EFFECT OF SOWING TIMES ON PHENOLOGICAL DEVELOPMENT AND YIELD OF WHEAT

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EFFECT OF SOWING TIMES ON PHENOLOGICAL DEVELOPMENT AND YIELD OF WHEAT

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CERTIFICATE

This is to certify that the thesis entitled ***'EFFECT OF SOWING TIMES ON PHENOLOGICAL DEVELOPMENT AND YIELD OF WHEAT'*** *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 (MS)*** *in* ***AGRONOMY****, embodies the result of a piece of bona fide research work carried out by* ***MD. AFAZ UDDIN****, Registration number:* ***14-06197,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. H. M. M. Tariq Hossain
Department of Agronomy
Supervisor

Dedicated to
My Beloved
Parents

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The Author

EFFECT OF SOWING TIMES ON PHENOLOGICAL DEVELOPMENT AND YIELD OF WHEAT

ABSTRACT

A pot experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2019 to March 2020 to find out the effect of sowing times on phenological development and yield of wheat. The experiment comprised of two factors; Factor A: Variety- BARI Gom-26 (V_1) and BARI Gom-28 (V_2); Factors B: Sowing time- 5th November (S_1), 15th November (S_2), 25th November (S_3), 5th December (S_4) and 15th December, 2019 (S_5). The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Data were recorded and significant variation was observed for most of the characters studied. In the case of wheat varieties, the tallest and shortest plant (89.27 and 82.58 cm at harvest, respectively) was found from V_2 and V_1 treatment. Data revealed that the highest days to spike emergence (65.40) and days to maturity (107.80) were obtained from V_1 whereas the lowest days to spike emergence (57.80) and days to maturity (104.80) were recorded from V_2. The maximum and minimum grain yield (3.83 and 3.65 t ha^{-1}) was recorded from V_2 and V_1. In respect of different sowing times, the tallest and shortest plant (89.25 and 83.38 cm at harvest, respectively) was observed from S_2 and S_5 treatment. The highest days to spike emergence (64.50) was obtained from S_5 and days to maturity (110.00) was obtained from S_1. The lowest days to spike emergence (58.50) was obtained from S_2 and days to maturity (102.50) were recorded from S_5. The highest and lowest grain yield (4.05 and 3.42 t ha^{-1}) was observed from S_2 and S_5 treatment. Due to the combined effect of wheat varieties and sowing times, the tallest and shortest plant (92.67 and 79.75 cm at harvest, respectively) was observed from V_2S_2 and V_1S_5 treatment combination. The highest and lowest days to spike emergence (69.00 and 55.00) was obtained from V_1S_5 and V_2S_2 treatment combinations. The highest and lowest days to maturity (112.00 and 101.00) was obtained from V_1S_1 and V_2S_5 treatment combinations. The highest and lowest grain yield (4.23 and 3.39 t ha^{-1}) was observed from V_2S_2 and V_1S_5 treatment combinations. BARI Gom-28 sown on 15th November (V_2S_2) showed best in performing yield and yield components.

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LIST OF ACRONYMS

Acronym		Full meanings
AEZ	=	Agro-Ecological Zone
%	=	Percent
^0C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most widely cultivated cereal crop covering more of the earth's surface area than any other food crop. Wheat production is the world's third largest cereal production trailing only maize and rice (FAO, 2013). For millennia, FAO has recognized wheat as the key to the emergence of urban societies (FAO, 2013). One cup of whole wheat grain has 33 % protein, 29 % carbohydrate and 5% fat (Jones *et al.*, 2015). Currently around 65 % of wheat is used for food, 17 % for animal feed and 12 % for industrial applications (FAO, 2013).

The demand in the developing world is projected to increase 60 % by 2050 (Nelson *et al.*, 2010). Except in a few developing countries, the demand for wheat is being met increasingly through imports; wheat now accounts for the largest food import (43 %) to developing countries (Dixon *et al.*, 2009). Wheat is the second most significant cereal crop in Bangladesh after rice (Al-Musa *et al.*, 2012). The area under wheat cultivation in 2017-2018 was approximately 0.35 million ha, generating 1.09 million tons of wheat with an average yield of 3.14 tons ha^{-1} (BBS, 2019). However, the average wheat yield is quite low when compared to New Zealand, Netherlands, Germany, Japan, UK and France (8.84, 9.37, 7.39, 4.90, 8.93 and 7.74 t ha^{-1}, respectively) (FAO, 2019). However, the average wheat yield in Bangladesh can be increased to 6.8 t ha^{-1} (BARI, 2010). Furthermore, food scarcity has been a chronic issue in this country. As a result, cereal crop production such as wheat should be increased to fulfill the growing population's demand. Wheat production may be increased by using high yielding varieties and appropriate agronomic practices. Because of limited land resources and high population density horizontal expansion of wheat area is not possible in Bangladesh. As a result, the only option left is to improve wheat production by vertical means, i.e. management practices.

Planting the proper variety at the right time ensures that wheat flowers when the risk of freezing damage is at its lowest but before the assault of heat stress (Rahman *et al.*, 2015). Another crucial factor to consider is the moisture content of the soil. The key to increasing wheat yields is to select the proper variety and planting it at the right time to achieve optimal flowering and eventually maximum yield. There are no hard and fast rules when it comes to variety selection and planting. Both decisions are essentially concessions to Mother Nature. Different varieties respond differently to sowing time and the prevailing environment condition during the growing season. Recently, efforts were taken to increase the yield of wheat in Bangladesh by releasing a number of high yielding varieties. In Bangladesh although some varieties have been identified for late sowing condition (Islam *et al.,* 1993 and Ahmed *et al.,* 1989). Climate and weather circumstances have a significant impact on the yield and quality performance of new wheat cultivars (Wajid *et al.*, 2004; Sharma *et al.*, 2006; Abdullah *et al.*, 2007). Accurate knowledge of a variety's sowing window at a specific site is crucial for achieving a good grain yield (Ortiz-Monasterio *et al.*, 1994). Interactions between varieties and sowing times have been found to be highly important in terms of 1000-grain weight and bread quality, indicating that diverse varietal behavior occurs at different sowing times (Qamar *et al.*, 2004; Subhan *et al.*, 2004).

Planting early can boost crop establishment but can also result in early flowering, increasing the danger of frost damage. Wheat that is planted early is also more susceptible to pests and diseases. As a result, selecting the best variety for a certain area is challenging and requires field trails. The planting time is one of the most important elements impacting wheat productivity. This in turn is directly related to soil preparation which has a dramatic effect on the periodicity of weed seed germination, allowing for management of weed species composition (Berzsenyi, 2000). After T. aman, the majority of farmers in this country usually grow wheat on the same land. The harvest of rice and hence the sowing of wheat is frequently delayed.

Sowing time is one of the most important agronomic factors involved in producing high yielding small grain cereal crops, which affects the timing and duration of vegetative and reproductive stages (El-Sarag *et al.*, 2015). Sowing of wheat in Bangladesh often begins in November and ends in late December, depending on the weather, topography, and harvesting of previous crops. As a result of the late sowing, the wheat crop endures high temperatures during the flowering period resulting in grain sterility (Rahman *et al*., 2009). Timely sowing of wheat provides optimum environment for crop growth to accumulate more biomass and finally higher grain yield. Under late sown condition wheat crop exposed to low temperature at the germination which delayed the crop emergence and to higher temperature at the reproductive phase leads to force maturity and result in reduction of the yield and yield attributes (Gupta *et al.*, 2017).

Wheat is often sown in November to ensure optimal crop growth and to avoid high temperatures. After that, if wheat is sown in the field, it will be subjected to a wide range of temperatures for growth and development as well as yield potential. Among different variables late sowing of wheat is one of the primary reasons of yield reduction, because roughly 60 % of the wheat is cultivated under late sowing circumstances after harvesting of the transplanted aman rice (Badaruddin *et al.*, 1994). Temperature is one of the primary environmental elements that impacts grain yields in wheat considerably. Wheat photosynthesis is at its peak between 22 and 250 ºC (Kobza and Edwards, 1987) and begins to decline dramatically above 350 ºC (Al-Khatib and Paulsen, 1990).

One of the major causes of yield reduction in our country is late wheat sowing (Badaruddin *et al.*, 1994). Late planted wheat plants experience severe temperature stress throughout reproductive phases resulting in decreased kernel number spike^{-1} and kernel weight as well as decreased seed yield (Bhatta *et al.*, 1994; Islam *et al.*, 1993). In such a climate, the choice of sowing time is a key management option for optimizing wheat grain yield (Radmehr *et al.*, 2003; Turner, 2004). Numerous publications have demonstrated enhanced wheat production with early planting and a decrease in yield when seeds are sown after the optimum period (Bassu *et al.*, 2009; Bannayan *et al.*, 2013). Many research have also confirmed the negative impacts of late sowing (Singh and Dhaliwal, 2000; Wajid *et al.*, 2002; Singh and Pal, 2003; Kumar and Sharma, 2003). In Bangladesh, information on the precise time of sowing of different wheat varieties to improve wheat yield within the farmer's restricted resources is lacking. So, in consideration of the above-mentioned circumstances of wheat production in Bangladesh, the current piece of work was done with the following objectives-

Objectives:

1. To evaluate the effect of variety on growth and yield of wheat
2. To determine the effect of sowing times on growth and yield of wheat
3. To identify the suitable combination of variety and sowing time for maximizing yield of wheat.

CHAPTER II

REVIEW OF LITERATURE

Wheat (*Triticum aestivum* L.) has been established as the second most economically important food grain crop in Bangladesh in order to reduce the gap between food production and import. It is important to select and identify the optimum sowing time for wheat varieties. This chapter discusses related study findings on the effect of sowing times on wheat varieties growth, yield, and yield components.

2.1 Effect of varieties on growth and yield of wheat

A field experiment was conducted by Yusuf *et al.* (2019) during *Rabi* season of 2017-18 at wheat research farm of CCS Haryana Agricultural University, Hisar, India to study the effect of sowing times and varieties on yield and quality performance of wheat *(Triticum aestivum* L.). The experiment was laid out in split plot design with three replications containing four sowing times *viz*. 5th November, 25th November, 15th December and 5th January as main plot treatments and seven wheat varieties *i.e*. HS 562, HD 2967, HD 3086, HI 1544, MACS 6222, WR 544 and WH 1105 as sub plot treatments. On the basis of one year study it was concluded that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains spike^{-1} (45.51), unfilled grains spike^{-1} (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}), straw yield (7631 kg ha^{-1}), biological yield (12551 kg ha^{-1}), harvest index (39.2 %), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties. While comparing the interaction of varieties with time of sowing, HI 1544 produced significantly higher grain higher yield (6007 kg ha^{-1}) of wheat sown at 5th November which was statistically at par with WH 1105 (5833 kg ha^{-1}) and HD 3086 (5616 kg ha^{-1}) at same time of sowing. Delayed sowing of HI 1544 from 5th November to 25th November reduced the grain yield by 9.1 %; to 15th of December by 21.0 % and to 5th January by 42.3 %.

Islam and Jahiruddin (2008) conducted a study to determine the influence of sowing times on wheat varieties. They selected three wheat varieties, namely BARI Gom 19 (Sourov), BARI Gom 21 (Shatabdi), and BARI Gom 24 (Prodip) for their research.

They observed that plant height differed greatly between varieties. BARI Gom 21 (Shatabdi) had the tallest plants (80.94 cm), which was significantly different from Sourav (78.75 and BARI Gom 24 (Prodip) (78.58 cm). Alam *et al.* (2013) conducted an experiment to determine the influence of wheat variety and sowing time on growth and yield. They came to the conclusion that variety had no effect on wheat plant height. Islam and Jahiruddin (2008) also conducted a study to determine the influence of sowing times on wheat varieties. They selected three wheat cultivars, namely BARI Goms 19 (Sourov), 21 (Shatabdi), and 24 (Shatabdi) (Prodip). They observed no significant impact of variety on wheat plant tillering. Sulewska (2004) conducted an experiment with 22 wheat genotypes to compare vegetation period, plant height, number of stems and spikes, and yield per spike. Because of the variety, he noticed a tallest plant. He also stated that the variety Waggershauser, Hohenh, Weisser, Kolben produced the tallest plant.

Qasim *et al.* (2008) studied the growth and yield response of three wheat varieties (Suliman-96, Chakwal-97, and Inqalab-91) to different sowing times at Karakoram Agricultural Research Institute, (Northern Areas) Gilgit, Pakistan and found that plant height varied for different cultivars of wheat. Khokhar *et al.* (2010) conducted a study in Sindh to assess the effects of planting times on the growth and yield of various wheat genotypes. There were four sowing times and six wheat genotypes utilized (V-7001, V-7002, V-7004, MPT-6, Abadgar-93, and Anmol-91). Wheat genotype V-7002 showed improved plant growth. Al-Musa *et al.* (2012) conducted a pot experiment at Patuakhali Science and Technology University to investigate the performance of certain BARI wheat varieties in the Patuakhali coastal area. Four wheat varieties were planted in the field to compare their performance: BARI ghom-23, BARI ghom-24, BARI ghom-25, and BARI ghom-26. BARI ghom-26 produced the tallest plant among the BARI varieties (47.91 cm). Mohsen *et al.* (2013) conducted a study in Iran to examine the effects of sowing times on the growth and yield components of various wheat varieties. In this experiment, five planting times and five wheat varieties (Pishgam, Parsi, Bahar, Sivand, and Pishtaz) were used. The results showed that varieties had a significant impact on all parameters.

Kumar *et al.* (2013) conducted an experiment to determine the effect of sowing times on different wheat varieties, and they showed that variety had a significant impact on grain yield. Zia-ul-Hassan *et al.* (2014) conducted a field experiment at Adaptive

Research Farm, Bhaun, Chakwal, to investigate the responsiveness of high yielding varieties to varied sowing times under rainfed circumstances. Five varieties viz. GA 2002, Chakwal 50, Farid 2006, Wafaq 2001, and Sehar 2006 were the treatments, with four sowing times. In terms of plant height, the data showed that variety remained significant.

Al-Khatib and Paulesn (1990) assessed the yield performance of ten wheat genotypes grown under moderate ($22/17^0$C, day/night) and high ($32/27^0$C, day/night) temperature conditions. At maturity, the yield component of ten genotypes reacted differently to high temperature. Spike per plant decreased significantly in three genotypes and increased in one genotype as temperature rose, whereas kernel per spike decreased in four genotypes. Kernel weight decreased significantly in all genotypes, with the reduction ranging from 10% to 30%. Yajam and Madani (2013) conducted a field experiment with Iranian winter wheat cultivars to see how they responded to a delayed sowing time. The experiment was split plot completely randomized with three replications, with the main plots consisting of four winter wheat cultivars, namely B. C. Roshan, Alvand, Amirkabir, Shahriar, and sub plots had six sowing times ranging from very early to very late. The results revealed significant differences between cultivars the first time around.

Islam *et al.* (1993) compare the performance of existing (Sonalika) and newly released wheat varieties (Ananda, Kanchan, Barkat, Akbar, and Aghrani) seeded at 15-day intervals from 1 November to 15 January. Variety had a significant impact on spike/m^2, grain/spike, and 1000-grain weight. Improper variety selection also has an impact on crop yield because the performance of varieties varies inversely with their genetic potential and adaptability to the environment, so there is potential for increasing wheat yield through the cultivation of climate resilient varieties (Hussain *et al.*, 2012). Wheat yield can be increased 10 to 80% through proper selection of sowing time and suitable cultivars (Coventry *et al.*, 2011).

Habibi and Fazily (2020) conducted a field experiment entitled “Effect of sowing times on growth, yield attributes and yield of four wheat varieties” during winter season of 2016-17 on sandy loam soils of Poz-e-Ishan Research Farm of Agricultural Faculty of Baghlan University. The experiment was laid out in split plot design viz. four times of sowing comprised of (16^{th} November, 01^{st} December, 16^{th} December and 31st December 2016) as main plot treatments and four varieties (Solh 02, Gul 09, Muqawim 09, Kabul 013) as sub plot treatments with four replications. The highest plant height, number of effective tillers per plant, test weight and grain yield of wheat was recorded with all varieties sown on 16 Nov-16, which was statistically identical with all treatments sown on 01 Dec-16 but significantly higher over rest of time of sowing. Among wheat varieties Kabul 013 and Gul 09 produced significantly higher plant height, number of effective tillers per plant, test weight and grain yield of wheat over rest of the varieties.

Roshan *et al.* (2021) conducted a field experiment in Dar-ul-Aman Research Farm, Kabul Afghanistan in 2017 to study the influence of sowing times and varieties on the biological yield of wheat crop (*Triticum aestivum* L.). The experiment was laid out in RCBD with a split-plot arrangement having three replications. Wheat was sown in different sowing times i.e., October 24th, November 2nd, 12th, and 22nd in main plots, whereas five wheat varieties (Chounth # 1-2010, Moqawim-09, Shisham Bagh- 08, Dar-ul-Aman-07 and Solh 2002) were in sub plots. November 2nd planted wheat had a highest biological yield of (6642.1 kg ha^{-1}) followed by October 24th and November 12th which gave (6576.5 kg ha^{-1}) and (5711.0 kg ha^{-1}) respectively. The lowest biological yield of (2975.1 kg ha^{-1}) was given by the wheat varieties sown on November 22nd. Among the all-wheat varieties, Solh 2002, had significantly higher biological yield of (6263.7 kg ha^{-1}) followed by Shisham Bagh-08 with biological yield of (5571.8 kg ha^{-1}). However, Moqawim-09 had lowest biological yield of (4976.8 kg ha^{-1}) compare to other varieties. While, evaluating performance of different wheat varieties on different sowing times, Solh 2002, resulted in maximum biological yield (7476.2 kg ha^{-1}) on November 2nd followed by Darul-Aman-07 (6933.3 kg ha^{-1}) and Shisham Bagh-08 (6860.0 kg ha^{-1}) on November 2nd and October 24th respectively. On the other hand, Dar-ul-Aman-07 had lowest biological yield among the varieties (2015.5 kg ha^{-1}) on 22nd November, it shows that, Dar-ul-Aman-07 had highest biological yield on early planting but lower yield on late sowing times. The study shows that delay in wheat planting or selection of other varieties rather than Solh 2002 and Dar-ul-Aman-07 reduces the biological yield of the crop.

WRC (2003) of Bangladesh conducted an experiment at the Wheat Research Centre Nashipur, Dinajpur to assess genotype performance across various tillage operations and to identify the effects of genotype-tillage interaction. In the main plot, two cultivation methods were used, and ten wheat genotypes (Kanchan, Gourav, Shatabdi, Sourav, BAW 1008, BAW 1006, BAW 1004, BAW 969, BAW 968, and BAW 966) were examined in the sub plots. For yield-related characteristics, the genotypes revealed a wide range of variation. Shatabdi produced the most grain spike^{-1} and 1000 grain weight. Suleiman *et al.* (2014) conducted field experiments at the Demonstration Farm of the College of Agriculture, University of Bahri to evaluate the performance of different wheat cultivars under varied sowing times. The experiment included four sowing times and five wheat cultivars in subplots: Al Nilein, Debiera, Imam, Sasaraib, and Wad el Neil. The cultivars Imam and Wad el Neil came in first place in terms of the number of grains spike^{-1}.

Al-Khatib and Paulesn (1990) also assessed the yield performance of ten wheat genotypes grown under moderate (22/17^{0}C, day/night) and high (32/27^{0}C, day/night) temperature conditions. Grain yield decreased by 23 percent from 22/17 to 32/27^{0}C, or 0.75 to 0.58 g per tiller. Yields were constant for three genotypes and reduced by 40% for the other three. BARI (2003) investigated the performance of different wheat cultivars and discovered that Shatabdi produced the greatest yield (2.72 t ha^{-1}) followed by the variety Gourav (2.66 t ha^{-1}). Kanchan produced the lowest yield (2.52 t ha^{-1}). Samson *et al.* (1995) carried out an experiment and observed the variety Sowghat produced the highest grain yield (3.5 t ha^{-1}) among the different varieties, closely followed by the variety BAW-748. The yields of the other four types, Sonalika, CB-84, Kanchan and Seri-82 were 2.70, 2.83, 3.08, and 3.15 t ha^{-1}, respectively. Maiksteniene *et al.* (2006) conducted a field experiment to evaluate changes in winter wheat production and quality parameters. The varieties tested were Ada and Bussard (with extremely good food characteristics) and Lars and Tauras (with satisfactory food qualities). When comparing variants with adequate food qualities to those with very good food qualities, variations with satisfactory food qualities generated a greater grain yield.

Refay (2011) investigated the effects of genotypes, sowing times, and their interactions on grain yield and yield component features of bread wheat. Two promising lines, KSU-105 and KSU-106, as well as the introduction cv. Yecora Rojo, as well as two planting times, were chosen. KSU-106 outperformed the other two genotypes by 2.0 and 11.3 %, respectively. Rita Costa *et al.* (2013) carried out a study to examine the effects of sowing time and seeding rate on grain yield and test weight of fifteen bread wheat varieties as well as five advanced lines, and comparing the results obtained in the two studied locations, Beja showed a 3.0 t ha^{-1} higher average yield than Elvas for the majority of the varieties.

A field study was conducted by Madhu *et al.* (2018) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to investigate the effect of sowing time on the performance of wheat varieties. The experiment, laid out in RCBD with three replications, comprised four sowing times viz.,15 November, 30 November, 15 December and 30 December, and four varieties of wheat viz. BARI Gom 25, BARI Gom 26, BARI Gom 27 and Shatabdi. The results suggested that the highest plant population m^{-2} (58.17) and the highest plant height (89.59 cm) were obtained in 15 November sowing. BARI Gom 25 produced the highest plant population m^{-2} (50.33) and the highest plant height (86.32) while the same trend was observed in the interaction of BARI Gom 25 × 15 November sowing. The lowest performance of these two parameters was observed in the interaction of Shatabdi × 30 December sowing. The highest grain yield (2.18 ha^{-1}) was found in the interaction of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers $hill^{-1}$ (4.73), the highest number of spikelets $spike^{-1}$ (17.77), the highest number of filled grains $spike^{-1}$ (37.89), minimum number of unfilled grains $spike^{-1}$ (1.68) and the highest 1000-grain weight (29.99 g). The individual effect of the BARI Gom 25 and 15 November sowing on those parameters was also observed as the highest. The lowest grain yield (1.5 t ha^{-1}) was found in the interaction of Shatabdi × 30 December sowing because of the poor performance of the yield components of this treatment combination. The variety BARI Gom 25 and BARI Gom 26 both gave better yield when sown on 15 November. Therefore, BARI Gom 25 and BARI Gom 26 should be sown on 15 November rather than late sowing to obtain better performance and grain yield of wheat.

Rahman *et al.* (2015) conducted a field experiment at the Hill Agricultural Research Station, BARI, Khagrachari for the two consecutive years (2009-10 and 2010-11) to find out the wheat variety suitable for hilly environment and investigate the interaction of sowing times and varieties to recommend the promising variety with proper sowing time. The experiment was laid out in split-plot design with three replications where three times of sowing (Nov. 20, Nov. 30 and Dec. 10) were assigned in the main plots and five modern wheat varieties (Shatabdi, Sufi, Sourav, Bijoy and Prodip) were tested in the sub-plots. The yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental soil and environmental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years. Shatabdi produced higher yield under early sowing (Nov. 20) but yield was decreased due to late sowing (Dec. 10). Initially the plant population and finally spikes/m^2 were affected by late sowing that caused less yield in Shatabdi. The mean yield of all varieties pulled over the sowing time indicated that wheat yield was not affected due to delay sowing up to 10th December. The experimental result demonstrated that Shatabdi could be recommended only for early sowing whereas Bijoy and Sourav could be recommended both for early and late sowing under the experimental soil and environmental conditions at hilly region of Khagrachari.

Al-Musa *et al.* (2012) conducted a pot experiment in which four wheat varieties, BARI ghom-23, BARI ghom-24, BARI ghom-25, and BARI ghom-26, were planted in the field to evaluate their comparative performance. BARI ghom-26 produced the highest HI among the BARI varieties (44.03 %). Chauhan *et al.* (2020) conducted a field experiment at Agromet, Research Farm, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) during *Rabi* season 2016-17 to study the effect of different times of sowing on growth and yield of wheat (*Triticum aestivum* L.) cultivars. The experiment comprised of 9 treatment combinations and tested in randomized block design (RBD) with four replications. Experiment consisted of two factors, *viz*. times of sowing and cultivars. Three wheat varieties, *viz*. Malviya-234, PBW-343 and NW-1012 were sown under three times *i.e.* 20 November, 30 November and 10 December. Sowing times and cultivars significantly influenced the growth characters of wheat crop. The crop sown on 20 November along with variety PBW-343 recorded highest initial plant population (m^{-2}), plant height (cm), number of tillers m^{-2}, dry matter accumulation (g m^{-2}), leaf area index, days taken to 50% ear emergence and days taken to maturity as compared to rest of sowing times and varieties. Highest net returns per rupee invested (1.33) was found with the variety 'PBW- 343' sown on 20 November.

2.2 Effect of sowing times on growth and yield of wheat

Tahir *et al.* (2009) investigated the influence of sowing time on wheat production and found that early sowing resulted in increased dry matter accumulation and total number of tillers per m^2. Anwar *et al.* (2011) conducted the study to identify the best time to sow promising wheat genotypes and compare their yield behavior to that of currently approved cultivars. Wheat varieties Inqilab-91, Uqab-2000, Shafaq-2006, and Seher-2006, as well as eight new promising lines V-03079, V-04188, V-04189, V-03094, V-03138, V-04022, V-04112 and V-04178, were seeded at six sowing times. Most genotypes generated reduced yield at later planting times; however, genotypes responded differently. Mukherjee (2012) carried out an experiment and revealed that under timely seeded conditions, wheat crop experienced prolonged favorable growing environment, which resulted in larger accumulation of carbon photosynthates and subsequently significantly enhanced yield qualities. Gupta *et al.* (2017) revealed that timely sowing of wheat provides optimum environment for crop growth to accumulate more biomass and finally higher grain yield. Under late sown condition, wheat crop exposed to low temperature at the germination which delayed the crop emergence and to higher temperature at the reproductive phase leads to force maturity and resulted in reduction of the yield and yield attributes.

Suleiman *et al.* (2014) conducted field trials to evaluate the performance of various wheat cultivars at various sowing times. The experiment included four sowing times and five wheat cultivars in subplots: Al Nilein, Debiera, Imam, Sasaraib, and Wad el Neil. In terms of grain yield t ha^{-1}, the varieties Imam and Wad el Neil took first place. Higher yield attributes and yield with 5^{th} November sowing might be due to favorable climatic condition, which prolonged vegetative as well as reproductive phases of the crop and resulted in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink, which caused the plant to produce higher yield up and ultimately resulted in higher grain yield. The results are in line with Kamrozzaman *et al*. (2016), Baloch *et al*. (2012) and Spink *et al*. (2000).

Muhammad *et al.* (2015) found that crops sown on 11^{th} November had longer spike lengths, more grains per spike, and higher grain test weights than crops sown on 6^{th} December. BARI (1984) reported that in a study using cultivar Balaka in Joydepur and Jessore, the tallest plant (76.83 cm) was obtained at Jessore when sowing was done on 20 November and the lowest with 30 December sowing. Kaur *et al.* (2010) reported that protein content of the wheat grain was higher under late sowing than timely sowing, while the hectoliter weight was higher in case of 15^{th} November time of sowing. Also it was reported that in Hisar, delayed sowing resulted in significantly higher protein content (11.7 %) followed by early sowing (10.5 %) and the lowest protein content (10.4 %) was observed under normal time of sowing (Anonymous,1993).

The time of sowing has a substantial influence on the plant height of barely. Moula (1999) conducted an experiment to investigate the influence of sowing time on the growth and development of barley varieties and observed that the tallest plant was recorded by November 25 sowing (111.8 cm) and the shortest plant was recorded by December 25 sowing (111.8 cm) (73.8 cm). Chowdhury (2002) observed that delaying sowing reduced plant height in an experiment using four sowing times. The highest plant height was observed at the last harvest in November, 01 planted plant. However, the largest plant height was observed at 60 DAS in December, with 15 seeded plants. Sial *et al.* (2005) evaluated twelve wheat genotypes bred at this Institute for yield and quality metrics at two levels of sowing times, namely normal (18^{th} November) and late sowing (11^{th} December). Plant organ growth and transfer from source to sink were significantly hampered by delayed planting, as seen by an overall shortening of plant height.

Zia-ul-Hassan *et al.* (2014) conducted a field experiment at Adaptive Research Farm, Bhaun, Chakwal, to assess the response of high yielding varieties to varied sowing times under rainfed circumstances. Four sowing times (D_1 (October 15), D_2 (October 30), D_3 (November 15), and D_4 (November 30) were used, as well as five varieties (GA 2002, Chakwal 50, Farid 2006, Wafaq 2001, and Sehar 2006). The findings revealed that sowing times had a significant impact on plant height.

Netam *et al.* (2020) conducted a field experiment during the *Rabi* season of 2016-17, at the Instructional Farm, Shaheed Gundadhoor College of Agriculture and Research Station, Kumhrawand, Jagdalpur District- Bastar (Chhattisgarh) to evaluate the growth and yield of wheat (*Triticum aestivum* L.) varieties as influenced by different sowing times under bastar plateau zone of Chhattisgarh. The soil of experimental site was sandy loam; it was low in organic carbon (0.41 %) and available amount of nitrogen (228.90 kg ha^{-1}) and medium in available amount of phosphorus (12.26 kg ha^{-1}) and potassium (286.25 kg ha^{-1}) and acidic in reaction (6.1 pH).The experiment was laid out in spilt plot design with four sowing times and four varieties of wheat. Four sowing times *viz*. 15^{th} November (D_1), 30^{th} November (D_2), 15^{th} December (D_3) and 30^{th} December (D_4) were applied in main plot and four varieties *viz*. GW- 273 (V_1), Lok- 1 (V_2), Sujata (V_3) and Kanchan (V_4) in sub-plot and replicated 3 times. The results revealed that sowing on 15^{th} December recorded significantly higher plant height (36.39 cm) at 30 DAS whereas sowing on 30^{th} December recorded higher plant height (90.42 cm) at 60 DAS. Sowing on 15^{th} November recorded significantly higher plant height (103.58 cm) at 90 DAS and (104.05 cm) at harvest. Varieties Sujata recorded significantly higher plant height (34.44 cm) at 30 DAS, (92.87 cm) at 60 DAS, (118.26 cm) at 90 DAS and (119.12 cm) at harvest. Sowing on 30^{th} December recorded significantly higher number of tillers m^{-2} (1000) at 30 DAS whereas sowing on 30^{th} November recorded significantly higher number of tillers m^{-2} (742.5). Sowing on 15^{th} November recorded relatively higher number of tillers m^{-2} (767.5) at 90 DAS and (764.83) at harvest. Varieties Sujata recorded significantly higher number of tillers (951.67), (753.75), (764.92) and (761.50) at 30 DAS, 60 DAS, 90 DAS and at harvest, respectively. Sowing on 15^{th} November recorded significantly higher duration for CRI (21.42 day), panicle emergence (62.63 day), 50 % flowering (67.58 day), milking (82.67 day) and maturity stage (111.42 day). As compare to sowing on 15^{th} November, duration of wheat crop reduces by 4 day with sown on 30^{th} November, 11 day with sown on 15^{th} December and 19 day with sown on 30^{th} December. Sowing on 15^{th} November recorded significantly higher grain yield (40.50 q ha^{-1}), straw yield (31.98 q ha^{-1}), gross return (Rs. ha^{-1} 61763), net return (Rs. ha^{-1} 35498) and B: C ratio (2.35). Varieties GW-273 recorded significantly higher grain yield (38.70 q ha^{-1}), gross return (Rs. ha^{-1} 59018), net return (Rs. ha^{-1} 32903) and B: C ratio (2.26), whereas Sujata produced significantly higher straw yield (30.42 q ha^{-1}).

Roshan *et al.* (2021) conducted a field experiment in Dar-ul-Aman Research Farm, Kabul Afghanistan in 2017 to study the influence of sowing times and varieties on the biological yield of wheat crop (*Triticum aestivum* L.). The experiment was laid out in RCBD with a split-plot arrangement having three replications. Wheat was sown in different sowing times i.e., October 24^{th}, November 2^{nd}, 12^{th}, and 22^{nd} in main plots, whereas five wheat varieties (Chounth # 1-2010, Moqawim-09, Shisham Bagh- 08, Dar-ul-Aman-07 and Solh 2002) were in sub plots. November 2nd planted wheat had a highest biological yield of (6642.1 kg ha^{-1}) followed by October 24th and November 12th which gave (6576.5 kg ha^{-1}) and (5711.0 kg ha^{-1}) respectively. The lowest biological yield of (2975.1 kg ha^{-1}) was given by the wheat varieties sown on November 22nd. Among the all-wheat varieties, Solh 2002, had significantly higher biological yield of (6263.7 kg ha^{-1}) followed by Shisham Bagh-08 with biological yield of (5571.8 kg ha^{-1}). However, Moqawim-09 had lowest biological yield of (4976.8 kg ha^{-1}) compare to other varieties. While, evaluating performance of different wheat varieties on different sowing times, Solh 2002, resulted in maximum biological yield (7476.2 kg ha^{-1}) on November 2nd followed by Darul-Aman-07 (6933.3 kg ha^{-1}) and Shisham Bagh-08 (6860.0 kg ha^{-1}) on November 2nd and October 24th respectively. On the other hand, Dar-ul-Aman-07 had lowest biological yield among the varieties (2015.5 kg ha^{-1}) on 22nd November, it shows that, Dar-ul-Aman-07 had highest biological yield on early planting but lower yield on late sowing times. The study shows that delay in wheat planting or selection of other varieties rather than Solh 2002 and Dar-ul-Aman-07 reduces the biological yield of the crop.

A field study was conducted by Madhu *et al.* (2018) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to investigate the effect of sowing time on the performance of wheat varieties. The experiment, laid out in RCBD with three replications, comprised four sowing times viz.,15 November, 30 November, 15 December and 30 December, and four varieties of wheat viz. BARI Gom 25, BARI Gom 26, BARI Gom 27 and Shatabdi. The results suggested that the highest plant population m^{-2} (58.17) and the highest plant height (89.59 cm) were obtained in 15 November sowing. BARI Gom 25 produced the highest plant population m^{-2} (50.33) and the highest plant height (86.32) while the same trend was observed in the interaction of BARI Gom 25 × 15 November sowing. The lowest performance of these two parameters was observed in the interaction of Shatabdi × 30 December sowing. The highest grain yield (2.18 ha^{-1}) was found in the interaction of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89), minimum number of unfilled grains spike^{-1} (1.68) and the highest 1000-grain weight (29.99 g). The individual effect of the

BARI Gom 25 and 15 November sowing on those parameters was also observed as the highest. The lowest grain yield (1.5 t ha^{-1}) was found in the interaction of Shatabdi × 30 December sowing because of the poor performance of the yield components of this treatment combination. The variety BARI Gom 25 and BARI Gom 26 both gave better yield when sown on 15 November. Therefore, BARI Gom 25 and BARI Gom 26 should be sown on 15 November rather than late sowing to obtain better performance and grain yield of wheat.

Qasim *et al.* (2008) investigated the growth and yield response of three wheat varieties (Suliman-96, Chakwal-97, and Inqalab-91) to different sowing periods at Karakoram Agricultural Research Institute, (Northern Areas) Gilgit, Pakistan. Three sowing times were tested: November 15, November 30, and December 15. Wheat that was sown early provided the highest plant height (79.81 cm). Baloch *et al.* (2010) conducted an experiment on different sowing times viz. October-25, November-10, November-25, December-10, and December-25 with different seeding rates in order to optimize seed rate and time of sowing of wheat variety Hashim-8. According to the data, sowing wheat between October 25 and November 10 resulted in the tallest plants, which then dropped with following sowing times.

Mohsen *et al.* (2013) conducted research in Iran to assess the effects of sowing times on the growth and yield components of various wheat cultivars. The main plots had five sowing times, namely October 31, November 15 and 30, and December 15 and 30, whereas the sub plots had five wheat cultivars. The influence of sowing time on all parameters was considerable, according to the results. Nasim *et al*. (2006) conducted a field trail on effect of planting time on wheat grain yield and its related variables which increased with early sowing (November) over late sowing (December). Similar results were observed by Alisial *et al*. (2010).

A field experiment was carried out by Chauhan *et al.* (2020) at Agromet, Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) during *Rabi* season 2016-17 to study the effect of different times of sowing on growth and yield of wheat (*Triticum aestivum* L.) cultivars. The experiment comprised of 9 treatment combinations and tested in randomized block design (RBD) with four replications. Experiment consisted of two factors, *viz*. times of sowing and cultivars. Three wheat varieties, *viz*. Malviya-234, PBW-343 and NW-1012 were sown under three times *i.e.* 20 November, 30 November and 10 December. Sowing times and cultivars significantly influenced the growth characters of wheat crop. The crop sown on 20 November along with variety PBW-343 recorded highest initial plant population (m^{-2}), plant height (cm), number of tillers m^{-2}, dry matter accumulation (g m^{-2}), leaf area index, days taken to 50 % ear emergence and days taken to maturity as compared to rest of sowing times and varieties. Highest net returns per rupee invested (1.33) was found with the variety 'PBW- 343' sown on 20 November.

Rahman *et al*. (2009) revealed that wheat yield increased when seed sowing on November and decreased with late sowing on December. Sial *et al.* (2005) evaluated twelve wheat genotypes bred at this Institute for yield and quality parameters at two levels of sowing times, normal (18th November) and late sowing (December) (11th December). Plant organ growth and transfer from source to sink were significantly hampered by delayed planting, as seen by a drop in overall yield components. Ahmed *et al.* (2006) conducted a field experiment at the Farming System Research and Development (FSRD) site, Chabbishnagar, Godagari, Rajshahi, throughout the rabi seasons to determine the best variety and sowing time (30 November, 15 December and 30 December). In both years, they found that early sowing (30 November) considerably enhanced the number of tillers in all varieties. Aslam *et al.* (2013) conducted a field experiment at the Adaptive Research Farm in Rahim Yar Khan, Pakistan. The effect of four planting times, namely the 25th of October, the 5th of November, the 15th of November, and the 25th of November, on wheat yield and yield components was investigated. The 5th November sowing produced the most tillers (359 m^{-2}) on average across two years, followed by the 15th November sowing. Due to the high temperature, which was not conducive to wheat plant growth, the 25th October sowing produced the lowest tillers (232 m^{-2}).

Suleiman *et al.* (2014) conducted field experiments at the Demonstration Farm of the College of Agriculture, University of Bahri to evaluate the performance of various wheat cultivars under various sowing times. The experiment included four sowing times: November 1st, November 15th, December 1st, and December 15th, as well as five wheat cultivars. The sowing times had a significant impact on yield components, which dropped as the sowing time was delayed, with the highest values obtained when cultivars were sown on November 1st and 15th. Zhao *et al.* (1985) found that with delay in sowing tiller and ear number/10 plants decreased from 64 to 41 in 1982-83 and from 49 to 18 in 1983-84. Early sowing decreased the number of spikelets spike^{-1} but increased 1000-grain weight and yield of wheat. Late sowing, however, decreased 1000 grain weight and yields (Sekhon *et al.*, 1991 and Ryu *et al.*, 1992).

Rahman *et al.* (2015) conducted a field experiment at the Hill Agricultural Research Station, BARI, Khagrachari for the two consecutive years (2009-10 and 2010-11) to find out the wheat variety suitable for hilly environment and investigate the interaction of sowing times and varieties to recommend the promising variety with proper sowing time. The experiment was laid out in split-plot design with three replications where three times of sowing (Nov. 20, Nov. 30 and Dec. 10) were assigned in the main plots and five modern wheat varieties (Shatabdi, Sufi, Sourav, Bijoy and Prodip) were tested in the sub-plots. The yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental soil and environmental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years. Shatabdi produced higher yield under early sowing (Nov. 20) but yield was decreased due to late sowing (Dec. 10). Initially the plant population and finally spikes/m^2 were affected by late sowing that caused less yield in Shatabdi. The mean yield of all varieties pulled over the sowing time indicated that wheat yield was not affected due to delay sowing up to 10th December. The experimental result demonstrated that Shatabdi could be recommended only for early sowing whereas Bijoy and Sourav could be recommended both for early and late sowing under the experimental soil and environmental conditions at hilly region of Khagrachari.

A field experiment was conducted by Yusuf *et al.* (2019) during *Rabi* season of 2017-18 at wheat research farm of CCS Haryana Agricultural University, Hisar, India to study the effect of sowing times and varieties on yield and quality performance of wheat *(Triticum aestivum* L.). The experiment was laid out in split plot design with three replications containing four sowing times *viz*. 5th November, 25th November, 15th December and 5th January as main plot treatments and seven wheat varieties *i.e*. HS 562, HD 2967, HD 3086, HI 1544, MACS 6222, WR 544 and WH 1105 as sub plot treatments. On the basis of one year study it was concluded that among sowing times, 5th November sowing is the most economical and suitable than rest of the sowing times. 5th November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3 per m^2), total grains per spike (48.6), filled grains $spike^{-1}$ (45.89), unfilled grains $spike^{-1}$ (2.71), 1000-grain weight (39.9 g), grain appearance score (8.3), hectoliter weight (82.9 kg/hl), grain yield (5432 kg ha^{-1}), straw yield (8496 kg ha^{-1}), biological yield (13928 kg ha^{-1}) and harvest index (39.0 %) compared to rest of the sowing times, while highest protein content (12.9 %) was observed with 5th January sown crop. Maximum net return (Rs.54,262 ha^{-1}) and B: C (1.73) were recorded with 5th November sowing.

Zende *et al.* (2005) conducted an experiment in Akola, Maharashtra, India, during the rabi season to assess the effects of sowing time (15 November, 1 December, and 15 December) on durum wheat growth and yield. Abdullah *et al.* (2007) conducted an experiment at the Wheat Research Institute in Faisalabad to investigate the effect of planting time on quality characteristics of wheat varieties Inqilab-91 and AS-2002. The crop was planted 15 days apart from the 25th of October to the 10th of January. With delayed sowing, characteristics such as 1000-grain weight decreased. These had a maximum value on the first planting time, which was 25th October and a minimum value on the last planting time which was 10th January. Qasim *et al.* (2008) investigated the growth and yield response of three wheat varieties to different sowing times at Karakoram Agricultural Research Institute, (Northern Areas) Gilgit, Pakistan. Three sowing times were tested: November 15, November 30, and December 15. The maximum grains $spike^{-1}$ (44.14) and 1000-grain weight were produced by early planted wheat (39.17 g).

Baloch *et al.* (2010) conducted an experiment at the Agricultural Research Institute, Dera Ismail Khan, on different sowing times, namely October-25, November-10, November-25, December-10, and December-25, with sowing rates of 100, 125, 150, 175 and 200 kg ha^{-1} in order to optimize seed rate and time of sowing of wheat variety Hashim-8. According to the data, sowing wheat on October 25 and November 10 resulted in the longest spike length, 1000-grain weight, and grain yield, which then decreased as the sowing times progressed. Said *et al.* (2012) conducted a study to evaluate the impact of different sowing times and seeding rates on wheat yield and yield components. Four planting times (1st November, 15th November, 1st December and 15th December) and three seeding rates were used in the experiment. Wheat yield components are affected by sowing times. For the number of grains spike^{-1} and 1000 grain weight, there were significant variances between the planting times. From November 1st to 15th, the highest number of grains spike^{-1} (53.99) and 1000 grain weight (40.2 g) were produced followed by number of grains spike^{-1} (50.1) and 1000 grain weight (32.1 g) produced from late sowing (15th December).

Dagash *et al.* (2014) conducted a field experiment at the College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Khartoum, during winter season in 07/2008 and 08/2009 to investigate the effect of nitrogen fertilization, sowing methods and sowing times on yield and yield attributes of wheat (*Triticum aestivum* L.) local variety (Wadi Elneel). Nitrogen fertilizer was applied in the form of urea at the rate of 0, 40, 80 and 120 kg N ha^{-1}. Four sowing methods *viz.* planting on flat, mastaba, ridge and ridge with line were tested. Three sowing times namely; early November, mid-November and early December were chosen and applied. The results of the study showed that nitrogen application displayed significant effect on plant height, total dry matter, 1000-seed weight and grain yield in both seasons but nitrogen fertilizer had no significant effect on harvest index for season 08/2009. Generally, planting on ridge and ridge with line achieved higher 1000-seed weight and grain yield for both seasons. Harvest index was superior for season 07/2008, whereas plant height and total dry matter had higher values for season 08/2009. Generally, crop sown at mid-November produced higher grain yield, total dry matter and tallest plant for season 07/2008. Also higher plant height and harvest index were recorded for season 08/2009. The early sown (early November) obtained greater 1000-seed weight and harvest index for season 07/2008 and higher amount of 1000-seed weight and total dry matter for season 08/2009. The late sown (early December) produced higher grain yield for season 08/2009. It can be concluded neglecting the differences between the two seasons for yield and their components that wheat can be grown at early and mid-November on ridge and ridge with line with 120 kg N/ha fertilizer. Similar result was also observed by Jat *et al.* (2013).

Aslani and Mehrvar (2012) conducted a field experiment on farmer's fields at the Seed and Plant Improvement Institute in Karaj (Iran) to investigate the effect of two sowing times on yield and yield components of eight wheat genotypes: optimum sowing time (1st November) and late sowing time (20th November). In comparison to the late sowing, the optimum sowing yield higher 1000-grains weight and spike meter^{-2}. Aslam *et al.* (2003) conducted an experiment at the Adaptive Research Farm in Rahim Yar Khan, Pakistan. The effect of four planting times, namely 25th October, 5th November, 15th November and 25th November on wheat yield and yield components was investigated. Sowing times had a considerable impact on yield and yield characteristics, according to the findings. An average of two years' worth of data revealed that sowing on November 5th resulted in a considerable rise in yield which was linked to a progressive increase in all growth components.

At the Adaptive Research Farm in Bhaun, Chakwal, Zia-ul-Hassan *et al.* (2014) conducted a field experiment to assess the responsiveness of high yielding varieties to changing sowing times under rainfed conditions. The experiment's treatments included four sowing times, D_1 (October 15), D_2 (October 30), D_3 (November 15), and D_4 (November 30), as well as five types. Sowing times remained significant on spike length, spikelets per spike and grains spike^{-1} with early sowing producing the best results. Eslami *et al.* (2014) conducted research in Iran to assess the impact of sowing times and seeding density on the growth and yield of wheat variety N-85-5. Three planting times were used, namely December 21, December 30, and January 29, and the results demonstrate that sowing wheat on December 21 produced the most spikes, spike weight and 1000-grain weight, which declined with subsequent sowing times. Due to a higher number of grains spike^{-1} and the highest 1000-grain weight, Hossain *et al.* (1990) found that the highest grain yield was produced when wheat was sown on November 20. After a two-year study in Ireland on malting barley cv. Blenhiem sown in March, early April, and late April, Comy (1995) reported that the earliest sowed spring barley yielded the maximum yield and grain quality. BARI (1997) found that the grain yield was statistically different among the five sowing times in Jamalpur during the rabi season, namely November 5, November 20, December 5, December 20 and January 5. The crop sown on December 20 yielded the lowest grain yield, closely followed by the crop sown on January 5. When the crop was sown on December 5 or later, the grain yield was drastically reduced.

Ahmed *et al.* (2006) conducted a field experiment at the Farming System Research and Development (FSRD) site, Chabbishnagar, Godari, Rajshahi, throughout the rabi seasons to determine the best variety and sowing timing (30 November, 15 December and 30 December). They found that early seeding (30 November) increased grain and straw yields significantly in all cultivars. Early sowing (30 November) produced the maximum grain (2.55 t ha^{-1}) and straw yield (4.28 t ha^{-1}) while delay sowing produced the lowest grain yield (1.23 t ha^{-1}) and straw yield (3.21 t ha^{-1}). Abdullah *et al.* (2007) conducted an experiment at the Wheat Research Institute in Faisalabad to determine the effect of planting time on the qualitative attributes of spring wheat varieties Inqilab-91 and AS-2002. The crop was planted 15 days apart from the 25th of October to the 10th of January. Characteristics such as grain yield decreased as sowing were delayed. These had a maximum value on the first planting time, October 25th and a minimum value on the last planting time 10th January. Said *et al.* (2012) conducted research into the impact of different sowing times and seeding rates on wheat yield and yield components (*Triticum aestivum* L.). Four planting times (1st November, 15th November, 1st December and 15th December) and three seeding rates were used in the experiment. Harvest index was unaffected by sowing times.

From the above review of literature it is evident that variety and sowing time has a significant influence on yield and yield components of wheat. The literature suggests that early or delay sowing other than optimum time reduces the grain yield of wheat which is directly related with the temperature of the growing period of the crop. From the above review of literature it is evident that variety itself influenced the yield and yield contributing components of wheat. The literature revealed that accurate knowledge of the sowing time of any particular variety at a particular area is critical to achieve a higher grain yield of wheat.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect sowing times on phonological development and yield of different wheat varieties. The details of the materials and methods i.e. location of experimental site, soil characteristics and climate condition of the experimental plot, materials used, experimental design, data collection and procedure of data analysis those were used or followed in this experiment have been presented below under the following headings:

3.1 Site description

The pot experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2019 to March 2020. Geographically the experimental area is located at $23^0$41' N latitude and $90^0$22' E longitudes at the elevation of 8.6 m above the sea level. The experimental field was medium high land belonging to the Madhupur Tract (AEZ 28).

3.2 Climate and weather

The experimental site belongs to subtropical climates characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March (Edris *et al.*, 1979). The monthly means of daily maximum, minimum and average temperature, relative humidity and total rainfall received at the experimental site during the period from November 2019 to March 2020 have been presented in Appendix I.

3.3 Characteristics of soil used in pot

Soil was collected from the bank of the river Dhaleshwari, Hemayetpur, Savar which was alluvial in nature. The texture of the soil was sandy clay loam. The soil pH was 6.2 and organic matter content 0.78%. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix II.

3.4 Preparation of potting media and filling of pots

The size of the pot was 30 cm top diameter with a height of 25 cm. Thus, the surface area of an individual pot was 706.50 cm^2. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with fertilizers and manures as per treatment before filling the pot. The pots were placed in the net house with cover for seven days before sowing the seeds.

3.5 Treatments of the experiment

The experiment comprised of two factors

Factor A: Wheat variety (2)

i) BARI Gom-26 (V_1)

ii) BARI Gom-28 (V_2)

Factors B: Sowing time (5)

i) 5^{th} November, 2019 (S_1)

ii) 15^{th} November, 2019 (S_2)

iii) 25^{th} November, 2019 (S_3)

iv) 5^{th} December, 2019 (S_4)

v) 15^{th} December, 2019 (S_5)

There were in total 10 (2×5) treatment combinations such as V_1S_1, V_1S_2, V_1S_3, V_1S_4, V_1S_5, V_2S_1, V_2S_2, V_2S_3, V_2S_4, and V_2S_5.

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. There were 40 unit pots altogether in the experiment where each 10 pots contained 10 different treatments combination. The experimental pots were placed in ambient air at the net house. The distance maintained between two replications was 1.0 m. The layout of the experiment is shown in Appendix III.

3.7 Growing of crops

3.7.1 Seeds collection

The seeds of different wheat varieties were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur**.** BARI Gom-26 was released in 2010 (BARI, 2012) and “BARI Gom-28” was released in 2012 (BARI, 2012).

3.7.2 Sowing of seeds

Healthy and diseases free seeds were collected for sowing in the pots and 8 seeds were sown in each pot at 5 November, 15 November, 25 November, 5 December and 15 December, 2019 as per the sowing times treatment of the experiment. 8 Seeds were sown in the pots with uniform spacing. After sowing, seeds were covered with soil and slightly pressed by hand.

3.7.3 Fertilizers and manures application

The fertilizers N, P, K and S in the form of Urea, TSP, MoP and Gypsum, respectively were applied into the pots according to their requirement. Cowdung was applied @10 t ha^{-1}. The entire amount of TSP, MP and Gypsum and 2/3rd of urea were applied during the final preparation of pots. Rest of urea was top dressed after first and second light irrigation (BARI, 2011). The dose and method of application of fertilizers are presented below.

Fertilizers	**Recommended Doses (per ha)**	**Applied doses (per pot)**
Urea	220 kg	88 g
TSP	180 kg	72 g
MoP	50 kg	20 g
Gypsum	120 kg	48 g
Cowdung	10 ton	4 kg

3.8 Intercultural operations

Following seed germination, several intercultural operations such as light irrigation, weeding, fertilizer top dressing and plant protection measures were carried out to improve the growth and development of the wheat seedlings.

3.8.1 Irrigation

Three light irrigations at early stage of crop growth, tillering stage and panicle emergence stage were provided. Some small holes were made in the pot for proper drainage system for draining out excess water.

3.8.2 Weeding

Weeding was done to keep the pots weed-free, which resulted in enhanced growth and development of the wheat seedlings. The newly emerging weeds were carefully uprooted.

3.8.3 Plant protection

During the growing season, the crop was attacked by different kinds of insects. As a plant protection precaution, triel-20 mL was applied on 1st January, 2020 and sumithion-40 mL/20 litres of water were applied on 25th January, 2020. The crop was closely monitored during the growth season in order to adopt protective measures.

3.9 Harvesting, threshing and cleaning

The crop was harvested manually depending upon the maturity starting from the first week of March, 2020 and continued up to last week of March, 2020. The harvested crop of each pot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of wheat grain. Fresh weight of wheat grain and straw were recorded pot wise and then converted into 1 m^2 area. The grains were dried (3-4 days on sun), cleaned and weighed for individual pot. Yields of wheat grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.10 Data collection

3.10.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 45, 60 and 75 DAS (Days After Sowing) and at harvest as the average of 5 plants selected from the same treatment combination pots that were tagged earlier. The height was measured from the ground level to the tip of the plant by a meter scale.

3.10.2 Number of tillers plant^{-1}

The number of tillers plant^{-1} was recorded at the time of 30, 45, 60 and 75 DAS and at harvest, respectively. Data were recorded by counting tillers from each plant and as the average of 5 plants selected from the same treatment combination pots.

3.10.3 Days to spike emergence

Days to starting of spike emergence was recorded by calculating the number of days from sowing to starting of spike emergence by keen observation of the experimental pots during the experimental period.

3.10.4 Days to maturity

Days to 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 pots.

3.10.5 Number of spikes plant^{-1}

The total number of spikes plant^{-1} was recorded by calculating spikes plant^{-1}. Data on number of spikes plant^{-1} were counted from 5 selected plants at harvest and average value was recorded.

3.10.6 Number of spikelets plant^{-1}

The total number of spikelets spike^{-1} was counted as the number of spikelets from 5 selected spikes from same treatment combination pots and average value was recorded.

3.10.7 Spike length

The length of spike was measured with a meter scale from 5 selected spikes from same treatment combination pots and the average value was recorded.

3.10.8 Number of filled grains spike^{-1}

The number of filled grains spike^{-1} was counted as the number of filled grains from 5 selected spikes from same treatment combination pots and average value was recorded.

3.10.9 Number of unfilled grains spike^{-1}

The total number of unfilled grains spike^{-1} was counted as the number of unfilled grains from 5 selected spikes from same treatment combination pots and average value was recorded.

3.10.10 Number of total grains spike^{-1}

The total number of grains spike^{-1} was counted by adding the number of filled and unfilled grains from 5 selected spikes from same treatment combination pots and average value was recorded.

3.10.11 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested grains of from same treatment combination pots and then weighed in grams and recorded.

3.10.12 Grain yield

Grains obtained from each unit pot were converted into 1.0 m^2 area were sun-dried and weighed carefully. The dry weight of grains of 1 m^2 area was used to record grain yield m^{-2} and this was converted into t ha^{-1}.

3.10.13 Straw yield

Straw obtained from each unit pot were converted into 1.0 m^2 area were sun-dried and weighed carefully. The dry weight of straw of 1 m^2 area was used to record straw yield m^{-2} and this was converted into t ha^{-1}.

3.10.14 Biological yield

Grain yield and straw yield together were regarded as biological yield of wheat. The biological yield was calculated with the following formula:

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.10.15 Harvest index

Harvest index was calculated from per hectare grain and straw yield that were obtained from each unit pot and expressed in percentage.

$$HI = \frac{\text{Economic yield (Grain yield)}}{\text{Biological yield}} \times 100$$

Where, Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.11 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the wheat variety and sowing times and their interaction. The mean values of all the parameters were calculated and analysis of variance was performed by a computer package program MSTAT-C. The significance of the difference among the treatment means was estimated by the Least Significance Differences (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

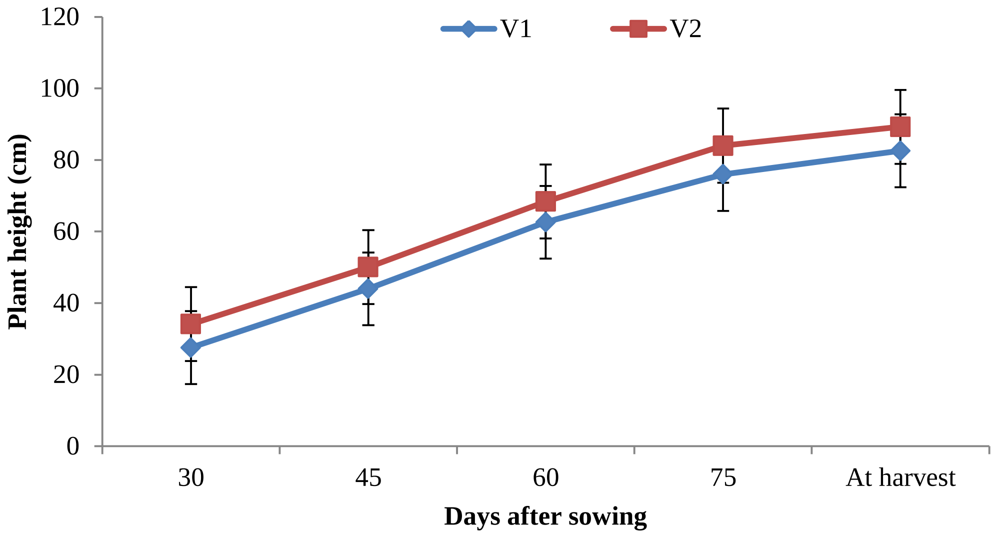
RESULTS AND DISCUSSION

The pot experiment was conducted to study the effect of sowing times on phonological development and yield of wheat. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings listed below.

4.1 Plant height

4.1.1 Effect of variety

Plant height exhibits an important morphological attribute that acts as a potential indicator of availability of growth resources in its approach. Significant influenced was observed on plant height by different variety of wheat at different growth stages (Figure 1). From the results of the experiment showed that the highest plant height (34.14, 50.03, 68.38, 84.01 and 89.27 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed on V_2 (BARI Gom-28) where lowest plant height (27.56, 43.99, 62.61, 75.98 and 82.58 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed in V_1 (BARI Gom-26). The result of the experiment was also coincided with the findings of Habibi and Fazily (2020) who conducted a field experiment entitled “Effect of sowing times on growth, yield attributes and yield of four wheat varieties” and reported that among wheat varieties Kabul 013 and Gul 09 produced significantly higher plant height, number of effective tillers per plant, test weight and grain yield of wheat over rest of the varieties.. Islam and Jahiruddin (2008) who reported the similar findings that plant height differed greatly between varieties. Zia-ul-Hassan *et al.* (2014) observed the similar results and reported that In terms of plant height, the data showed that variety remained significant. Qasim *et al.* (2008) also observed the similar findings and reported that different cultivars varied in plant height in response of variety. Dissimilar findings observed by Alam *et al.* (2013) who reported that variety had no effect on wheat plant height.

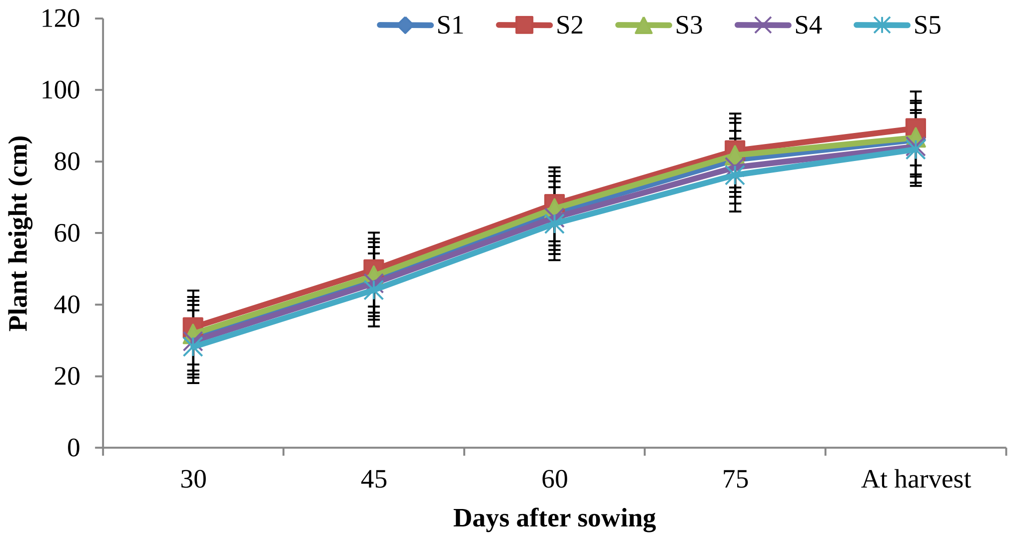


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 1. Effect of different varieties on plant height (cm) of wheat at different days after sowing ($LSD_{0.05}$= 2.60, 2.81, 1.85, 2.01 and 2.86 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.1.2 Effect of sowing time

Plant height at different growth stages was significantly influenced by different sowing times in the study (Figure 2). It was observed that the highest plant height (33.61, 49.77, 68.05, 83.06 and 89.25 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was obtained from the treatment S_2 where the lowest plant height (28.23, 44.11, 62.62, 76.22 and 83.38 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was found from the treatment S_5. The findings of the experiment was coincided with the results of Madhu *et al.* (2018) who reported that Combined of BARI Gom 25 × 15 November sowing performed the highest plant height. Zia-ul-Hassan *et al.* (2014) observed the similar findings who reported that sowing times had a significant impact on plant height. Similar trends also observed by Dagash *et al.* (2014) who showed that sowing time displayed significant effect on plant height, total dry matter, 1000-seed weight and grain yield in both seasons but nitrogen fertilizer had no significant effect on harvest index for season 08/2009. Aslam *et al.* (2003) reported that sowing times had a considerable impact on yield and yield characteristics of wheat. Netam *et al.* (2020) also observed the same result and reported that sowing on 15^{th} November recorded relatively higher plant height.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 2. Effect of different sowing times on plant height (cm) of wheat at different days after sowing ($LSD_{0.05}$= 4.11, 4.44, 2.94, 3.18 and 4.53 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.1.3 Combined effect of varieties and sowing times

Significant difference on plant height of wheat at different growth stages was observed in the study. Combined effect of different varieties and sowing times showed significant variation (Table 1 and Appendix IV). Results observed that the highest plant height (37.43, 53.18, 71.34, 87.10 and 92.67 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was found from the treatment combination of V_2S_2 which were statistically similar with V_2S_3, V_2S_1 and V_2S_4 at 30 DAS; with V_2S_3, V_2S_1, V_2S_4 and V_2S_5 at 45 DAS; with V_2S_3 and V_2S_1 at 60 DAS and 75 DAS, respectively and V_2S_3, V_2S_1, V_2S_4 and V_2S_5 at harvest. The lowest plant height (25.60, 40.91, 60.34, 71.75 and 79.75 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was obtained from the treatment combination of V_1S_5 which was statistically at par with V_1S_4, V_1S_1, V_1S_3, V_1S_2 and V_2S_5 at 30 DAS; with V_1S_4, V_1S_1, V_1S_3 and V_1S_2 at 45 DAS; with V_1S_4, V_1S_1 and V_1S_3 at 60 DAS; with V_1S_4 at 75 DAS and V_1S_4, V_1S_1, V_1S_3 and V_1S_2 at harvest, respectively.

Table 1. Combined effect of different varieties and sowing times on plant height (cm) of wheat at different days after sowing

Treatment combinations	Plant height (cm) at different days after sowing				
	30	45	60	75	At harvest
V_1S_1	27.27 de	44.18 c-e	62.40 ef	76.33 ef	83.00 c-e
V_1S_2	29.78 b-e	46.36 b-e	64.75 de	79.03 d-f	85.83 b-e
V_1S_3	28.53 c-e	45.45 b-e	63.55 d-f	78.26 d-f	83.19 c-e
V_1S_4	26.67 e	43.05 de	62.00 ef	74.52 fg	81.12 de
V_1S_5	25.60 e	40.91 e	60.34 f	71.75 g	79.75 e
V_2S_1	34.32 a-c	50.06 a-c	68.92 a-c	84.68 a-c	89.11 a-c
V_2S_2	37.43 a	53.18 a	71.34 a	87.10 a	92.67 a
V_2S_3	35.18 ab	50.73 ab	70.19 ab	85.27 ab	90.25 ab
V_2S_4	32.90 a-d	48.89 a-d	66.57 b-d	82.32 b-d	87.33 a-d
V_2S_5	30.86 b-e	47.31 a-d	64.89 c-e	80.69 c-e	87.00 a-d
$LSD_{0.05}$	**5.81**	**6.28**	**4.16**	**4.51**	**6.41**
CV%	**12.99**	**9.22**	**4.37**	**3.88**	**5.15**

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

Notes:

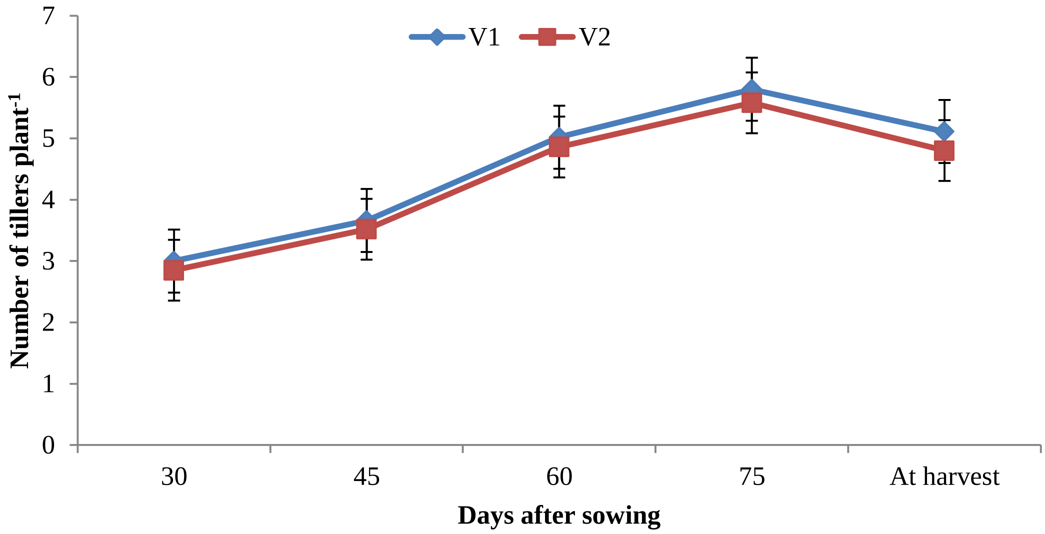
V_1= BARI Gom-26 and V_2= BARI Gom-28;

S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

4.2 Number of tillers plant^{-1}

4.2.1 Effect of variety

Wheat exerted remarked variation on number of tillers plant^{-1} due to the effect of variety at different days after sowing (Figure 3). Result from the experiment revealed that the maximum number of tillers palnt^{-1} (3.00, 3.66, 5.02, 5.80 and 5.11 at 30, 45, 60, 75 DAS and at harvest, respectively) were obtained from V_1 treatment. On the other hand minimum number of tillers plant^{-1} (2.85, 3.52, 4.86, 5.58 and 4.80 at 30, 45, 60, 75 DAS and at harvest, respectively) were observed in V_2 treatment. Similar trends was observed by Yusuf *et al.* (2019) who reported that variety had significant influence on number of tillers plant^{-1}. Habibi and Fazily (2020) observed the similar results who reported that among wheat varieties Kabul 013 and Gul 09 produced significantly higher plant height, number of effective tillers per plant, test weight and grain yield of wheat over rest of the varieties. Madhu *et al.* (2018) observed the similar trends and reported that BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1}. Chauhan *et al.* (2020) found the similar results and revealed that the variety PBW-343 recorded highest number of tillers m^{-2} as compared to rest of varieties. Highest net returns per rupee invested (1.33) was found with the variety 'PBW- 343' sown on 20 November.

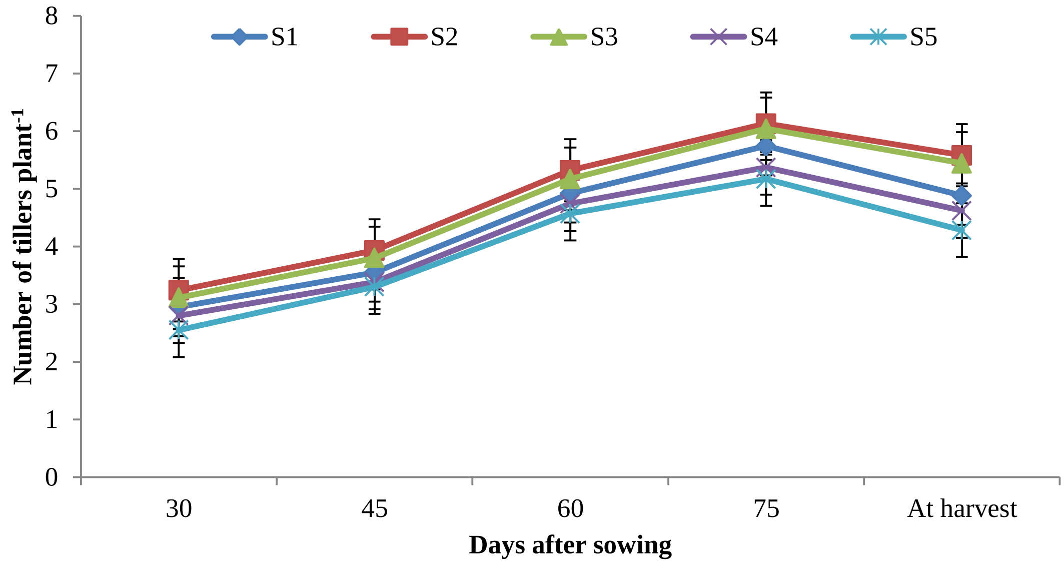


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 3. Effect of different varieties on number of tillers plant^{-1} (no.) of wheat at different days after sowing ($LSD_{0.05}$= 0.14, 0.13, 0.14, 0.13 and 0.14 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.2.2 Effect of sowing time

Number of tillers plant^{-1} exerted significant variation due to different sowing times at different days after sowing (Figure 4). Results from the experiment revealed that the maximum number of tillers plant^{-1} (3.24, 3.93, 5.32, 6.13 and 5.58 at 30, 45, 60, 75 DAS and at harvest, respectively) were achieved from S_2 treatment which was statistically as similar with S_3 treatment at 30, 45, 60, 75 DAS and at harvest, respectively. On the other hand the minimum number of tillers palnt^{-1} (2.55, 3.30, 4.57, 5.17 and 4.28 at 30, 45, 60, 75 DAS and at harvest, respectively) were obtained from S_5 treatment which was statistically similar with S_4 treatment at 45, 60 and 75 DAS. Similar results was also found by Tahir *et al.* (2009) who investigated the influence of sowing time on wheat production and found that early sowing resulted in increased dry matter accumulation and total number of tillers per m^2. Netam *et al.* (2020) also observed the same result and reported that sowing on 15^{th} November recorded relatively higher number of tillers m^{-2}. Similar results was also coincided with the result of the experiment by Chauhan *et al.* (2020) who reported that The crop sown on 20 November along with variety PBW-343 recorded highest initial plant population (m^{-2}), plant height (cm), number of tillers m^{-2}, dry matter accumulation (g m^{-2}), leaf area index, days taken to 50 % ear emergence and days taken to maturity as compared to rest of sowing times and varieties. Ahmed *et al.* (2006) reported that early sowing (30 November) considerably enhanced the number of tillers in all varieties. Aslam *et al.* (2013) observed the similar result and reported that the 5^{th} November sowing produced the most tillers (359 m^{-2}) on average across two years followed by the 15^{th} November sowing.



S_1= 5^{th} November, S_2= 15^{th} November, S_3= 25^{th} November, S_4= 5^{th} December and S_5= 15^{th} December

Figure 4. Effect of different sowing times on number of tillers plant^{-1} (no.) of wheat at different days after sowing ($LSD_{0.05}$= 0.23, 0.20, 0.21, 0.21 and 0.22 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.2.3 Combined effect of varieties and sowing times

Statistically significant difference was exerted for number of tillers plant^{-1} at different growth stages of wheat due to combined effect of different varieties and sowing times in the study (Table 2 and Appendix V). Results showed that the highest number of tillers plant^{-1} (3.41, 4.06, 5.47, 6.33 and 5.83 at 30, 45, 60, 75 DAS and at harvest, respectively) was achieved from the treatment combination of V_1S_2 which was statistically similar with V_1S_3 at 30 DAS and at harvest, respectively; with V_1S_3 and V_2S_2 at 45 DAS and 60 DAS, respectively. The lowest number of tillers plant^{-1} (2.47, 3.27, 4.53, 5.10 and 4.13 at 30, 45, 60, 75 DAS and at harvest, respectively) was revealed from the treatment combination of V_2S_5 which was statistically similar with V_2S_4 and V_1S_5 at 30 DAS and 75 DAS, respectively; with V_2S_4, V_1S_4 and V_2S_1 at 45 DAS; with V_2S_4, V_1S_5 and V_1S_4 at 60 DAS; with V_1S_5 at harvest.

Table 2. Combined effect of different varieties and sowing times on number of tillers plant^{-1} of wheat at different days after sowing

Treatment combinations	Number of tillers plant^{-1} at different days after sowing				
	30	45	60	75	At harvest
V_1S_1	2.97 bc	3.63 b-d	4.93 bc	5.80 c	4.93 cd
V_1S_2	3.41 a	4.06 a	5.47 a	6.33 a	5.83 a
V_1S_3	3.18 ab	3.90 ab	5.33 a	6.20 ab	5.67 a
V_1S_4	2.83 cd	3.40 c-e	4.77 c-e	5.43 de	4.70 d-f
V_1S_5	2.63 de	3.32 e	4.60 de	5.23 ef	4.43 fg
V_2S_1	2.93 b-d	3.47 c-e	4.90 b-d	5.67 cd	4.83 de
V_2S_2	3.07 bc	3.80 ab	5.17 ab	5.93 bc	5.33 b
V_2S_3	3.03 bc	3.69 bc	5.00 bc	5.87 c	5.20 bc
V_2S_4	2.77 c-e	3.36 de	4.71 c-e	5.31 ef	4.53 ef
V_2S_5	2.47 e	3.27 e	4.53 e	5.10 f	4.13 g
$LSD_{0.05}$	**0.33**	**0.29**	**0.31**	**0.29**	**0.31**
CV%	**7.81**	**5.62**	**4.33**	**3.63**	**4.43**

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

Notes:

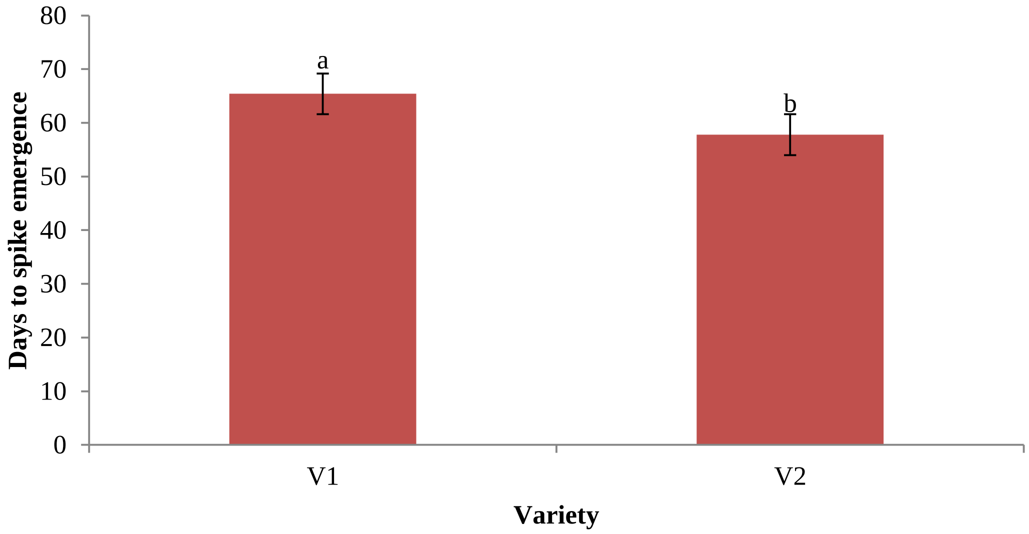
V_1= BARI Gom-26 and V_2= BARI Gom-28;

S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

4.3 Days to spike emergence

4.3.1 Effect of variety

Different wheat varieties exerted statistically significant difference on days to spike emergence (Figure 5). The highest days to spike emergence (65.40) was observed from V_1 whereas the lowest days to spike emergence (57.80) was obtained from V_2. Although management practices influenced the days to starting of ear emergence on wheat but the genotypes itself contributed the days to starting of ear emergence on wheat. Similar result was also observed by Netam *et al.* (2020) who reported that varieties Sujata recorded significantly panicle emergence (62.63 day), 50 % flowering (67.58 day), milking (82.67 day) and maturity stage (111.42 day). As compare to sowing on 15th November, duration of wheat crop reduces by 4 day with sown on 30th November, 11 day with sown on 15th December and 19 day with sown on 30th December.

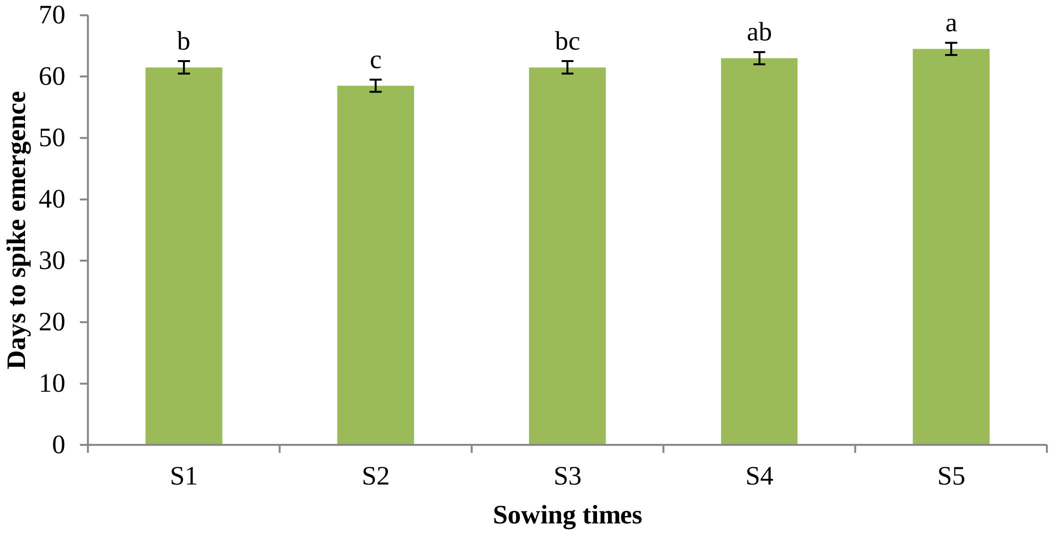


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 5. Effect of different varieties on days to spike emergence of wheat ($LSD_{0.05}$= 1.59)

4.3.2 Effect of sowing time

Statistically significant differences were exerted in respects of days to spike emergence due to different sowing times (Figure 6). The highest days to spike emergence (64.50) was obtained from S_5 which was statistically as par with S_4 while the lowest days to spike emergence (58.50) was observed from S_2 which was statistically similar with S_3. Netam *et al.* (2020) who reported that varieties Sujata recorded significantly panicle emergence (62.63 day), 50 % flowering (67.58 day), milking (82.67 day) and maturity stage (111.42 day). As compare to sowing on 15th November, duration of wheat crop reduces by 4 day with sown on 30th November, 11 day with sown on 15th December and 19 day with sown on 30th December.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 6. Effect of different sowing times on days to spike emergence of wheat ($LSD_{0.05}$= 2.51)

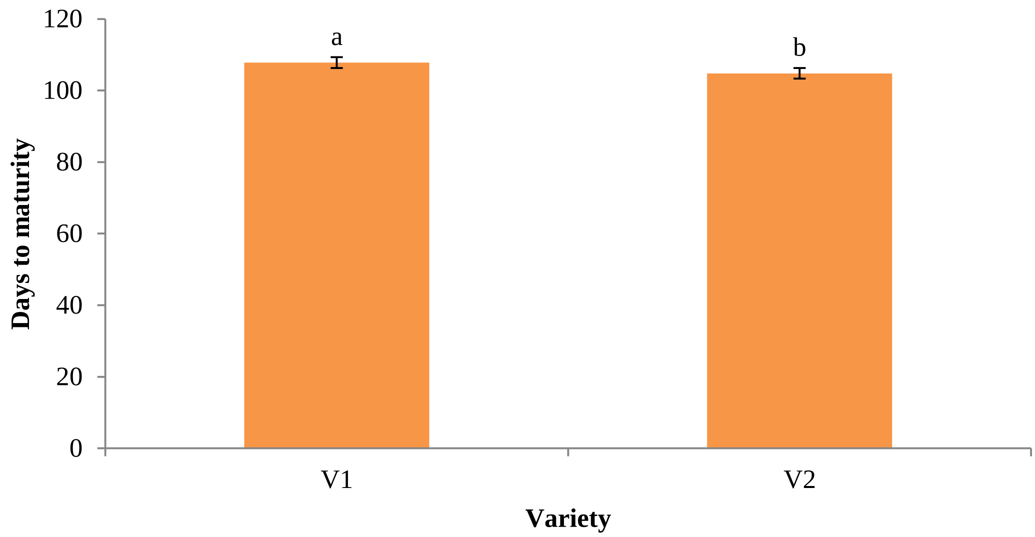
4.3.3 Combined effect of varieties and sowing times

Days to spike emergence showed significant differences due to combined effect of different varieties and sowing times under the study (Table 3 and Appendix VI). Results from the experiment showed that the highest days to spike emergence (69.00) was obtained from the treatment combination V_1S_5 which was statistically similar with V_1S_4. On the other hand the lowest days to spike emergence (55.00) was observed from the treatment combination V_2S_2 which was statistically similar with V_2S_1 and V_2S_3.

4.4 Days to maturity

4.4.1 Effect of variety

Different wheat varieties exerted statistically significant difference on days to maturity (Figure 7). The highest days to maturity (107.80) was obtained from V_1 whereas the lowest days to maturity (104.80) was obtained from V_2. Although management practices influenced the days to maturity on wheat but the genotypes itself contributed the days to maturity on wheat. Similar results was also observed by Netam *et al.* (2020) who reported that varieties Sujata recorded significantly panicle emergence (62.63 day), 50 % flowering (67.58 day), milking (82.67 day) and maturity stage (111.42 day). As compare to sowing on 15th November, duration of wheat crop reduces by 4 day with sown on 30th November, 11 day with sown on 15th December and 19 day with sown on 30th December.

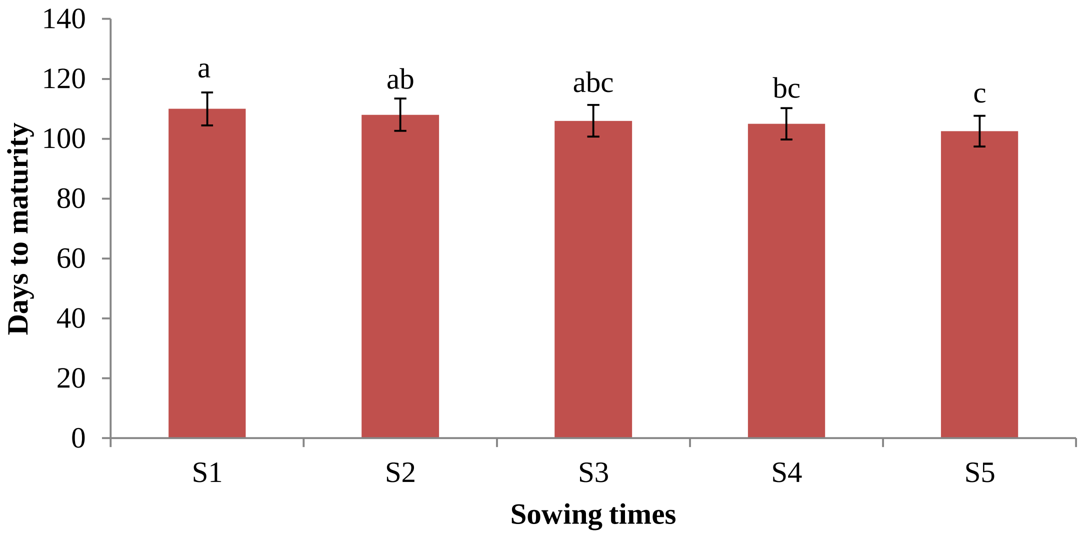


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 7. Effect of different varieties on days to maturity of wheat ($LSD_{0.05}$= 2.94)

4.4.2 Effect of sowing time

Significant differences were exerted in case of days to maturity due to different sowing times (Figure 8). The highest days to maturity (110.00) was obtained from S_1 which was statistically as par with S_2 and S_3 while the lowest days to maturity (102.50) was obtained from S_5 which was statistically similar with S_4. The result of the experiment was in coincided with the findings of Netam *et al.* (2020) who reported that varieties Sujata recorded significantly panicle emergence (62.63 day), 50 % flowering (67.58 day), milking (82.67 day) and maturity stage (111.42 day). As compare to sowing on 15th November, duration of wheat crop reduces by 4 day with sown on 30th November, 11 day with sown on 15th December and 19 day with sown on 30th December.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 8. Effect of different sowing times on days to maturity of wheat ($LSD_{0.05}$= 4.66)

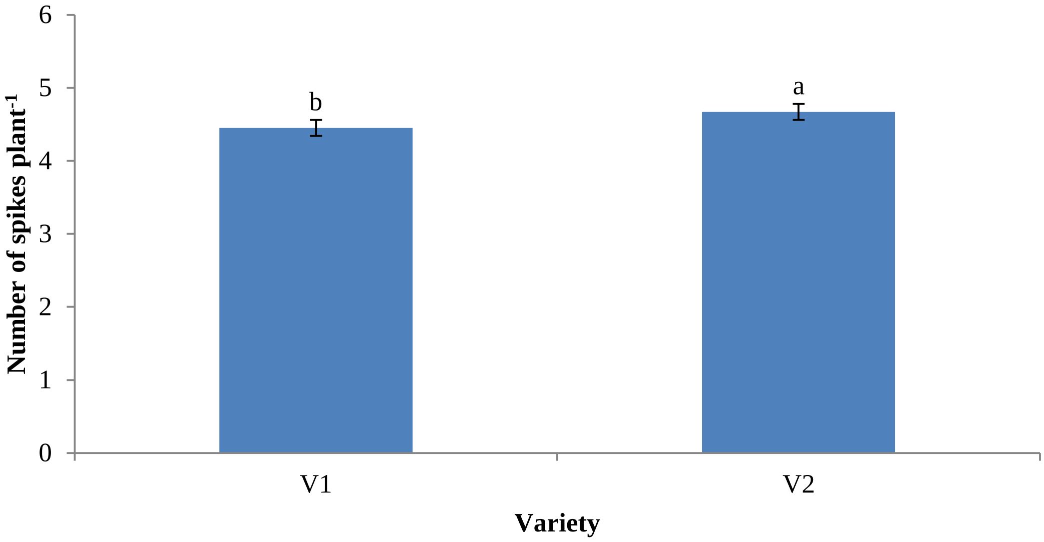
4.4.3 Combined effect of varieties and sowing times

Days to maturity showed significant influences due to combined effect of different varieties and sowing times under the study (Table 3 and Appendix VI). Results from the experiment showed that the highest days to maturity (112.00) was obtained from the treatment combination V_1S_1 which was statistically similar with V_1S_2, V_1S_4, V_1S_3, V_2S_1 and V_2S_2. On the other hand the lowest days to maturity (101.00) was recorded from the treatment combination V_2S_5 which was statistically similar with V_2S_4, V_2S_3 and V_1S_5.

4.5 Number of spikes plant^{-1}

4.5.1 Effect of variety

Significant difference was observed on number of spikes plant^{-1} due to different variety of wheat (Figure 9). Results revealed that the highest number of spikes plant^{-1} (4.67) was obtained from the variety V_2 (BARI Gom-28) where the lowest number of spikes plant^{-1} (4.45) was observed from the variety V_1 (BARI Gom-26). Similar trends were observed by Sulewska (2004) who reported that number of spikes plant^{-1} was significantly influenced by variety. Al-Khatib and Paulesn (1990) reported that spike per plant decreased significantly in three genotypes and increased in one genotype as temperature rose, whereas kernel per spike decreased in four genotypes. Similar result was observed by Rahman *et al.* (2015) who reported yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental soil and environmental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years. Shatabdi produced higher yield under early sowing (Nov. 20) but yield was decreased due to late sowing (Dec. 10). Initially the plant population and finally spikes/m^2 were affected by late sowing that caused less yield in Shatabdi. The findings of the experiment was also coincided with the findings of Islam *et al.* (1993) who reported that variety had a significant impact on spike/m^2, grain/spike, and 1000-grain weight.

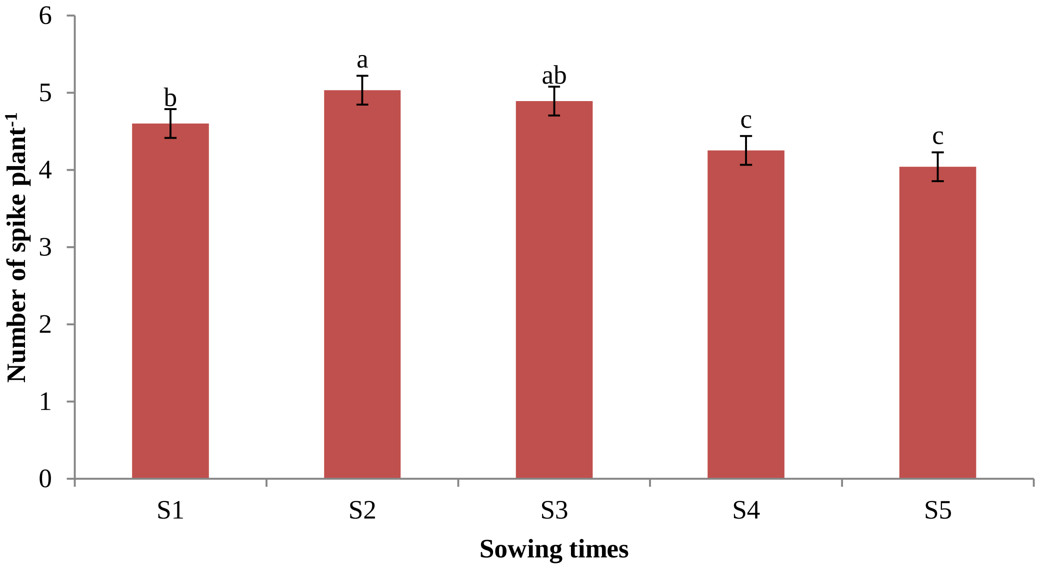


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 9. Effect of different varieties on number of spikes plant^{-1} of wheat ($LSD_{0.05}$= 0.20)

4.5.2 Effect of sowing time

Number of spikes plant^{-1} of wheat was significantly affected by different sowing times under the study (Figure 10). Results exposed that the highest number of spikes plant^{-1} (5.03) was obtained from the treatment S_2 which was statistically similar with S_3. On the other hand, the lowest number of spikes plant^{-1} (4.04) was obtained from the treatment S_5 followed by S_4. Similar results was also observed by Suleiman *et al.* (2014) who reported that higher yield attributes such as number of spikes plant^{-1} and yield with 5th November sowing might be due to favorable climatic condition, which prolonged vegetative as well as reproductive phases of the crop and resulted in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink, which caused the plant to produce higher yield up and ultimately resulted in higher grain yield. The results are in line with Kamrozzaman *et al*. (2016), Baloch *et al*. (2012) and Spink *et al*. (2000). Eslami *et al.* (2014) observed the similar trends and reported that planting times namely December 21, December 30, and January 29 showed significant influence on yield components and yield. The results demonstrate that sowing wheat on December 21 produced the most spikes plant^{-1}, spike weight and 1000-grain weight which declined with subsequent sowing times.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 10. Effect of different sowing times on number of spikes plant^{-1} of wheat ($LSD_{0.05}$= 0.32)

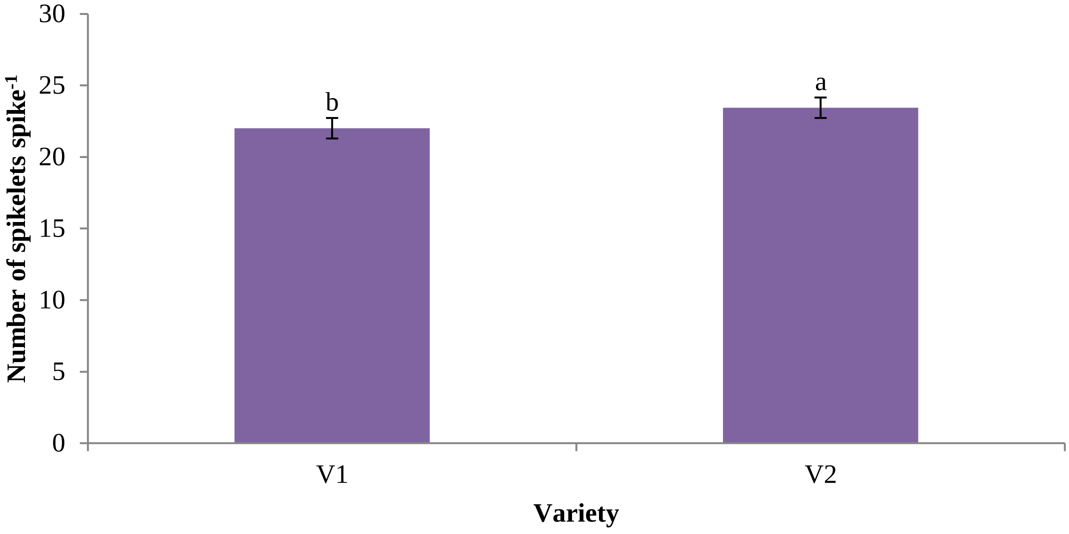
4.5.3 Combined effect of varieties and sowing times

Number of spikes plant^{-1} showed significant influences due to combined effect of different varieties and sowing times under the study (Table 3 and Appendix VI). Results from the experiment showed that the maximum number of spikes plant^{-1} (5.23) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3 and V_1S_2. On the other hand the minimum number of spikes plant^{-1} (3.97) was recorded from the treatment combination V_1S_5 which was statistically similar with V_1S_4, V_2S_4 and V_2S_5.

4.6 Number of spikelets spike^{-1}

4.6.1 Effect of variety

Significant difference was found on number of spikelets spike^{-1} due to different variety of wheat (Figure 11). Results revealed that the highest number of spikelets spike^{-1} (23.44) was obtained from the variety V_2 (BARI Gom-28) where the lowest number of spikelets spike^{-1} (22.01) was obtained from the variety V_1 (BARI Gom-26). The result of the experiment was also coincided with the findings of Sulewska (2004) who conducted an experiment with 22 wheat genotypes to compare vegetation period, plant height, number of spikes plant^{-1} and spikelets spike^{-1} and yield per spike. He noticed that variety had a significant impact on yield attributes and yield of wheat. Zia-ul-Hassan *et al.* (2014) reported that variety influences the yield components like spikes plant^{-1}, number of spikelets spike^{-1} etc. The findings of the experiment was coincided with the findings of Madhu *et al.* (2018) who reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89) and the highest 1000-grain weight (29.99 g).

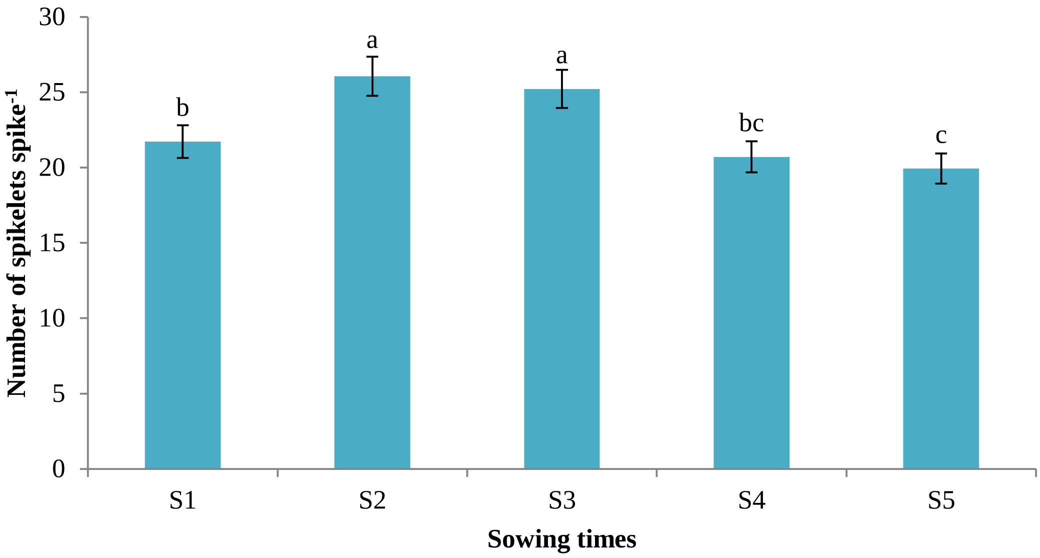


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 11. Effect of different varieties on number of spikelets spikes^{-1} (no.) of wheat ($LSD_{0.05}$= 0.80)

4.6.2 Effect of sowing time

Number of spikelets spike^{-1} of wheat was significantly affected by different sowing times under the study (Figure 12). Results exposed that the highest number of spikelets spike^{-1} (26.06) was obtained from the treatment S_2 which was statistically similar with S_3. On the other hand, the lowest number of spikelets spike^{-1} (19.93) was obtained from the treatment S_5 followed by S_4. The findings of the study was similar with the findings of Madhu *et al.* (2018) who reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89) and the highest 1000-grain weight (29.99 g). Similar result was observed by Rahman *et al.* (2015) who reported that initially the plant population and finally spikes/m^2 were affected by late sowing that caused less yield in Shatabdi. Muhammad *et al.* (2015) found that crops sown on 11th November had maximum spikes plant^{-1}, number of spikelets spike^{-1}, 1000-grain weight.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 12. Effect of different sowing times on number of spikelets spike^{-1} (no.) of wheat ($LSD_{0.05}$= 0.32)

4.6.3 Combined effect of varieties and sowing times

Number of spikelet spike^{-1} showed significant variation due to combined effect of different varieties and sowing times under the study (Table 3 and Appendix VI). Results from the experiment showed that the maximum number of spikelets spike^{-1} (27.24) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3. On the other hand the minimum number of spikelet spike^{-1} (19.70) was recorded from the treatment combination V_1S_5 which was statistically similar with V_1S_4, V_2S_4, V_2S_5 and V_1S_1.

Table 3. Combined effect of different varieties and sowing times on days to spike emergence, days to maturity, number of spikes plant^{-1} and number of spikelets spike^{-1} of wheat

Treatment combinations	Days to spike emergence	Days to maturity	Number of spikes plant^{-1}	Number of spikelets spike^{-1}
V_1S_1	65.00 bc	112.00 a	4.53 c-e	21.23 de
V_1S_2	62.00 cd	110.00 ab	4.83 a-c	24.87 b
V_1S_3	64.00 bc	107.00 a-c	4.75 b-d	23.69 bc
V_1S_4	67.00 ab	106.00 a-c	4.19 ef	20.57 de
V_1S_5	69.00 a	104.00 bc	3.97 f	19.70 e
V_2S_1	58.00 ef	108.00 ab	4.67 b-d	22.22 cd
V_2S_2	55.00 f	106.00 a-c	5.23 a	27.24 a
V_2S_3	57.00 ef	105.00 bc	5.02 ab	26.75 a
V_2S_4	59.00 de	104.00 bc	4.31 d-f	20.85 de
V_2S_5	60.00 de	101.00 c	4.10 ef	20.15 e
$LSD_{0.05}$	**3.56**	**6.59**	**0.45**	**1.79**
CV%	**3.99**	**4.28**	**6.90**	**5.43**

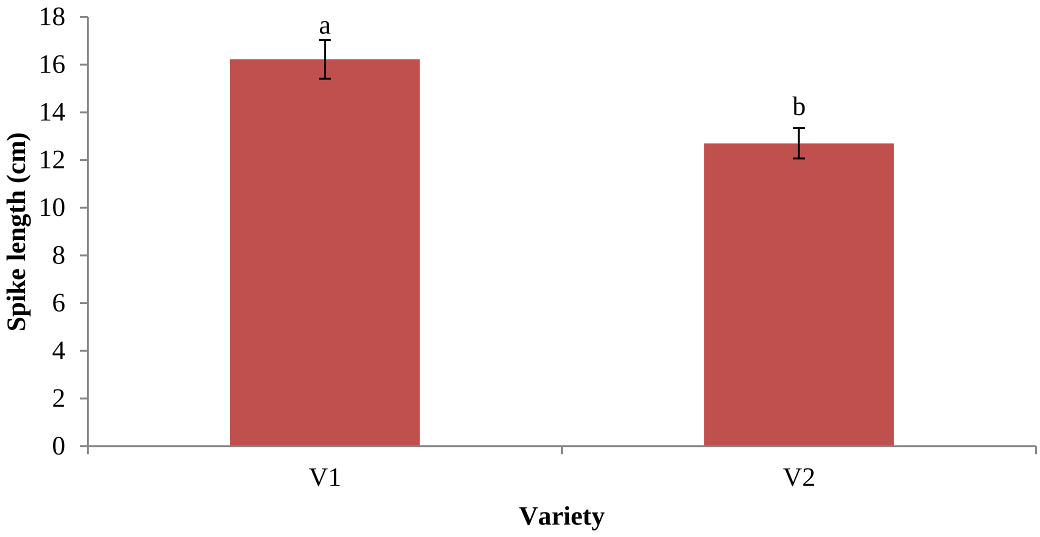
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Notes:
V_1= BARI Gom-26 and V_2= BARI Gom-28;
S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

4.7 Spike length

4.7.1 Effect of variety

Significant variation on spike length was exerted due to different variety of wheat (Figure 13). It was revealed that the highest spike length (16.22 cm) was observed from the variety V_1 (BARI Gom-26) where the lowest spike length (12.70 cm) was achieved from the variety V_2 (BARI Gom-28). Similar result was observed by Yusuf *et al.* (2019) who reported that variety WH 1105 resulted in longer spike (11.5 cm) among the seven varieties. Sulewska (2004) observed the same result that variety had influences on spike length. Zia-ul-Hassan *et al.* (2014) observed the similar trends on spike length that influenced by varietal treatment.

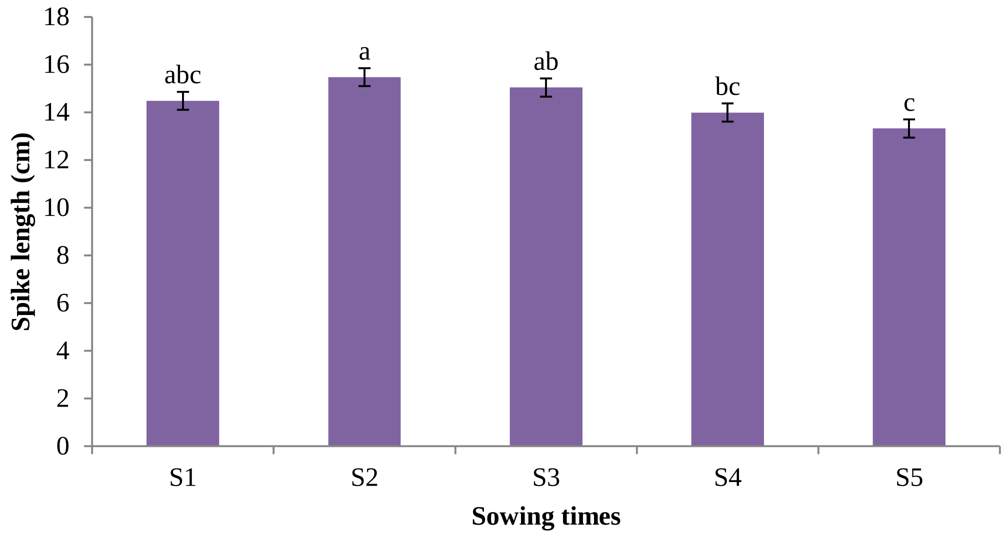


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 13. Effect of different varieties on spike length (cm) of wheat ($LSD_{0.05}$= 0.80)

4.7.2 Effect of sowing time

Significant variation was found in terms of spike length influenced by different sowing times of wheat (Figure 14). It was achieved that the highest spike length (15.47 cm) was obtained from the treatment S_2 which was statistically similar with S_3 and S_1 where the lowest spike length (13.32 cm) was obtained from the treatment S_5 followed by S_4. Similar result was observed by Muhammad *et al.* (2015) who reported that crops sown on 11th November had longer spike lengths, more grains per spike, and higher grain test weights than crops sown on 6th December. Baloch *et al.* (2010) observed the same result who reported that according to the data sowing wheat on October 25 and November 10 resulted in the longest spike length, 1000-grain weight, and grain yield, which then decreased as the sowing times progressed. Zia-ul-Hassan *et al.* (2014) revealed that sowing times remained significant on spike length, spikelets per spike, and grains spike^{-1}, with early sowing producing the best results. Said *et al.* (2012) revealed that different sowing times and seeding rates on wheat yield and yield components directly impacted on wheat yield components.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 14. Effect of different sowing times on spike length (cm) of wheat ($LSD_{0.05}$= 1.27)

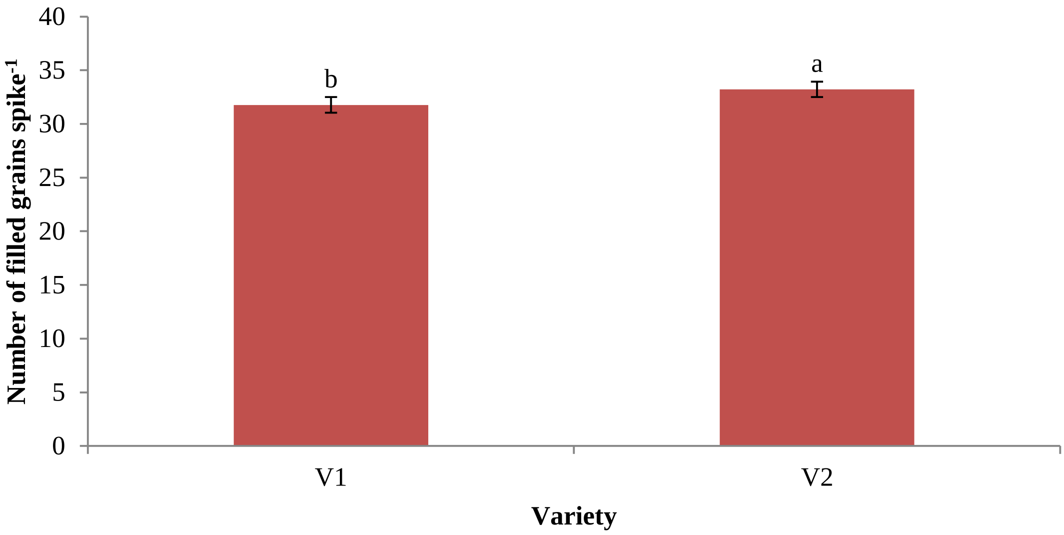
4.7.3 Combined effect of varieties and sowing times

Significant difference on spike length was observed due to combined effect of different varieties and sowing times under the study (Table 4 and Appendix VII). Results from the experiment showed that the highest spike length (17.38 cm) was obtained from the treatment combination V_1S_2 which was statistically similar with V_1S_3, V_1S_1 and V_1S_4. On the other hand the lowest spike length (11.83 cm) was recorded from the treatment combination V_2S_5 which was statistically similar with V_2S_4, V_2S_1, V_2S_3 and V_2S_2.

4.8 Number of filled grains spike^{-1}

4.8.1 Effect of variety

Number of filled grains spike^{-1} of wheat varied significantly due to varietal treatments (Figure 15). Results from the experiment showed that BARI Gom-28 (V_2) produced the highest number of filled grains spike^{-1} (33.22) and the lowest number of filled grains spike^{-1} (31.77) was observed in BARI Gom-26 (V_1). Similar result was observed by Yusuf *et al.* (2019) who reported that varieties had significant effect on number of filled grains spike^{-1}. He examined and showed that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), grains per spike (48.4), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}) harvest index (39.2), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties. Madhu *et al.* (2018) also observed the same result. They reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers $hill^{-1}$ (4.73), the highest number of spikelets $spike^{-1}$ (17.77), the highest number of filled grains $spike^{-1}$ (37.89) and the highest 1000-grain weight (29.99 g).

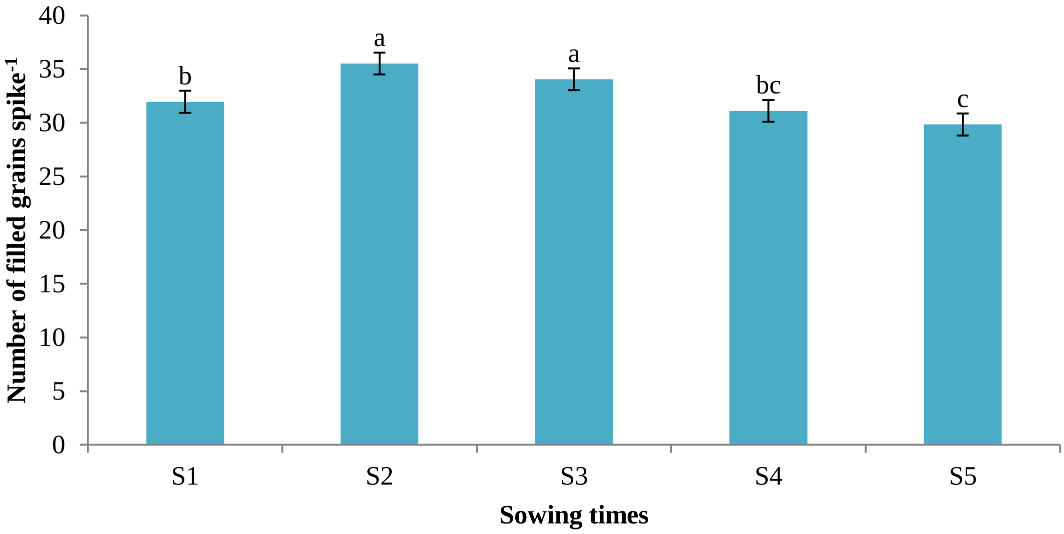


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 15. Effect of different varieties on number of filled grains $spike^{-1}$ of wheat ($LSD_{0.05}$= 1.10)

4.8.2 Effect of sowing time

Significant variation of number of filled grains $spike^{-1}$ was observed due to various sowing time treatments (Figure 16). It was observed that S_2 produced the highest number of filled grains $spike^{-1}$ (35.52) which was statistically similar with S_3 and the lowest number of filled grains $spike^{-1}$ (29.84) was observed from S_5 which was statistically similar with S_4. The result of the study was in coincided with the findings of Suleiman *et al.* (2014) who reported that higher yield attributes and yield with 5^{th} November sowing might be due to favorable climatic condition, which prolonged vegetative as well as reproductive phases of the crop and resulted in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink, which caused the plant to produce higher yield up and ultimately resulted in higher grain yield. The results are in line with Kamrozzaman *et al*. (2016), Baloch *et al*. (2012) and Spink *et al*. (2000). Similar result was also observed by Hossain *et al.* (1990) who reported that due to a higher number of grains spike^{-1} and the highest 1000-grain weight, the highest grain yield was produced when wheat was sown on November 20. Zia-ul-Hassan *et al.* (2014) reported that sowing times remained significant on spike length, spikelets per spike and grains spike^{-1} with early sowing producing the best results. Said *et al.* (2012) reported that wheat yield components are affected by sowing times. For the number of grains spike^{-1} and 1000 grain weight, there were significant variances between the planting times. From November 1st to 15th, the highest number of grains spike^{-1} (53.99) and 1000 grain weight (40.2 g) were produced followed by number of grains spike^{-1} (50.1) and 1000 grain weight (32.1 g) produced from late sowing (15th December).



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 16. Effect of different sowing times on number of filled grains spike^{-1} of wheat ($LSD_{0.05}$= 1.74)

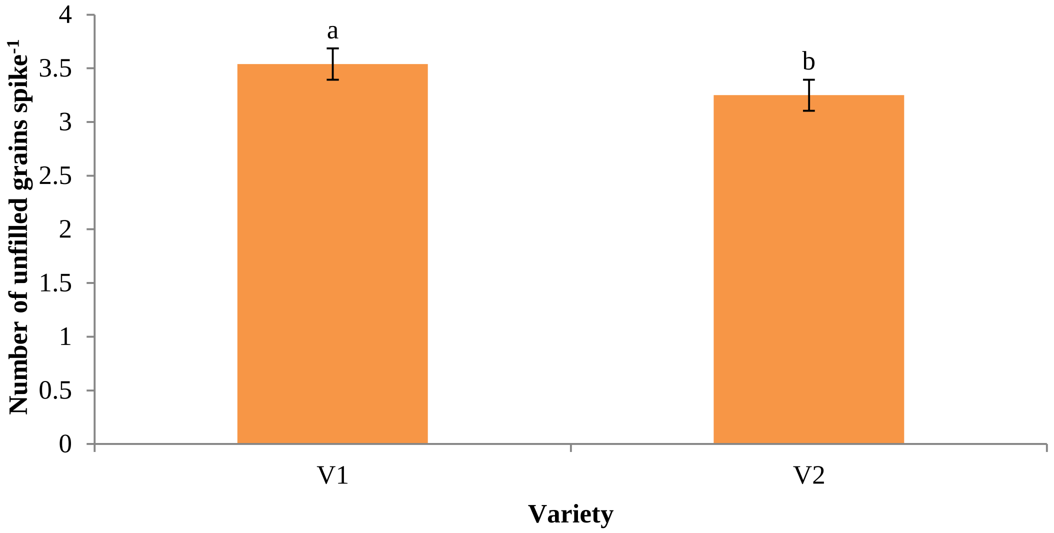
4.8.3 Combined effect of varieties and sowing times

Significant variation on number of filled grains spike^{-1} was observed due to combined effect of different varieties and sowing times under the study (Table 4 and Appendix VII). Results from the experiment showed that the maximum number of filled grains spike^{-1} (37.13) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3. On the other hand the minimum number of filled grains spike^{-1} (29.67) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5, V_1S_4, V_2S_4, V_1S_1 and V_2S_1.

4.9 Number of unfilled grains spike^{-1}

4.9.1 Effect of variety

Number of unfilled grains spike^{-1} of wheat varied significantly due to varietal treatments (Figure 17). Results from the experiment showed that BARI Gom-26 (V_1) produced the highest number of unfilled grains spike^{-1} (3.54) and the lowest number of unfilled grains spike^{-1} (3.25) was observed in BARI Gom-28 (V_2). The result of the experiment was coincided with the findings of Yusuf *et al.* (2019) who reported that the varieties HI 1544 recorded highest number of total grains per spike (48.4), filled grains spike^{-1} (45.51), lowest number of unfilled grains spike^{-1} (2.89) as compared to rest of the varieties. Similar result also found by Madhu *et al.* (2018) who reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89), minimum number of unfilled grains spike^{-1} (1.68) and the highest 1000-grain weight (29.99 g).

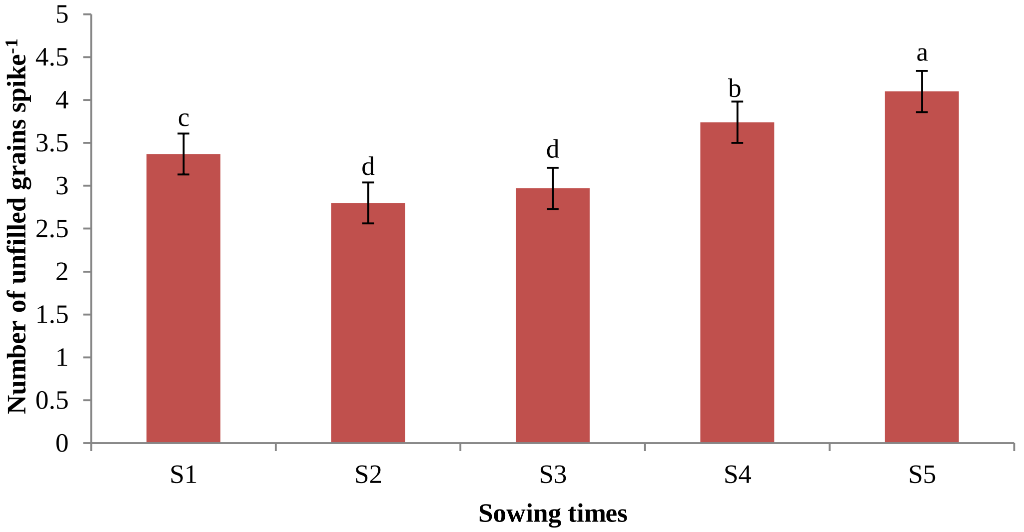


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 17. Effect of different varieties on number of unfilled grains spike^{-1} of wheat ($LSD_{0.05}$= 0.20)

4.9.2 Effect of sowing time

Significant variation of number of unfilled grains spike^{-1} was observed due to various sowing time treatments (Figure 18). It was observed that S_5 produced the highest number of unfilled grains spike^{-1} (4.10) which was statistically dissimilar with other treatments and the lowest number of unfilled grains spike^{-1} (2.80) was observed from S_2 which was statistically similar with S_3. The findings of the study was in coincided with the findings of Suleiman *et al.* (2014) who reported that higher yield attributes and yield with 5th November sowing might be due to favorable climatic condition which prolonged vegetative as well as reproductive phases of the crop and resulted in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink which caused the plant to produce higher yield up and ultimately resulted in higher grain yield. The results are in line with Kamrozzaman *et al*. (2016), Baloch *et al*. (2012) and Spink *et al*. (2000).



S_1 = 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 18. Effect of different sowing times on number of unfilled grains spike^{-1} of wheat ($LSD_{0.05}$= 0.32)

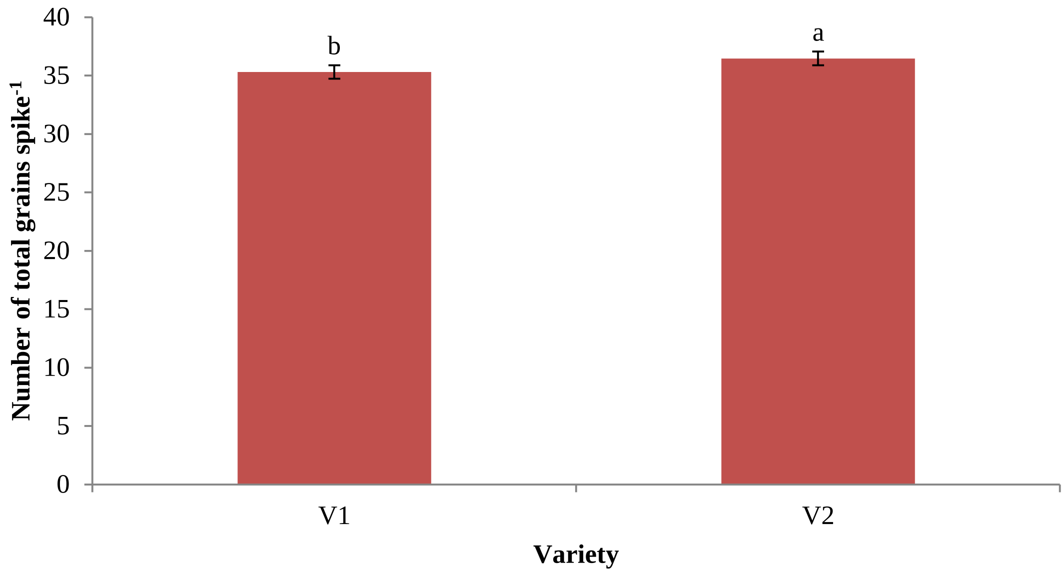
4.9.3 Combined effect of varieties and sowing times

Significant variation on number of unfilled grains spike^{-1} was observed due to combined effect of different varieties and sowing times under the study (Table 4 and Appendix VII). Results from the experiment showed that the maximum number of unfilled grains spike^{-1} (4.23) was obtained from the treatment combination V_1S_5 which was statistically similar with V_2S_5. On the other hand the minimum number of unfilled grains spike^{-1} (2.63) was recorded from the treatment combination V_2S_2 which was statistically similar with V_2S_3 and V_1S_2.

4.10 Number of total grains spike^{-1}

4.10.1 Effect of variety

Number of total grains spike^{-1} of wheat varied significantly due to varietal treatments (Figure 19). Results from the experiment showed that BARI Gom-28 (V_2) produced the highest number of total grains spike^{-1} (36.47) and the lowest number of total grains spike^{-1} (35.31) was observed in BARI Gom-26 (V_1). Islam and Jahiruddin (2008) also reported similar results. The findings was in coincided with the findings of Yusuf *et al.* (2019) who reported that the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains spike^{-1} (45.51), unfilled grains spike^{-1} (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}) harvest index (39.2 %). Suleiman *et al.* (2014) also observed the similar result and reported that the cultivars Imam and Wad el Neil came in first place in terms of the number of grains spike^{-1}.

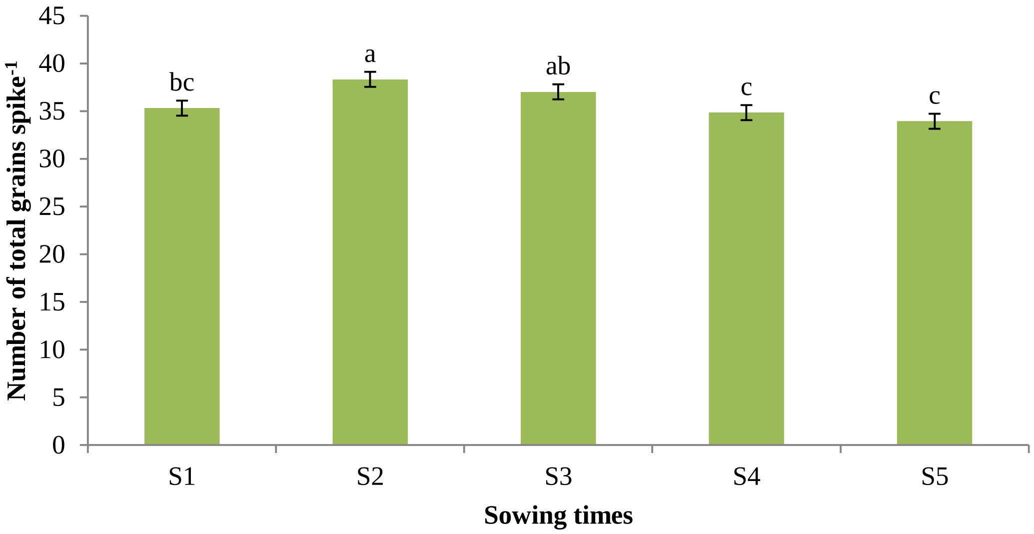


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 19. Effect of different varieties on number of total grains spike^{-1} of wheat ($LSD_{0.05}$= 1.12)

4.10.2 Effect of sowing time

Significant variation of number of total grains spike^{-1} was observed due to various sowing time treatments (Figure 20). It was observed that S_2 produced the highest number of total grains spike^{-1} (38.32) which was statistically similar with S_3 and the lowest number of total grains spike^{-1} (33.94) was observed from S_5 which was statistically similar with S_4. The findings of the experiment was coincided with the findings of Yusuf *et al.* (2019) who reported that on the basis of one year study it was concluded that among sowing times, 5th November sowing is the most economical and suitable than rest of the sowing times. 5th November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3 per m^2), total grains per spike (48.6), filled grains spike^{-1} (45.89), unfilled grains spike^{-1} (2.71), 1000-grain weight (39.9 g), grain appearance score (8.3), hectoliter weight (82.9 kg/hl), grain yield (5432 kg ha^{-1}) and harvest index (39.0 %) compared to rest of the sowing times. Due to a higher number of grains spike^{-1} and the highest 1000-grain weight, Hossain *et al.* (1990) found that the highest grain yield was produced when wheat was sown on November 20. Aslani and Mehrvar (2012) reported that sowing on November 5th resulted in a considerable rise in yield which was linked to a progressive increase in all growth components.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 20. Effect of different sowing times on number of total grains spike^{-1} of wheat ($LSD_{0.05}$= 1.77)

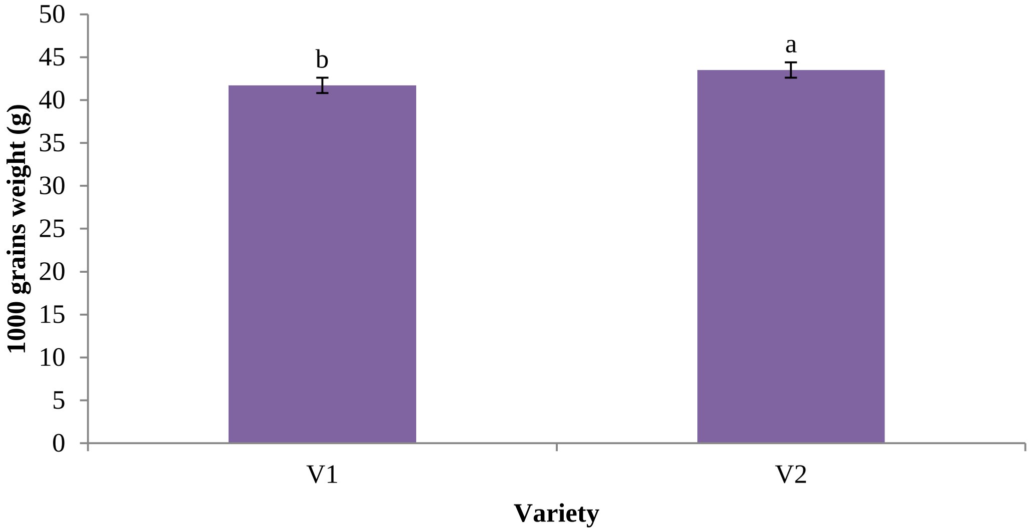
4.10.3 Combined effect of varieties and sowing times

Significant variation on number of total grains spike^{-1} was observed due to combined effect of different varieties and sowing times (Table 4 and Appendix VII). Results from the experiment showed that the maximum number of total grains spike^{-1} (39.76) were obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3. On the other hand the minimum number of total grains spike^{-1} (33.90) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5, V_1S_4, V_2S_4, V_1S_1, V_2S_1 and V_1S_3.

4.11 1000 grains weight

4.11.1 Effect of variety

Statistically significant differences on 1000 grains weight of wheat were observed due to varieties (Figure 21). It was observed that, BARI Gom-28 (V_2) produced the highest 1000 grains weight (43.51 g). On the other hand BARI Gom-26 (V_1) produced the lowest 1000 grains weight (41.72 g). The findings was in coincided with the findings of Yusuf *et al.* (2019) who reported that the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains spike^{-1} (45.51), unfilled grains spike^{-1} (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}) harvest index (39.2 %). Similar result was observed by Islam *et al.* (1993) who reported that Variety had a significant impact on spike/m^2, grain/spike, and 1000-grain weight. Improper variety selection also has an impact on crop yield because the performance of varieties varies inversely with their genetic potential and adaptability to the environment, so there is potential for increasing wheat yield through the cultivation of climate resilient varieties (Hussain *et al.*, 2012). Wheat yield can be increased 10 to 80% through proper selection of sowing time and suitable cultivars (Coventry *et al.*, 2011). WRC (2003) revealed that for yield-related characteristics among the 10 genotypes, the genotypes revealed a wide range of variation. Shatabdi produced the most grain spike^{-1} and 1000 grain weight. Similar trends also observed by Madhu *et al.* (2018) who reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89), minimum number of unfilled grains spike^{-1} (1.68) and the highest 1000-grain weight (29.99 g).

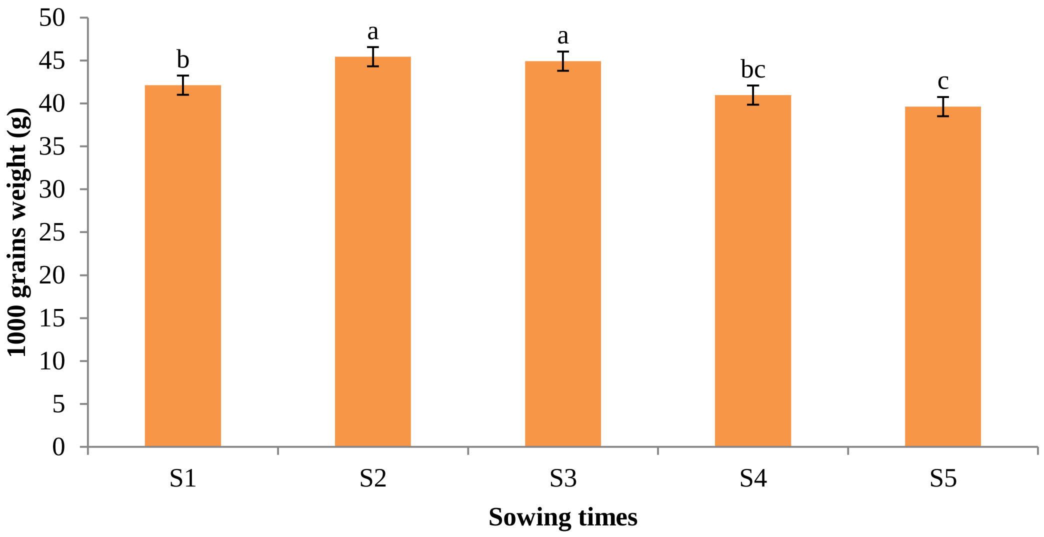


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 21. Effect of different varieties on 1000 grains weight (g) of wheat ($LSD_{0.05}$= 1.02)

4.11.2 Effect of sowing time

Weight of 1000 grains wheat varied significantly due to different sowing time treatments (Figure 22). It was observed that S_2 produced the highest 1000 grains weight (45.43 g) which was statistically similar with S_3 while the lowest 1000 grains weight (39.64 g) was obtained from S_5 which was statistically similar with S_4. Similar trends also observed by Madhu *et al.* (2018) who reported that in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers hill^{-1} (4.73), the highest number of spikelets spike^{-1} (17.77), the highest number of filled grains spike^{-1} (37.89), minimum number of unfilled grains spike^{-1} (1.68) and the highest 1000-grain weight (29.99 g). Dagash *et al.* (2014) also revealed that early sown (early November) obtained greater 1000-seed weight and harvest index for season 07/2008 and higher amount of 1000-seed weight and total dry matter for season 08/2009. Due to a higher number of grains spike^{-1} and the highest 1000-grain weight, Hossain *et al.* (1990) found that the highest grain yield was produced when wheat was sown on November 20. Eslami *et al.* (2014) found the dissimilar result and revealed that sowing wheat on December 21 produced the most spikes, spike weight and 1000-grain weight, which declined with subsequent sowing times. Baloch *et al.* (2010) stated that sowing wheat on October 25 and November 10 resulted in the longest spike length, 1000-grain weight, and grain yield, which then decreased as the sowing times progressed. Zende *et al.* (2005) reported that with delayed sowing, characteristics such as 1000-grain weight decreased. The result was coincided with the findings of Qasim *et al.* (2008) who reported that the maximum grains spike^{-1} (44.14) and 1000-grain weight were produced by early planted wheat (39.17 g).



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 22. Effect of different sowing times on 1000 grains weight (g) of wheat ($LSD_{0.05}$= 1.61)

4.11.3 Combined effect of varieties and sowing times

Significant variation on weight of 1000 grains was observed due to combined effect of different varieties and sowing times (Table 4 and Appendix VIII). Results from the experiment showed that the maximum weight of 1000 grains (47.02 g) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3. On the other hand the minimum weight of 1000 grains (39.27) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5, V_1S_4 and V_2S_4.

Table 4. Combined effect of different varieties and sowing times on spike length (cm), filled grains spike^{-1} (no.), unfilled grains spike^{-1} (no.), total grains spike^{-1} (no.) and 1000 grains weight (g) of wheat

Treatment combinations	Spike length (cm)	Filled grains spike^{-1} (no.)	Unfilled grains spike^{-1} (no.)	Total grains spike^{-1} (no.)	1000 grains weight (g)
V_1S_1	16.23 ab	31.87 c-e	3.43 c	35.30 cd	41.77 b-e
V_1S_2	17.38 a	33.90 bc	2.97 d-f	36.87 bc	43.83 b
V_1S_3	16.93 a	32.67 cd	3.17 c-e	35.84 b-d	43.05 bc
V_1S_4	15.77 ab	30.72 de	3.90 ab	34.62 cd	40.64 d-f
V_1S_5	14.81 bc	29.67 e	4.23 a	33.90 d	39.27 f
V_2S_1	12.73 d	32.03 c-e	3.30 cd	35.33 cd	42.46 b-d
V_2S_2	13.57 cd	37.13 a	2.63 f	39.76 a	47.02 a
V_2S_3	13.15 cd	35.43 ab	2.77 ef	38.20 ab	46.81 a
V_2S_4	12.20 d	31.50 c-e	3.57 bc	35.07 cd	41.25 c-f
V_2S_5	11.83 d	30.00 e	3.97 ab	33.97 d	40.00 ef
$LSD_{0.05}$	**1.79**	**2.47**	**0.44**	**2.50**	**2.27**
CV%	**8.55**	**5.23**	**9.12**	**4.82**	**3.69**

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

Notes:

V_1= BARI Gom-26 and V_2= BARI Gom-28;

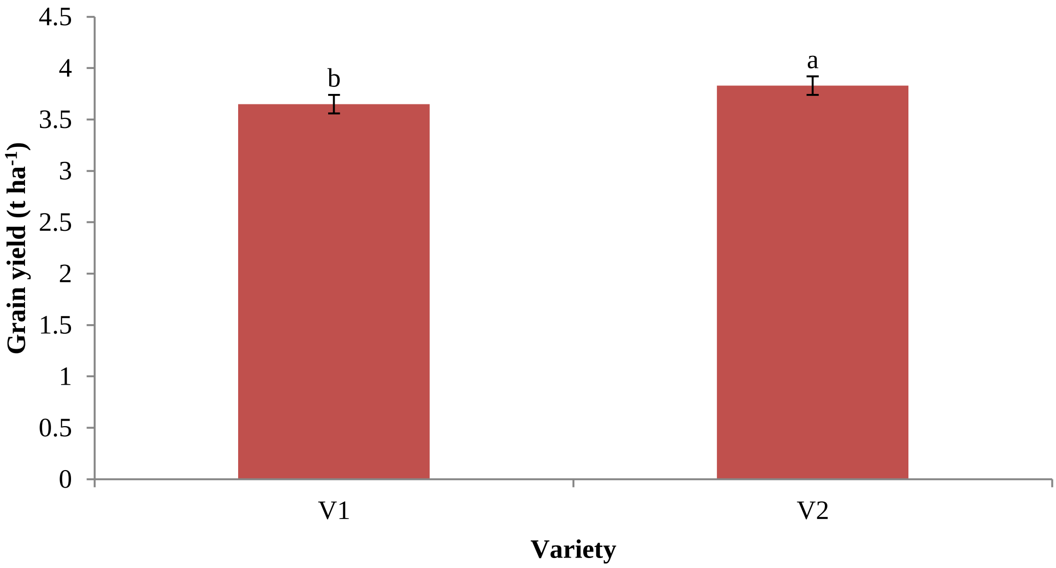
S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

4.12 Grain yield

4.12.1 Effect of variety

Grain yield was significantly affected by different variety of wheat (Figure 23). It was observed that the highest grain yield (3.83 t ha^{-1}) was obtained from the variety V_2 (BARI Gom-28) where the lowest grain yield (3.65 t ha^{-1}) was found from the variety V_1 (BARI Gom-26). The findings of the experiment was in coincided with the findings of Yusuf *et al.* (2019) who conducted an experiment and reported that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains spike^{-1} (45.51), unfilled grains spike^{-1} (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}) harvest index

(39.2 %), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties. Kumar *et al.* (2013) revealed that variety had a significant impact on grain yield. Habibi and Fazily (2020) also observed the similar result and reported that among wheat varieties Kabul 013 and Gul 09 produced significantly higher grain yield of wheat over rest of the varieties. Samson *et al.* (1995) observed the variety Sowghat produced the highest grain yield (3.5 t ha^{-1}) among the different varieties, closely followed by the variety BAW-748. Madhu *et al.* (2018) revealed that the highest grain yield (2.18 ha^{-1}) was found in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers $hill^{-1}$ (4.73), the highest number of spikelets $spike^{-1}$ (17.77), the highest number of filled grains $spike^{-1}$ (37.89), minimum number of unfilled grains $spike^{-1}$ (1.68) and the highest 1000-grain weight (29.99 g). Rahman et al. (2015) also observed the similar findings and revealed that the yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental soil and environmental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years.

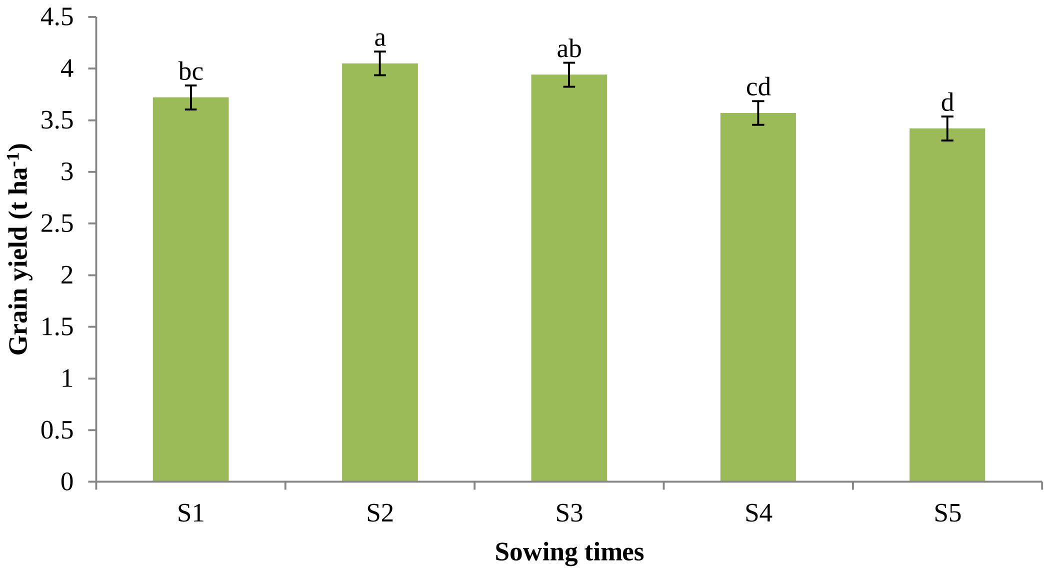


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 23. Effect of different varieties on grain yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.17)

4.12.2 Effect of sowing time

Statistically marked difference was found in terms of grain yield affected by different sowing time treatments (Figure 24). Results showed that the highest grain yield (4.05 t ha^{-1}) was obtained from the treatment S_2 followed by S_3 where the lowest grain yield (3.42 t ha^{-1}) was found from the treatment S_5 which was statistically identical with S_4. The result of the study was coincided with the findings of Gupta *et al.* (2017) who revealed that timely sowing of wheat provides optimum environment for crop growth to accumulate more biomass and finally higher grain yield. Suleiman *et al.* (2014) reported that in terms of grain yield t ha^{-1} the varieties Imam and Wad el Neil took first place. Higher yield attributes and yield with 5^{th} November sowing might be due to favorable climatic condition, which prolonged vegetative as well as reproductive phases of the crop and resulted in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink, which caused the plant to produce higher yield up and ultimately resulted in higher grain yield. The results are in line with Kamrozzaman *et al*. (2016), Baloch *et al*. (2012) and Spink *et al*. (2000). Netam *et al.* (2020) stated that sowing on 15^{th} November recorded significantly higher grain yield (40.50 q ha^{-1}). Madhu *et al.* (2018) reported that the highest grain yield (2.18 ha^{-1}) was found in the Combined of BARI Gom 25 × 15 November sowing as contributed by its highest number of effective tillers $hill^{-1}$ (4.73), the highest number of spikelets $spike^{-1}$ (17.77), the highest number of filled grains $spike^{-1}$ (37.89), minimum number of unfilled grains $spike^{-1}$ (1.68) and the highest 1000-grain weight (29.99 g). The individual effect of the BARI Gom 25 and 15 November sowing on those parameters was also observed as the highest. Similar results was observed by Dagash *et al.* (2014) who reported that Generally, crop sown at mid-November produced higher grain yield, total dry matter and tallest plant. Also higher plant height and harvest index were recorded. The early sown (early November) obtained greater 1000-seed weight and harvest index and higher amount of 1000-seed weight and total dry matter. The late sown (early December) produced higher grain yield. BARI (1997) reported that the crop sown on December 20 yielded the lowest grain yield, closely followed by the crop sown on January 5. When the crop was sown on December 5 or later, the grain yield was drastically reduced.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 24. Effect of different sowing times on grain yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.28)

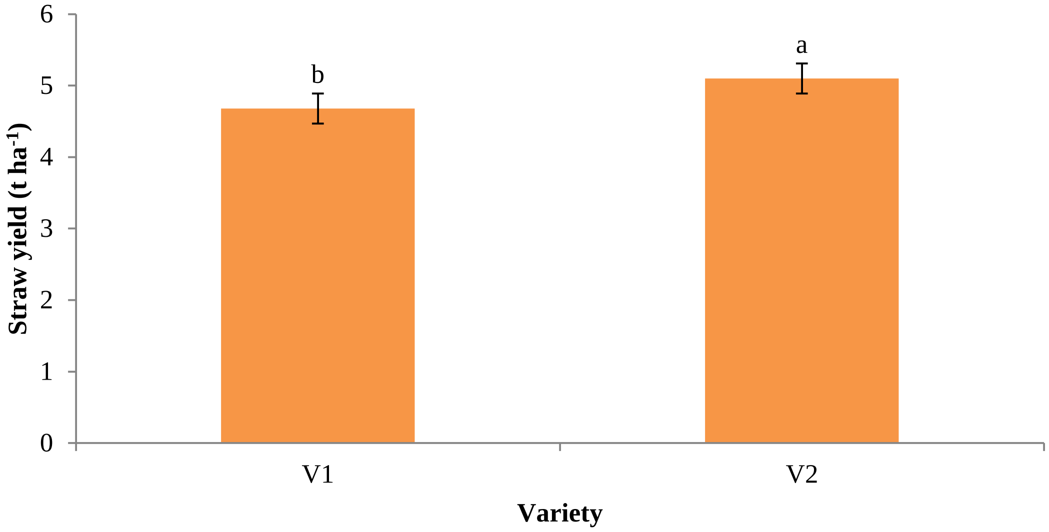
4.12.3 Combined effect of varieties and sowing times

There was marked variation on grain yield of wheat was observed due to combined effect of different varieties and sowing times (Table 5 and Appendix VIII). Results from the experiment it was noted that the maximum grain yield (4.23 t ha^{-1}) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3 and V_1S_2. On the other hand the minimum grain yield (3.39 t ha^{-1}) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5, V_1S_4, V_2S_4, V_1S_4, V_1S_1 and V_2S_1.

4.13 Straw yield

4.13.1 Effect of variety

Significant influence on straw yield was found because of different variety of wheat (Figure 25). Considering varietal variation, the highest straw yield (5.10 t ha^{-1}) was observed from the variety V_2 (BARI Gom-28) which was statistically dissimilar with V_1 (BARI Gom-26) where the lowest straw yield (4.68 t ha^{-1}) was obtained from the variety V_1 (BARI Gom-26). The findings of the experiment were coincided with the findings of Yusuf *et al.* (2019) who reported that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains $spike^{-1}$ (45.51), unfilled grains $spike^{-1}$ (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}), straw yield (7631 kg ha^{-1}), biological yield (12551 kg ha^{-1}), harvest index (39.2 %), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties.

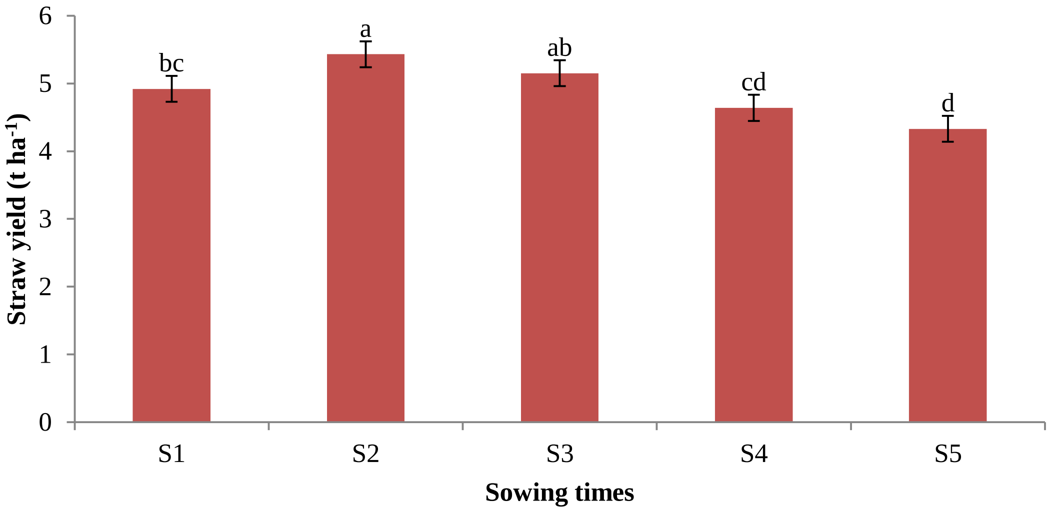


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 25. Effect of different varieties on straw yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.23)

4.13.2 Effect of sowing time

Significant impact was observed in terms of straw yield influenced by different sowing times under the study (Figure 26). Among the different sowing times treatment, the highest straw yield (5.43 t ha^{-1}) was noted from the treatment S_2 which was statistically similar with S_3 where the lowest straw yield (4.33 t ha^{-1}) was observed from the treatment S_5 which was statistically similar with S_4. Similar result was observed by Netam *et al.* (2020) who reported that sowing on 15th November recorded significantly higher grain yield (40.50 q ha^{-1}), straw yield (31.98 q ha^{-1}), gross return (Rs. ha^{-1} 61763), net return (Rs. ha^{-1} 35498) and B: C ratio (2.35). Yusuf *et al.* (2019) also observed the similar trends. They observed that 5th November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3 per m^2), total grains per spike (48.6), filled grains $spike^{-1}$ (45.89), unfilled grains $spike^{-1}$ (2.71), 1000-grain weight (39.9 g), grain appearance score (8.3), hectoliter weight (82.9 kg/hl), grain yield (5432 kg ha^{-1}), straw yield (8496 kg ha^{-1}), biological yield (13928 kg ha^{-1}) and harvest index (39.0 %). The result of the experiment was in coincided with the findings of Ahmed *et al.* (2006) who reported that early seeding (30 November) increased grain and straw yields significantly in all cultivars. Early sowing (30 November) produced the maximum grain (2.55 t ha^{-1}) and straw yield (4.28 t ha^{-1}) while delay sowing produced the lowest grain yield (1.23 t ha^{-1}) and straw yield (3.21 t ha^{-1}).



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 26. Effect of different sowing times on straw yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.36)

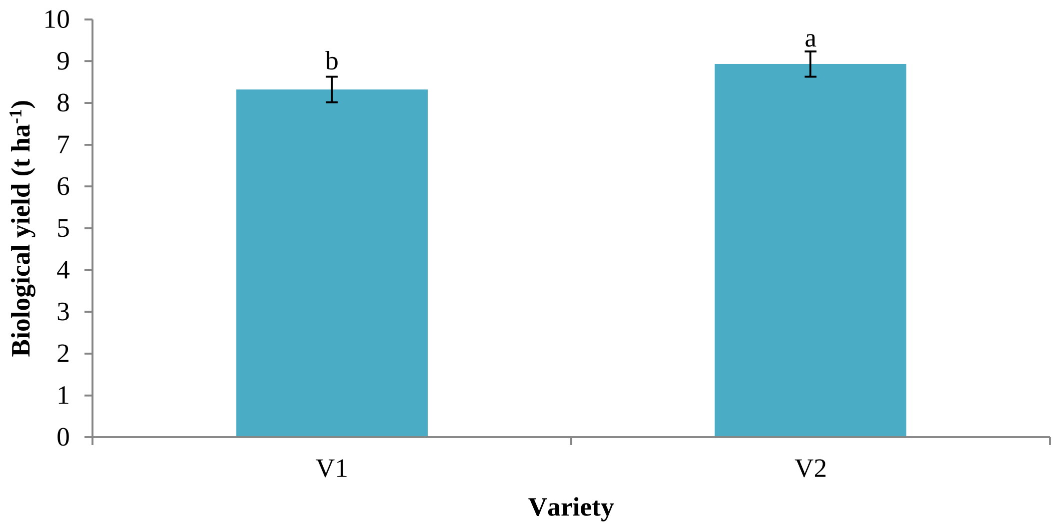
4.13.3 Combined effect of varieties and sowing times

There was marked variation was observed on straw yield of wheat due to combined effect of different varieties and sowing times under the study (Table 5 and Appendix VIII). Results from the experiment it was noted that the maximum straw yield (5.88 t ha^{-1}) was obtained from the treatment combination V_2S_2 which was statistically similar with V_2S_3. On the other hand, the minimum straw yield (4.19 t ha^{-1}) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5 and V_1S_4.

4.14 Biological yield

4.14.1 Effect of variety

Significant difference was observed on biological yield because of different variety of wheat (Figure 27). It was found that the highest biological yield (8.93 t ha^{-1}) was obtained from the variety V_2 (BARI Gom-28) where the lowest biological yield (8.32 t ha^{-1}) was observed from the variety V_1 (BARI Gom-26). The findings of the experiment were in coincided with the findings of Yusuf *et al.* (2019) who reported that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains $spike^{-1}$ (45.51), unfilled grains $spike^{-1}$ (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}), straw yield (7631 kg ha^{-1}), biological yield (12551 kg ha^{-1}), harvest index (39.2 %), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties. Roshan *et al.* (2021) reported that the lowest biological yield of (2975.1 kg ha^{-1}) was given by the wheat varieties sown on November 22^{nd}. Among the all-wheat varieties, Solh 2002, had significantly higher biological yield of (6263.7 kg ha^{-1}) followed by Shisham Bagh-08 with biological yield of (5571.8 kg ha^{-1}). However, Moqawim-09 had lowest biological yield of (4976.8 kg ha^{-1}) compare to other varieties.

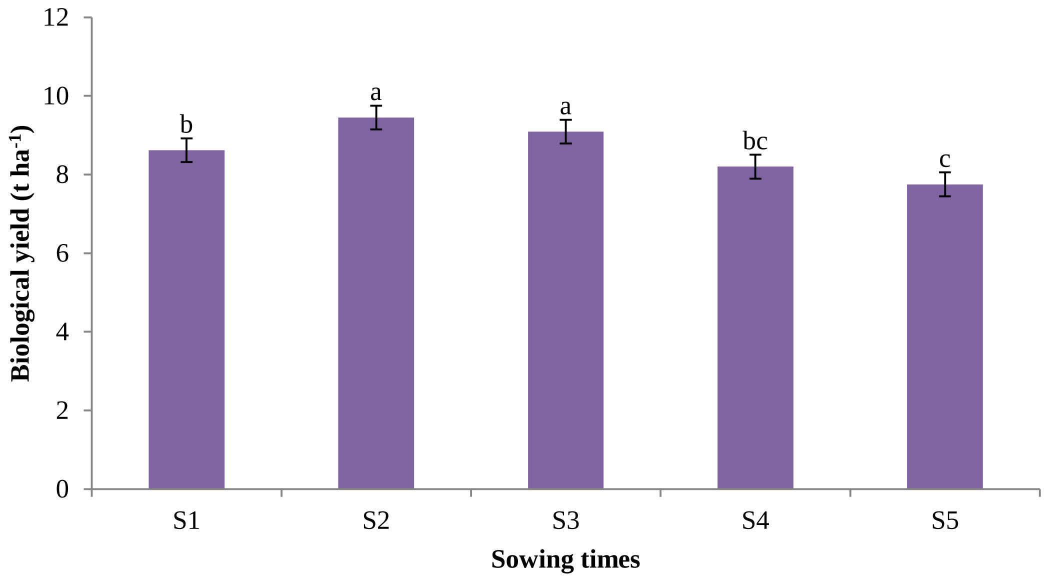


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 27. Effect of different varieties on biological yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.29)

4.14.2 Effect of sowing time

Biological yield of wheat was significantly influenced by different sowing times under the study (Figure 28). Results showed that the highest biological yield (9.45 t ha^{-1}) was achieved from the treatment S_2 which was statistically similar with the treatment S_3 where the lowest biological yield (7.75 t ha^{-1}) was observed from the treatment S_5 which was statistically similar with treatment S_4. Similar trends of result were observed by Yusuf *et al.* (2019) who reported that 5^{th} November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3 per m^2), total grains per spike (48.6), filled grains $spike^{-1}$ (45.89), unfilled grains $spike^{-1}$ (2.71), 1000-grain weight (39.9 g), grain appearance score (8.3), hectoliter weight (82.9 kg/hl), grain yield (5432 kg ha^{-1}), straw yield (8496 kg ha^{-1}), biological yield (13928 kg ha^{-1}) and harvest index (39.0 %). Roshan *et al.* (2021) reported that November 2^{nd} planted wheat had a highest biological yield of (6642.1 kg ha^{-1}) followed by October 24^{th} and November 12^{th} which gave (6576.5 kg ha^{-1}) and (5711.0 kg ha^{-1}) respectively. The lowest biological yield of (2975.1 kg ha^{-1}) was given by the wheat varieties sown on November 22^{nd}.



S_1= 5^{th} November, S_2= 15^{th} November, S_3= 25^{th} November, S_4= 5^{th} December and S_5= 15^{th} December

Figure 28. Effect of different sowing times on biological yield (t ha^{-1}) of wheat ($LSD_{0.05}$= 0.45)

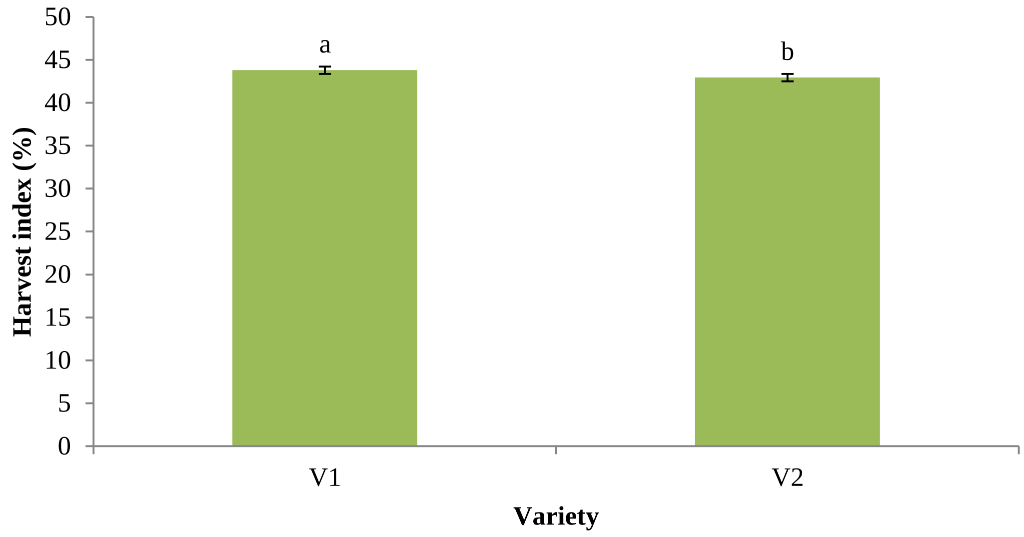
4.14.3 Combined effect of varieties and sowing times

There was marked variation was observed on biological yield of wheat due to combined effect of different varieties and sowing times under the study (Table 5 and Appendix VIII). Results from the experiment it was noted that the maximum biological yield (10.11 t ha^{-1}) was obtained from the treatment combination V_2S_2 which was statistically dissimilar with other treatment combination under the study. On the other hand, the minimum biological yield (7.58 t ha^{-1}) was recorded from the treatment combination V_1S_5 which was statistically similar with V_2S_5 and V_1S_4.

4.15 Harvest index

4.15 Effect of variety

Harvest index was significantly affected by different variety of wheat (Figure 29). It was expressed that the highest harvest index (43.79 %) was obtained from the variety V_1 (BARI Gom-26) where the lowest harvest index (42.93 %) was achieved from the variety V_2 (BARI Gom-28). The findings of the study were similar to the findings of Yusuf *et al.* (2019) who did an experiment and reported that among the varieties, HI 1544 recorded significantly higher number of effective tillers (94.6 per m^2), total grains per spike (48.4), filled grains $spike^{-1}$ (45.51), unfilled grains $spike^{-1}$ (2.89), 1000-grain weight (38.6 g), grain yield (4920 kg ha^{-1}), straw yield (7631 kg ha^{-1}), biological yield (12551 kg ha^{-1}), harvest index (39.2 %), grain appearance score (8.1) and hectoliter weight (82.0 kg/hl), while variety WH 1105 resulted in longer spike (11.5 cm) and WR 544 in higher protein content (12.6 %) as compared to rest of the varieties.

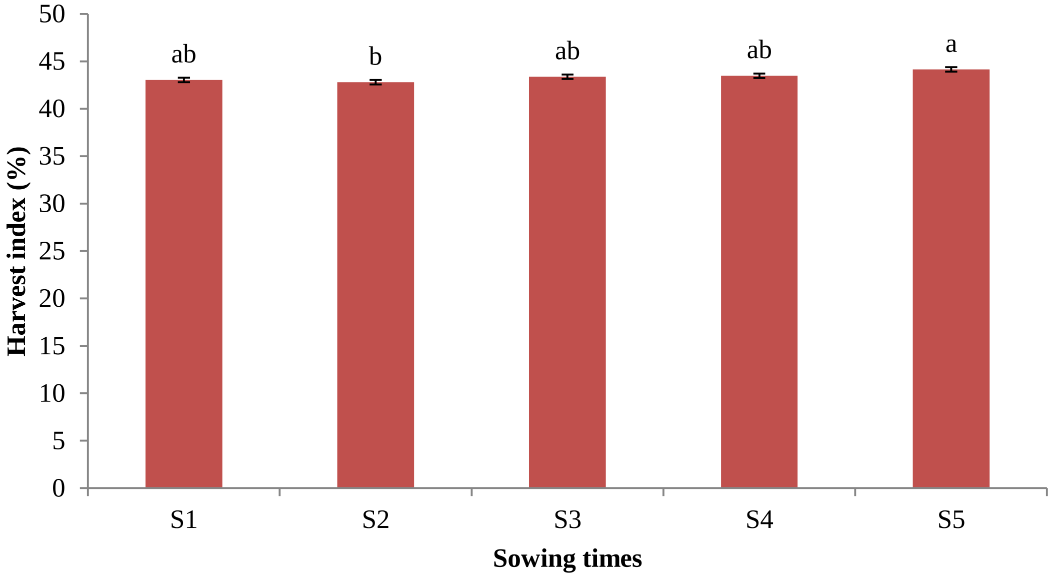


V_1= BARI Gom-26 and V_2= BARI Gom-28

Figure 29. Effect of different varieties on harvest index (%) of wheat ($LSD_{0.05}$= 0.74)

4.15.2 Effect of sowing time

Marked variation was exerted in terms of harvest index of wheat influenced by different sowing time treatments (Figure 30). Results showed that the highest harvest index (44.14 %) was achieved from the treatment S_5 followed by S_4, S_3 and S_1. On the other hand the lowest harvest index (42.79 %) was obtained from the treatment S_2. Similar trends were followed by Yusuf *et al.* (2019). The reported that 5th November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3 per m^2), total grains per spike (48.6), filled grains spike^{-1} (45.89), unfilled grains spike^{-1} (2.71), 1000-grain weight (39.9 g), grain appearance score (8.3), hectoliter weight (82.9 kg/hl), grain yield (5432 kg ha^{-1}), straw yield (8496 kg ha^{-1}), biological yield (13928 kg ha^{-1}) and harvest index (39.0 %) compared to rest of the sowing times. Dagash *et al.* (2014) did an experiment with three sowing times namely; early November, mid-November and early December were chosen and applied. The results of the study showed that nitrogen application displayed significant effect on plant height, total dry matter, 1000-seed weight and grain yield in both seasons but nitrogen fertilizer had no significant effect on harvest index for season 08/2009. The early sown (early November) obtained greater 1000-seed weight and harvest index for season 07/2008 and higher amount of 1000-seed weight and total dry matter for season 08/2009. The late sown (early December) produced higher grain yield for season 08/2009. Dissimilar result was observed by Said *et al.* (2012) who reported that Harvest index was unaffected by sowing times.



S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

Figure 30. Effect of different sowing times on harvest index (%) of wheat ($LSD_{0.05}$= 1.17)

4.15.3 Combined effect of varieties and sowing times

Combined effect of different varieties and sowing times showed remarkable impact on harvest index of wheat (Table 5 and Appendix VIII). It was indicated that the highest harvest index (44.72 %) was obtained from the treatment combination of V_1S_5 followed by V_1S_2, V_1S_3, V_2S_5, V_1S_4 and V_1S_1. The lowest harvest index (41.84 %) was achieved from the treatment combination of V_2S_2 which was statistically similar with V_2S_3 and V_2S_1.

Table 5. Combined effect of different varieties and sowing times on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of wheat

Treatment combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_1	3.67 b-e	4.83 cd	8.50 cd	43.18 a-c
V_1S_2	3.87 a-c	4.98 b-d	8.85 bc	43.73 ab
V_1S_3	3.82 b-d	4.89 cd	8.71 c	43.86 ab
V_1S_4	3.48 c-e	4.53 c-e	8.01 de	43.45 a-c
V_1S_5	3.39 e	4.19 e	7.58 e	44.72 a
V_2S_1	3.76 b-e	5.01 bc	8.77 c	42.87 bc
V_2S_2	4.23 a	5.88 a	10.11 a	41.84 c
V_2S_3	4.06 ab	5.41 ab	9.47 b	42.87 bc
V_2S_4	3.65 c-e	4.74 cd	8.39 cd	43.50 a-c
V_2S_5	3.45 de	4.47 de	7.92 de	43.56 ab
$LSD_{0.05}$	**0.40**	**0.51**	**0.64**	**1.66**
CV%	**7.38**	**7.26**	**5.10**	**2.65**

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

Notes:

V_1= BARI Gom-26 and V_2= BARI Gom-28;

S_1= 5th November, S_2= 15th November, S_3= 25th November, S_4= 5th December and S_5= 15th December

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment were conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2019 to March 2020 to find out the effect of sowing times on the phenological development and yield of wheat. The experiment included two factors; Factor A: Variety (2)- BARI Gom-26 (V_1) and BARI Gom-28 (V_2); Factors B: Sowing time (5) - 5th November, 2019 (S_1), 15th November, 2019 (S_2), 25th November, 2019 (S_3), 5th December, 2019 (S_4) and 15th December, 2019 (S_5). The experiment was carried out in a Randomized Complete Block Design (RCBD) with four replications. Data were recorded on growth, yield attributes and yield of wheat and significant variation were observed for most of the characters studied.

In respect of wheat varieties, the longest plants (34.14, 50.03, 68.38, 84.01 and 89.27 cm, respectively) were found from V_2 (BARI Gom-28) while the shortest plants (27.56, 43.99, 62.61, 75.98 and 82.58 cm, respectively) were recorded from V_1 (BARI Gom-26) at 30, 45, 60, 75 DAS and at harvest, respectively. Data revealed that the maximum number of tillers plant^{-1} (3.00, 3.66, 5.02, 5.80 and 5.11, respectively) were recorded from V_1 (BARI Gom-26), whereas the minimum number of tillers plant^{-1} (2.85, 3.52, 4.86, 5.58 and 4.80, respectively) were observed from V_2 (BARI Gom-28) at 30, 45, 60, 75 DAS and at harvest, respectively. The highest days to spike emergence (65.40) were obtained from V_1 (BARI Gom-26) whereas the lowest days to spike emergence (57.80) were recorded from V_2 (BARI Gom-28). The highest days to maturity (107.80) were recorded from V_1 (BARI Gom-26). On the other hand the lowest days to maturity (104.80) were found from V_2 (BARI Gom-28). The highest number of spikes plant^{-1} (4.67) was observed from V_2 while the lowest number of spikes plant^{-1} (4.45) was found from V_1. The highest number of spikelets spike^{-1} (23.44) was recorded from V_2 while the lowest number of spikelets spike^{-1} (22.01) was recorded from V_1. The maximum spike length (16.22 cm) was recorded from V_1. On the other hand the minimum spike length (12.70 cm) was observed from V_2. The highest number of filled grains spike^{-1} (33.22) was observed from V_2 whereas the lowest number of filled grains spike^{-1} (31.77) was recorded from V_1. The highest number of unfilled grains spike^{-1} (3.54) was found from V_1 while the lowest number of unfilled grains spike^{-1} (3.25) was recorded from V_2. Data revealed that the highest number of total grains spike^{-1} (36.47) was obtained from V_2 whereas the lowest number of total grains spike^{-1} (35.31) was found from V_1. The highest weight of 1000 grains (43.51 g) was recorded from V_2 (BARI Gom-28) while the lowest weight of 1000 grains (41.72 g) was found from V_1 (BARI Gom-26). The highest grain yield (3.83 t ha^{-1}) was found from V_2 while the lowest grain yield (3.65 t ha^{-1}) was found from V_1. The highest straw yield (5.10 t ha^{-1}) was obtained from V_2 whereas the lowest straw yield (4.68 t ha^{-1}) was recorded from V_1. Data revealed that the highest biological yield (8.93 t ha^{-1}) was observed from V_2 while the lowest biological yield (8.32 t ha^{-1}) was obtained from V_1. The highest harvest index (43.79 %) was found from V_1 and the lowest harvest index (42.93 %) was recorded from V_2.

In respect of different sowing times, the longest plant (33.61, 49.77, 68.05, 83.06 and 89.25 cm, respectively) were obtained from S_2, whereas the shortest plant (28.23, 44.11, 62.62, 76.22 and 83.38 cm, respectively) were found from S_5 at 30, 45, 60, 75 DAS and at harvest, respectively. Data revealed that the maximum number of tillers plant^{-1} (3.24, 3.93, 5.32, 6.13 and 5.58 at 30, 45, 60, 75 DAS and at harvest, respectively) were found from S_2 while the minimum number of tillers plant^{-1} (2.55, 3.30, 4.57, 5.17 and 4.28 at 30, 45, 60, 75 DAS and at harvest, respectively) were recorded from S_5. Result from the experiment revealed that the highest days to spike emergence (64.50) were observed from S_5. On the other hand the lowest days to spike emergence (58.50) were found from S_2. The highest days to maturity (110.00) were found from S_1 whereas the lowest days to maturity (102.50) were recorded from S_5. The highest number of spikes plant^{-1} (5.03) was recorded from S_2 whereas the lowest number of spikes plant^{-1} (4.04) was found from S_5. The highest number of spikelets spike^{-1} (26.06) was obtained from S_2 while the lowest number of spikelets spike^{-1} (19.93) was found from S_5. The maximum spike length (15.47 cm) was obtained from S_2 while the minimum spike length (13.32 cm) was recorded from S_5. The highest number of filled grains spike^{-1} (35.52) was recorded from S_2 whereas the lowest number of filled grains spike^{-1} (29.84) was observed from S_5. The highest number of unfilled grains spike^{-1} (4.10) was observed from S_5 whereas the lowest number of unfilled grains spike^{-1} (2.80) was obtained from S_2. The highest number of total grains spike^{-1} (38.32) was recorded from S_2 whereas the lowest number of total grains spike^{-1} (33.94) was observed from S_5. The highest weight of 1000 grains (45.43 g) was observed from S_2 whereas the lowest weight of 1000 grains (39.64 g) was observed from S_5. The highest grain yield (4.05 t ha^{-1}) was recorded from S_2. On the other hand the lowest grain yield (3.42 t ha^{-1}) was obtained from S_5. The highest straw yield (5.43 t ha^{-1}) was noted from S_2 while the lowest straw yield (4.33 t ha^{-1}) was obtained from S_5. The highest biological yield (9.45 t ha^{-1}) was recorded from S_2 whereas the lowest biological yield (7.75 t ha^{-1}) was recorded from S_5. The highest harvest index (44.14 %) was recorded from S_5. On the other hand the lowest harvest index (42.79 %) was obtained from S_2.

In case of combined effect of wheat varieties and sowing times, the longest plant (37.43, 53.18, 71.34, 87.10 and 92.67 cm, respectively) were obtained from V_2S_2 and the shortest plant (25.60, 40.91, 60.34, 71.75 and 79.75 cm) were obtained from the treatment combination V_1S_5 at 30, 45, 60, 75 DAS and at harvest, respectively. Data revealed that the maximum number of tillers $plant^{-1}$ (3.41, 4.06, 5.47, 6.33 and 5.83) were recorded from V_1S_2 whereas the minimum number of tillers $plant^{-1}$ (2.47, 3.27, 4.53, 5.10 and 4.13) were recorded from the treatment combination V_2S_5 at 30, 45, 60, 75 DAS and at harvest, respectively. From the result of the experiment revealed that the highest days to spike emergence (69.00) were obtained from the treatment combination of V_1S_5 while the lowest days to spike emergence (55.00) were obtained from the treatment combination V_2S_2. The highest days to maturity (112.00) were observed from the treatment combination of V_1S_1 and the lowest days to maturity (101.00) were recorded from the treatment combination V_2S_5. Data revealed that the highest number of spikes $plant^{-1}$ (5.23) were recorded from the treatment combination of V_2S_2 while the lowest number of spikes $plant^{-1}$ (3.97) were observed from the treatment combination of V_1S_5. Data revealed that the highest number of spikelets $spike^{-1}$ (27.24) was obtained from V_2S_2 while the lowest number of spikelets $spike^{-1}$ (19.70) was obtained from the treatment combination of V_1S_5. The highest spike length (17.38 cm) was obtained from the treatment combination of V_1S_1 whereas the lowest spike length (11.83 cm) was observed from the treatment combination of V_2S_5. The highest number of filled grains $spike^{-1}$ (37.13) was obtained from V_2S_2 whereas the lowest number of filled grains $spike^{-1}$ (29.67) was achieved from the treatment combination of V_1S_5. The highest number of unfilled grains $spike^{-1}$ (4.23) were observed from V_1S_5 while the lowest number of unfilled grains $spike^{-1}$ (2.63) were obtained from the treatment combination of V_2S_2. The highest number of total grains $spike^{-1}$ (39.76) was recorded from the treatment combination of V_2S_2 whereas the lowest number of total grains spike^{-1} (33.90) was recorded from the treatment combination of V_1S_5. The highest weight of 1000 grains (47.02 g) was recorded from V_2S_2 while the lowest weight of 1000 grains (39.27 g) was obtained from the treatment combination of V_1S_5. The highest grain yield (4.23 t ha^{-1}) was obtained from V_2S_2 while the lowest grain yield (3.39 t ha^{-1}) was recorded from the treatment combination of V_1S_5. The highest straw yield (5.88 t ha^{-1}) were obtained from the treatment combination of V_2S_2 while the lowest straw yield (4.19 t ha^{-1}) were achieved from the treatment combination of V_1S_5. The highest biological yield (10.11 t ha^{-1}) were found from the treatment combination of V_2S_2 and the lowest biological yield (7.58 t ha^{-1}) were obtained from the treatment combination of V_1S_5. The highest harvest index (44.72 %) was observed from the treatment combination of V_1S_5 while the lowest harvest index (41.84 %) was obtained from the treatment combination of V_2S_2.

CONCLUSION

From the findings it may be concluded that BARI Gom-28 (V_2) were superior to BARI Gom-26 (V_1) in respect of phenological attributes and yield that used in this experiment. BARI Gom-28 (V_2) was superior to BARI Gom-26 (V_1) in terms of plant height, days to spike emergence, days to maturity and grain yield. Seeds sown on 15th November (S_2) were the best treatment among the other sowing times in respect of phenological characters (Plant height, days to spike emergence and days to maturity) and grain yield. Among the different treatment combinations, BARI Gom-28 sown on 15th November (V_2S_2) showed promising phonological characteristics and grain yield in the present study. So, considering the results of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability and
2. Other management practices may be used for further study.

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APPENDICES

Appendix I. Monthly records of air temperature, relative humidity and total rainfall during the period from November 2019 to March 2020

Month and year	RH (%)	Air temperature (℃)			Rainfall
		Max.	*Min.*	*Mean*	(mm)
November, 2019	56.25	28.70	8.62	18.66	14.5
December, 2019	51.75	26.50	9.25	17.87	12.0
January, 2020	46.20	23.70	11.55	17.62	0.0
February, 2020	37.95	22.85	14.15	18.50	0.0
March, 2020	35.75	21.55	15.25	18.40	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212

Appendix II. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University, Dhaka
AEZ	Madhupur 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	Not Applicable

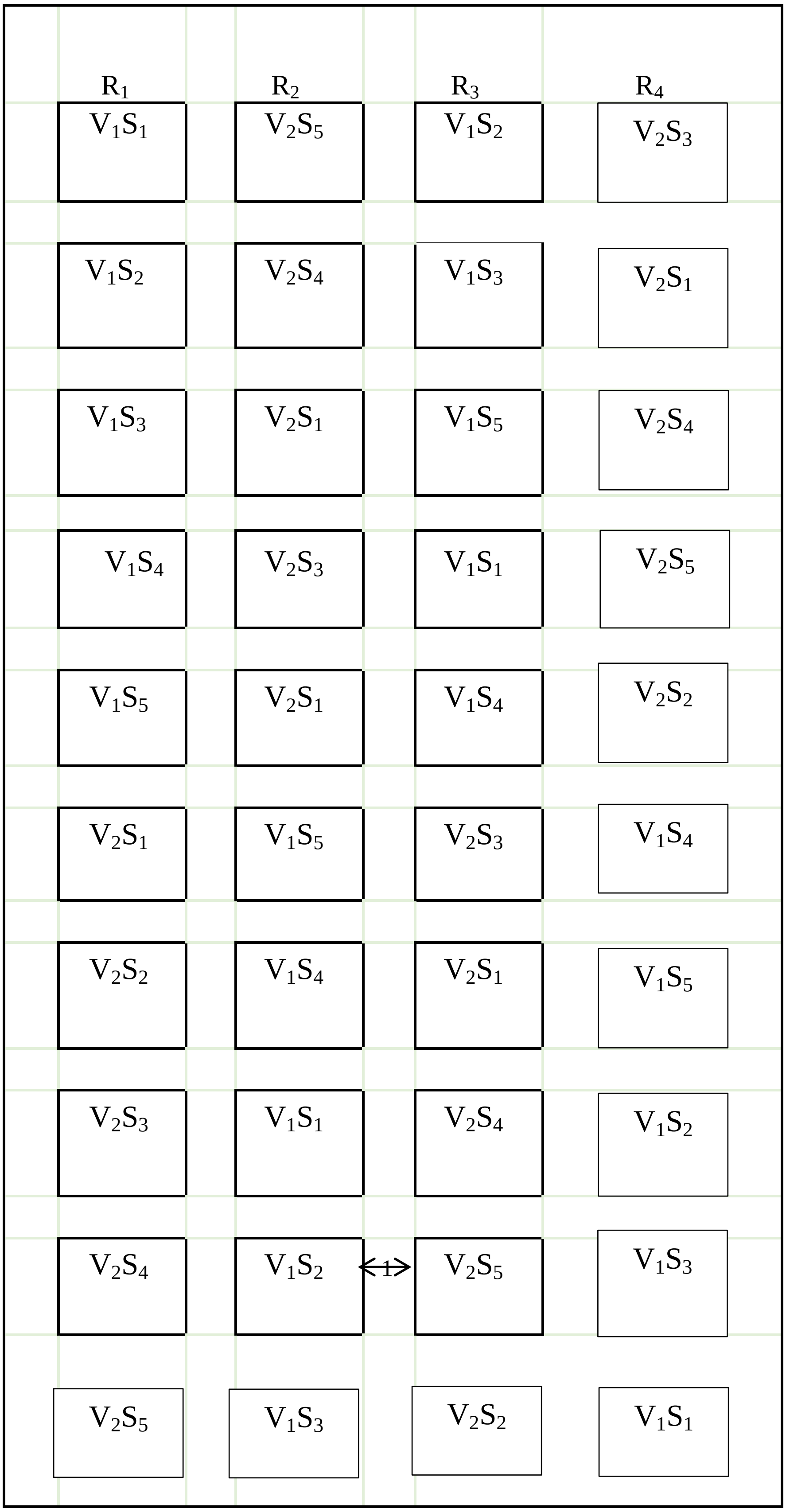
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

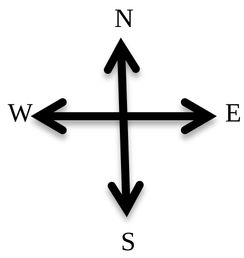
Characteristics	**Value**
Partical size analysis % Sand	57
%Silt	23
% Clay	20
Textural class	Sandy Clay Loam
pH	6.2
Organic matter (%)	0.78
Total N (%)	0.003
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45
Salinity (ds/m)	2

Source: Soil Resource Development Institute (SRDI)

Appendix III: Layout of the experimental field



Legends



Factor A: Wheat variety (2)

V_1= BARI Gom 26
V_2= BARI Gom 28

Factor B: Sowing time (5)

S_1= 5th November
S_2= 15th November
S_3= 25th November
S_4= 5th December
S_5= 15th December

Appendix IV. Mean square values of plant height at different days after sowing of wheat growing under the experiment

Sources of variation	Degrees of freedom	Mean square of plant height at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	3	1.727	47.125	60.033	463.182	201.112
Factor A	1	431.189**	365.360**	333.391**	646.094**	448.096**
Factor B	4	33.244*	36.562*	36.358**	59.089**	42.194*
A × B	4	1.618*	0.693*	2.460*	1.009*	0.520*
Error	27	16.057	18.777	8.202	9.654	19.549

* significant at 5% level of significance
** significant at 1% level of significance

Appendix V. Mean square values of number of tillers plant^{-1} at different days after sowing of wheat growing during experimentation

Sources of variation	Degrees of freedom	Mean square of number of tillers plant^{-1} at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	3	0.107	0.428	0.299	0.074	0.139
Factor A	1	0.222*	0.204*	0.249*	0.497**	0.948**
Factor B	4	0.577**	0.581**	0.753**	1.388**	2.395**
A × B	4	0.029*	0.019*	0.042*	0.035*	0.063*
Error	27	0.052	0.041	0.046	0.043	0.048

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of days to spike emergence, days to maturity, number of spikes plant^{-1} and number of spikelets spike^{-1} of wheat growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Days to spike emergence	Days to maturity	Number of spikes plant^{-1}	Number of spikelets spike^{-1}
Replication	3	266.400	190.217	0.204	20.795
Factor A	1	577.600**	90.000*	0.449*	20.492**
Factor B	4	42.400**	65.600*	1.399**	60.456**
A × B	4	1.600*	2.000*	0.029*	3.012*
Error	27	6.030	20.661	0.099	1.521

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VII. Mean square values of spike length, filled grains spike^{-1}, unfilled grains spike^{-1} and number of total grains spike^{-1} of wheat growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Spike length	Filled grain spike^{-1}	Unfilled grains spike^{-1}	Total grains spike^{-1}
Replication	3	6.965	11.185	0.205	14.091
Factor A	1	124.574**	21.083**	0.853**	13.456*
Factor B	4	5.772*	41.658**	2.296**	24.804**
A × B	4	0.224*	4.126*	0.021*	3.701*
Error	27	1.530	2.891	0.095	2.992

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of 1000 grains weight, grain yield, straw yield, biological yield and harvest index of wheat growing under the experiment

Sources of variation	Degrees of freedom	Mean square of				
		1000 grains weight	Grain yield	Straw yield	Biological yield	Harvest index
Replication	3	42.146	0.365	0.931	1.632	18.556
Factor A	1	32.041**	0.344*	1.747**	3.708**	7.396*
Factor B	4	50.250**	0.539**	1.477**	3.787**	2.129*
A × B	4	4.819*	0.029*	0.181*	0.331*	1.149*
Error	27	2.469	0.076	0.126	0.194	1.321

* significant at 5% level of significance
** significant at 1% level of significance

Appendix IX. Phenological developments of different treatment combinations

Spike emergence of treatment combinations	First spike visibility date	Maximum number of spikes	Duration (days)
V_1S_1 and V_2S_1	16/12/2019	30/12/2019	15
V_1S_2 and V_2S_2	30/12/2019	15/01/2020	17
V_1S_3 and V_2S_3	12/01/2020	25/01/2020	14
V_1S_4 and V_2S_4	16/01/2020	28/01/2020	13
V_1S_5 and V_2S_5	24/01/2020	03/02/2020	11