Gom 26, V_2 = BARI Gom 28, V_3 = BARI Gom 30

Table 3. Effect of irrigation on yield and yield contributing characters of wheat

Treatment	Number of effective tiller per plant	Number of non effective tiller per plant	Length of spike (cm)	Number of grain per spike
I_0	7.89 b	2.00 a	7.17 c	34.56 c
I_1	8.67 ab	1.11 b	8.11 b	36.33 b
I_2	9.22 ab	0.89 bc	8.44 ab	39.00 a
I_3	9.89 a	0.67 c	9.17 a	39.33 a
LSD $_{(0.05)}$	1.68	0.40	0.85	0.90
CV(%)	9.81	5.22	8.66	5.73

I_0 = No Irrigation throughout the growing season, I_1 = One irrigation (Irrigate at CRI stage), I_2= Two irrigation (Irrigate at CRI and grain filling), I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

Table 4. Interaction effect of variety and irrigation on yield and yield contributing characters of wheat

Treatment	Number of effective tiller per plant	Number of non effective tiller per plant	Length of spike (cm)	Number of grain per spike
V_1I_0	7.33 d	2.33 a	6.50 c	34.00 e
V_1I_1	8.67 abcd	0.67 cd	8.33 b	36.00 cde
V_1I_2	8.67 abcd	1.33 abcd	8.83 b	38.00 abcd
V_1I_3	9.67 abc	1.00 bcd	8.67 b	39.00 abc
V_2I_0	8.33 bcd	2.00 ab	7.50 bc	35.00 de
V_2I_1	8.33 bcd	0.67 cd	8.00 b	37.00 bcde
V_2I_2	9.00 abcd	0.67 cd	8.50 b	40.00 ab
V_2I_3	9.67 abc	1.00 bcd	8.50 b	37.00 bcde
V_3I_0	8.00 cd	1.67 abc	7.50 bc	34.67 de
V_3I_1	9.00 abcd	1.00 bcd	8.00 b	36.00 cde
V_3I_2	10.00 ab	0.33 d	8.00 b	40.00 ab
V_3I_3	10.33 a	1.33 abcd	10.33 a	41.00 a
LSD $_{(0.05)}$	1.48	1.03	1.21	3.43
CV(%)	9.81	5.22	8.66	5.73

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

V_1 = BARI Gom 26 — I_0 = No Irrigation throughout the growing season
V_2 = BARI Gom 28 — I_1 = One irrigation (Irrigate at CRI stage)
I_2= Two irrigation (Irrigate at CRI and grain filling)
V_3 = BARI Gom 30 — I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

4.3.2 Effect of irrigation

Different levels of irrigation varied significantly in terms of number of non effective tillers hill^{-1} of wheat at harvest under the present trial (Table 2). The highest number of non effective tillers hill^{-1} (2.00) was recorded from I_0, while the corresponding lowest number of non effective tillers hill^{-1} (0.67) was observed in I_3.

4.3.3 Interaction of variety and irrigation

Variety and irrigation showed significant differences on number of non effective tillers hill^{-1} of wheat due to interaction effect (Table 2). The highest number of non effective tillers hill^{-1} (2.33) were observed from V_1I_0 treatment combination, while the corresponding lowest number of non effective tillers hill^{-1} (0.33) were recorded from V_3I_2 treatment combination.

4.4. Spike length (cm)

4.4.1. Effect of variety

Insignificant variation was observed on spike length (cm) at applied three types of modern wheat variety as BARI Gom-26 (V_1), BARI Gom-28 (V_2), and BARI Gom-30 (V_3). From the experiment with that three types of varieties BARI Gom-30 (V_3) (8.46 cm) given the largest spike length and BARI Gom-26 (V_1) (8.08 cm) was given the lowest spike length (Table 2). Similar result was found using with different type varieties by Hefni *et al*. (2000).

4.4.2. Effect of irrigation

Different irrigation application have a statistically significant variation on spike length as irrigated condition (I_3) was given the maximum result (9.17 cm) and non irrigated condition (I_0) given the lowest spike length (7.17 cm) (Table 3). Ghulam Mustafa Laghari (2011) and Pal and Upasani (2007) applied different irrigation treatment at same way and found effect of irrigation on spike length (cm).

4.4.3. Interaction effect of irrigation and variety

Interaction effect of improved wheat variety and irrigation showed significant differences on spike length. Results showed that the highest spike length was obtained from V_3I_3 (10.33 cm). On the other hand the lowest spike length was observed at V_1I_0 (6.50cm) treatment combination (Table 4).

4.5. Grain spike^{-1}

4.5.1 Effect of variety

Significant variation was observed on grain spike^{-1} at these applied three types of modern wheat variety. The BARI Gom-30 (V_3) (37.75) given the maximum number of grain spike^{-1} and BARI Gom-26 (V_1) (36.92) was given the lowest number of grain spike^{-1}, which was statistically similar with V_2 treatment (Table 3). Different wheat genotypes have significant effect on grain spike^{-1} observed also by Rahman *et al.* (2009).

4.5.2. Effect of irrigation

Different irrigation application have a statistically significant variation on grain spike^{-1} as the irrigation condition (I_3) was given the maximum result (39.33), which was statistically similar with I_2 and non irrigated condition (I_0) given the lowest grain spike^{-1} (34.56) (Table 3). Sarkar *et al.* (2010) also observed that irrigation have a significant effect on grain spike^{-1}.

4.5.3. Interaction effect of irrigation and variety

Interaction effect of improved wheat variety and irrigation showed significant differences on grain spike^{-1}. Results showed that the highest grain spike^{-1} was obtained from V_3I_3 (41.0). On the other hand the lowest grain spike^{-1} was observed at V_1I_o (34.00) which were also statistically similar with V_3Io (34.67) (Table 4).

4.6. Thousand Seed weight

4.6.1. Effect of variety

There was significant variation was observed on thousand seed weight due to different types of modern wheat variety. The wheat variety of BARI Gom-30 (V_3) (50.40 g) given the maximum thousand seed weight and statistically different from BARI Gom-28 (V_2) (46.74 g). BARI Gom-26 (V_1) (46.22 g) was given the lowest thousand seed weight (Table 5). Rahman *et al.* (2009), Qasim *et al*. (2008), Islam *et al*., (1993) also conducted experiment with different variety and observed have effect of varieties on yield.

4.6.2. Effect of irrigation

Different irrigation application has a statistically significant variation on thousand seed weight. The I_3 was given the maximum thousand seed weight (48.91) and non irrigated condition (I_0) given the lowest yield (46.13 g) (Table 6). Sarkar *et al.* (2010), Baser *et al*. (2004) reported that grain yield under non-irrigated conditions was reduced by approximately 40%. Bazza *et al.* (1999) reported that one water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations but Meena *et al.* (1998) reported that wheat grain yield was the highest with 2 irrigations (2.57 ton/ha in 1993 and 2.64 ton/ha) at flowering and/or crown root initiation stages. Wheat is sown in November to ensure optimal crop growth and avoid high temperature and after that if wheat is sown in the field it faces high range of temperature for its growth and development as well as yield potential. Islam *et al*., (1993) reported that late planted wheat plants faced a period of high temperature stress during reproductive stages causing reduced kernel number spike^{-1} as well as the reduction of grain yield.

4.6.3 Interaction effect of irrigation and variety

Interaction effect of improved wheat variety and irrigation showed significant differences on thousand seed weight (Table 7). Results showed that the highest thousand seed weight (52.33 g) was obtained from V_3I_3 which was statistically similar with V_3I_2 (52.06 g). On the other hand the lowest yield (45.36 g) was observed at V_1I_1.

Table 5. Effect of variety on yield and yield of wheat

Treatment	Thousand seed weight (g)	Yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
V_1	46.22 c	3.21 b	1.87 b	5.08 b
V_2	46.74 b	3.43 a	1.90 b	5.33 ab
V_3	50.40 a	3.44 a	1.95 a	5.39 a
$LSD_{(0.05)}$	0.5091	0.1571	0.0497	0.2721
CV(%)	6.27	6.34	7.39	11.00

V_1 = BARI Gom 26, V_2 = BARI Gom 28, V_3 = BARI Gom 30

Table 6. Effect of irrigation on yield and yield of wheat

Treatment	Thousand seed weight (g)	Yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
I_0	46.13 d	2.97 b	1.80 c	4.77 d
I_1	47.49 c	3.16 b	1.88 bc	5.03 c
I_2	48.60 b	3.56 a	1.94 ab	5.50 b
I_3	48.91 a	3.74 a	2.01 a	5.76 a
$LSD_{(0.05)}$	0.27	0.28	0.12	0.23
CV(%)	6.27	6.34	7.39	11.00

I_0 = No Irrigation throughout the growing season, I_1 = One irrigation (Irrigate at CRI stage), I_2= Two irrigation (Irrigate at CRI and grain filling), I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

Table 7. Interaction effect of variety and irrigation on yield and yield of wheat

Treatment	Thousand seed weight (g)	Yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
V_1I_0	45.65 fg	2.93 d	1.78 e	4.72 f
V_1I_1	45.36 g	3.21 cd	1.89 cd	5.09 def
V_1I_2	46.70 cde	3.33 bcd	1.83 de	5.16 cde
V_1I_3	47.15 cd	3.38 bc	1.96 bc	5.34 cd
V_2I_0	46.10 ef	2.99 cd	1.79 e	4.77 ef
V_2I_1	46.55 de	3.26 bcd	1.91 cd	5.17 cde
V_2I_2	47.04 cd	3.60 ab	1.91 cd	5.51 bc
V_2I_3	47.25 c	3.86 a	2.00 ab	5.86 ab
V_3I_0	46.64 cde	3.00 cd	1.83 de	4.84 ef
V_3I_1	50.54 b	3.00 cd	1.83 de	4.83 ef
V_3I_2	52.06 a	3.75 a	2.07 a	5.82 ab
V_3I_3	52.33 a	3.99 a	2.08 a	6.07 a
Lsd $_{(0.05)}$	0.56	0.36	0.08	0.36
CV(%)	6.27	6.34	7.39	11.00

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

V_1 = BARI Gom 26
V_2 = BARI Gom 28
V_3 = BARI Gom 30

I_0 = No Irrigation throughout the growing season
I_1 = One irrigation (Irrigate at CRI stage)
I_2= Two irrigation (Irrigate at CRI and grain filling)
I_3= Three irrigation (irrigate at CRI, booting and grain filling stages)

4.7. Grain yield (t ha^{-1})

4.7.1 Effect of variety

Different wheat varieties showed significant difference for grain weight $hectare^{-1}$ (Table 5). The highest grain yield $hectare^{-1}$ (3.44 ton) was found from wheat variety BARI Gom-30 (V_3), which was statistically similar with V_2, whereas the lowest (3.21 ton) was observed from wheat variety BARI gom 26. Rahman *et al.* (2009), Qasim *et al*. (2008), Islam *et al*., (1993) also conducted experiment with different variety and observed have effect of varieties on yield

4.7.2. Effect of irrigation

Significant difference was observed for yield for different irrigation application. The three irrigation (I_3) was given the maximum yield (3.74 t ha^{-1}), which was statistically similar with I_2 treatment and non irrigated condition (I_0) given the lowest yield (2.97 t ha^{-1}) (Table 6). Sarkar *et al.* (2010), Baser *et al*. (2004) reported that grain yield under non-irrigated conditions was reduced by approximately 40%. Bazza *et al.* (1999) reported that one water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations but Meena *et al.* (1998) reported that wheat grain yield was the highest with 2 irrigations (2.57 ton/ha in 1993 and 2.64 ton/ha) at flowering and/or crown root initiation stages. Wheat is sown in November to ensure optimal crop growth and avoid high temperature and after that if wheat is sown in the field it faces high range of temperature for its growth and development as well as yield potential. Islam *et al*., (1993) reported that late planted wheat plants faced a period of high temperature stress during reproductive stages causing reduced kernel number spike^{-1} as well as the reduction of grain yield.

4.7.3. Interaction effect of irrigation and variety

Interaction effect of improved wheat variety and irrigation showed significant differences on yield (t ha^{-1}). Results showed that the highest yield (3.99 t ha^{-1}) was obtained from V_3I_3, which was statistically similar with V_2I_3 and V_3I_2. On the other hand the lowest yield (2.93 t ha^{-1}) was observed at V_1Io (Table 7).

4.8. Straw yield (t ha^{-1})

4.8.1. Effect of variety

Applied three types of wheat variety have a statistically significant variation on straw yield (t ha^{-1}). The maximum straw yield (1.95 t ha^{-1}) was obtained from BARI Gom-30 and BARI Gom-26 (V_1) was given the lowest straw yield (1.87 t ha^{-1}), which was statistically similar with V_2 treatment.

4.8.2. Effect of irrigation

Different irrigation application has a statistically significant variation on straw yield (t ha^{-1}) of wheat. The I_3 treatment for straw yield (2.01 t ha^{-1}) was given the maximum result and non irrigated condition (I_0) given the lowest (1.80 t ha^{-1}). Similler results were found by Ali and Amin (2004) through his experiment.

4.8.3. Interaction effect of irrigation and variety

Interaction effect of improved wheat variety and irrigation showed significant differences on straw yield (t ha^{-1}). The highest straw yield (2.08 t ha^{-1}) was obtained from V_3I_3 which was statistically similar with V_3I_2 (2.07 t ha^{-1}) treatment combination. On the other hand the lowest straw yield (1.78 t ha^{-1}) was observed at V_1Io, which was statistically similar with V_2I_0 (2.07 t ha^{-1}) treatment combination.

4.9. Biological yield

4.9.1 Effect of variety

Significant variation was attained for biological yield for different wheat varieties. The variety BARI Gom-30 given the maximum biological yield (5.39 t ha^{-1}) and BARI Gom-26 (V_1) was given the lowest biological yield (5.078 t ha^{-1}).

4.9.2 Effect of irrigation

Different irrigation application has a statistically significant variation biological yield (t ha^{-1}) of wheat. The I_3 treatment for biological yield (5.76 t ha^{-1}) was given the maximum result and non irrigated condition (I_0) given the lowest (4.77 t ha^{-1}). Similar results were found by Ali and Amin (2004) through his experiment.

4.9.3. Interaction effect of irrigation and variety

At the time of biological yield (t ha^{-1}) consideration with variety and irrigation statistically significance variation was observed as maximum biological yield (t ha^{-1}) at V_3I_3 (6.07 t ha^{-1}). On the other hand the lowest result was given at V_1Io (4.72 tha^{-1}).

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the Agronomy Field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period of November 17, 2016 to March 290, 2017 to Growth and yield performance of selected wheat genotypes at variable irrigation management as influenced by different varieties and different irrigated and non irrigated condition. In this experiment, the treatment consisted of three varieties viz. V_1 = BARI Gom 26, V_2 = BARI Gom 28, V_3 = BARI Gom 30, and four different irrigations condition viz. I_0 = No Irrigation throughout the growing season, I_1 = One irrigation (Irrigate at CRI stage), I_2= Two irrigation (Irrigate at CRI and grain filling), I_3= Three irrigation (irrigate at CRI, booting and grain filling stages). The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters.

Plant height varied significantly among the tested three varieties. BARI Gom-30 showed the tallest plant height (34.72 and 76.13 cm at 30 and 60 DAS, respectively). The highest number of effective tillers hill^{-1} **(**9.33) was obtained from BARI Gom-30 (V_3). The variety of BARI Gom-30 (V_3) (8.46 cm) given the largest spike length. The BARI Gom-30 (V_3) 37.75) given the maximum number of grain spike^{-1}. There was significant variation was observed on yield per plot due to different types of modern wheat variety. The wheat variety of

BARI Gom-30 (V_3) (50.40 g) given the maximum thousand seed weight. BARI Gom-26 (V_1) (46.22 g) was given the lowest thousand seed weight. The highest grain weight hectare^{-1} (3.44 ton) was found from wheat variety BARI Gom-30 (V_3). The maximum straw yield (1.95 t ha^{-1}) was obtained from BARI Gom-30. The variety BARI Gom-30 given the maximum biological yield (5.39 t ha^{-1}) and BARI Gom-26 (V1) was given the lowest biological yield (5.08 t ha-1).

Plant height of wheat showed statistically significant variation due to amount of irrigation at 30, 60 DAS under the present trial. The tallest plant (34.78 and 77.51 cm at 30 and 60 DAS, respectively) was recorded from I_3 (Three irrigation). The highest number of effective tillers hill^{-1} 9.89 was recorded from $I_{3.}$. The spike length as irrigated condition (I_3) was given the maximum result (9.17 cm). The grain spike^{-1} as three irrigation condition (I_3) was given the maximum result (39.33). The I_3 was given the maximum thousand seed weight (48.91 g) and non irrigated condition (I_0) given the lowest yield (46.13). The three irrigation (I_3) was given the maximum yield (3.74 t ha^{-1}). The I_3 treatment for straw yield (2.01 t ha^{-1}) was given the maximum result. The I_3 treatment for biological yield (5.76 t ha^{-1}) was given the maximum result and non irrigated condition (I_0) given the lowest (4.77 t ha^{-1}).

Interaction effect of variety and different amount of irrigation showed significant differences on all parameter of wheat. The highest plant height (38.00 and 78.50 cm at 30 and 60 DAS, respectively) obtained from V_3I_3 treatment. The highest number of effective tillers hill^{-1} (10.33) was observed from V_3I_3 treatment. The highest spike length was obtained from V_3I_3 (10.33 cm). The highest grain spike^{-1} was obtained from V_3I_3 (41.00). The highest thousand seed weight (52.33 g) was obtained from V_3I_3. Interaction effect of improved wheat variety and irrigation showed significant differences on yield (t ha^{-1}). Results showed that the highest yield (3.99 t ha^{-1}) was obtained from V_3I_3. On the other hand the lowest yield (2.93 t ha^{-1}) was observed at V_1Io. The highest straw yield (2.08 t ha^{-1}) was obtained from $V_{3}I_{3..}$ At the time of biological yield (t ha^{-1}) consideration with variety and irrigation statistically significance variation was observed as maximum biological yield (t ha^{-1}) at V_3I_3 (6.07 t ha^{-1}). On the other hand the lowest result was given at V_1Io (4.72 tha^{-1}).

It may be concluded within the scope and limitation of the present study that the optimum growth and higher yield of wheat cv. BARI Gom-30 could be obtained by applying three irrigations at irrigate at CRI, booting and grain filling stages. However, further studies are necessary to arrive at a definite conclusion.

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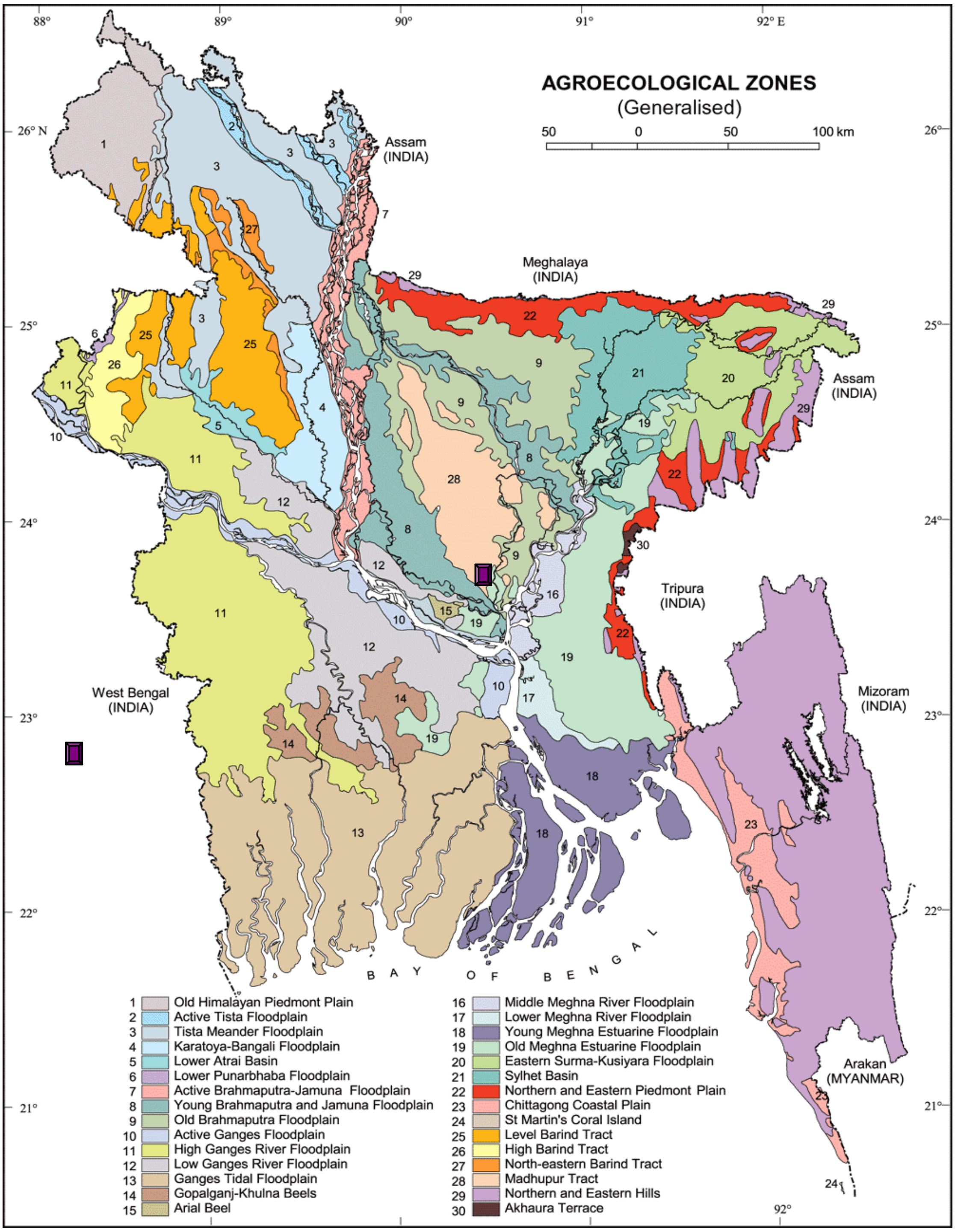
APPENDIES

Appendix I: Map showing the experimental sites under study



Appendix II: **Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka.**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

Source: SRDI

B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Source: SRDI