GRAIN GROWTH AND YIELD OF WHEAT AS INFLUENCED BY VARIETY AND SOWING DATE

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GRAIN GROWTH AND YIELD OF WHEAT AS INFLUENCED BY VARIETY AND SOWING DATE

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Dedicated

To

my parents

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF VARIETY AND SOWING DATE ON GRAIN GROWTH 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 (M.S.)** in **AGRONOMY,** embodies the results of a piece of *bona fide* research work carried out by **RAZIUDDIN,** Registration No. **07-02198** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Dr. Md. Shahidul Islam)
Professor
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GRAIN GROWTH AND YIELD OF WHEAT AS INFLUENCED BY VARIETY AND SOWING DATE

ABSTRACT

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka from November 2012 to April 2013. The experiment consisted of two factors: Factor A: Variety viz. BARI Gom-21 (V_1), BARI Gom-24 (V_2), BARI Gom-25 (V_3) and BARI Gom-26 (V_4) and Factor B: Sowing date viz. sowing at 20 November (S_1), sowing at 1December (S_2) and sowing at 12 December (S_3) following RCB design with three replications. It was evident from the results that morpho-physiological and yield contributing characters of wheat were significantly influenced by different genotypes, sowing dates and their interactions. In respect of effect of genotypes, BARI Gom-26 and BARI Gom- 25 performed better in yield and other yield contributing characters than others. Among the genotypes, BARI Gom-24 and BARI Gom-25 showed lowest initial lag phase duration (8 DAA and 12 DAA, respectively) while BARI Gom-21 showed the highest (16 DAA). Sowing at 1 December exhibited the highest grain growth rate than November 20 and December 12 sowing date. BARI Gom-26 maintained the highest average grain growth rate (0.5051 mg/grain) and BARI Gom-21 (Shatabdi) showed the lowest (0.3209 mg /grain). Sowing at 1 December showed the highest average growth rate (0.5647 mg /grain). The lowest average growth rate was recorded in 20 November sowing and 12 December sowing (0.3795 mg/grain and 0.3397 mg /grain). The maximum average grain growth rate was obtained from the combination of BARI Gom-26 with 1 December sowing (0.6997 mg/grain). For 20 November sowing, BARI Gom-24 gave the highest fertile tillers per m^2 (228.0), dry grain wt. after anthesis (0.431g), grains per spike (42.78) and yield (3.55 t/ha) whereas BARI Gom-21 gave the lowest (190.3, .270g, 38.78 and 2.67 t/ha, respectively). For December 1 sowing, BARI Gom-25 gave the highest yield (4.60 t/ha) whereas BARI Gom-21 gave the lowest (2.67t/ha). For 12 December sowing, BARI Gom-21 attained maximum yield (3.22 t/ha), fertile tillers per m^2 (226.3) and minimum dry grain wt. after anthesis (0.286 g) whereas BARI Gom-25 gave the lowest yield (2.99 t/ha). The highest yield (4.60 t/ha) was observed at intermediate sowing by BARI Gom-25 followed by BARI Gom-26 (4.53 t/ha) at December 1 sowing.

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LIST OF ACRONYMS

%	: Percentage
^{0}C	: Degree Celsius
AEZ	: Agro-ecological Zone
ANOVA	: Analysis of variance
BARC	: Bangladesh Agricultural Research Council
BARI	: Bangladesh Agricultural Research Institute
BBS	: Bangladesh Bureau of Statistics
cm	: Centimeter
cv.	: Cultivar
DAT	: Days after transplanting
e.g.	: Exempli gratia (by way of example)
et al.	: And others
FAO	: Food and Agriculture Organization
Fig.	: Figure
g	: Gram
i.e.	: edest (means That is)
LSD	: Least Significant Difference
MoP	: Muriate of Potash
pH	: Negative logarithm of hydrogen ion
RCBD	: Randomized Complete Block Design
TSP	: Triple Super Phosphate
Viz.	: Namely

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Wheat *(Triticum aestivum* L) is an important cereal grain crop in Bangladesh as well as in the world. It ranks first globally and second most important cereal next to rice in Bangladesh in terms of production and acreage (BBS, 2013 and FAO, 2009). In 2006-07, wheat covered an area of about 0.67 million hectare and produced 0.74 million tons of grain (BBS, 2013). But the actual yield (about 2 to 2.5 t/ha) is much more beyond from its yield potential. This may be due to many limiting factors of which high temperature stress is the vital physiological factor (Vijayalakshmi and Kolluru, 2007).

In Bangladesh, short winter environments (Saunders, 1991) and late planting (Islam *et al.,* 1993) would be the major reasons for low yield of wheat. Over 60% of the total wheat crop is late cultivated in Bangladesh due to delayed harvest of previous transplanted aman rice (Badruddin *et al*., 1994).

Among various factors responsible for low yield of wheat crop in the country, sowing time and varietal selection are of primary importance. Wheat is sown in winter and it has its own definite requirements for temperature and light for emergence, growth and flowering (Dabre *et al.*, 1993). Too early sowing produces weak plants with poor root system as the temperature is above optimum. Temperature above optimum leads to irregular germination and the embryo frequently dies and the endosperm may undergo decomposition due to activities of bacteria or fungi. Late planting results in poor tillering and crop grow generally slow because of low temperature. In late planting, the wheat variety should be short duration that may escape from high temperature at the grain filling stage (Phadnawis and Saini, 1992).

In Bangladesh, both early (October) and late (after 15 December) sown wheat receives high temperature respectively at early vegetative stage and heading stage resulting lower yield. Sensitivity to high temperature increases as vegetative growth develops and tillering proceeds towards the end of GS_1 (emergence to double ridge) (O'Toole and Stockle, 1991). The sensitivity to high temperature during this phase is Expressed as a decreased duration of GS_1 (Shpiler and Blum, 1986) and reduced leaf area and growth. A reduction in total number of leaves and spike-bearing tillers is also an effect of high temperature during this phase (Mid-more *et al.*, 1984).

A reduction of 28.9 % grain yields of wheat is occurred in response to heat stress and heat stress caused a reduction of 39.7%, 19.4%, 8.5%, 7.6%, 5.6% for grain filling stage, chlorophyll loss, 1000-grain weight, grain filling period and membrane injury (grain filling stage) respectively (Amandeep *et al*., 2007). With increase in stress intensity, a progressive and significant decrease was occurred in yield and yield attributing traits in all wheat varieties (Singh *et al.,* 2007)

The number of kernel per unit area decreases at a rate of 4% for each degree increase in mean temperature during the 30 days preceding anthesis (Fischer, 1985).

Exposure to high temperature during reproductive growth stage reduces grain filling period and remobilization of photosynthates (Fisher, 2007). With the rise of temperature the grain filling rate was found to increase but the duration of grain filling period decreased considerably (Karim, *et al.,* 2000, Spiertz, 1979). Over the range of 12° to 26°C increase in mean temperature during grain filling, grain weight was reduced at a rate of 4 to 8 percent/°C (Wardlaw *et al*., 1980; Wiegand and Cuellar, 1981).

Identification of wheat genotypes or crop characters of wheat suitable for heat stress condition would be an important step for achieving high yield potential of wheat. In Bangladesh, although some varieties were identified for late sowing time (Islam *et al.,* 1993 and Ahmed *et al.,* 1975) their heat tolerance is still obscured under short winter. However, the heat tolerance of wheat genotypes can be determined through empirical (yield performance) and/or analytical (physiological trait) methods.

Therefore, considering the above facts in view the present investigation was undertaken with the following objectives-

i. To find out the suitable sowing date of different wheat genotypes.
ii. To optimize the grain filling rate by growth study and increase the yield.

Chapter 2
Review of literature

Chapter II

REVIEW OF LITERATURE

Hexaploid wheat is a winter crop in Bangladesh. The optimum seeding time in Bangladesh is November 15 to November 30 (Anon., 2000) but the average winter temperature of this country is not favorable for both early and late planting of wheat. Time of sowing has a major yield is strongly dependent up on sowing time in cereals. In such conditions, the variation in weather from year to year makes it difficult to predict the optimum sowing time for wheat (Mahdi *et al.*, 1998). The successful growth of this crop is largely depending on the winter temperature variations. Temperature requirement of crop also varied depending on growth stages the optimum temperature for wheat crop growth is about 20° C (Al-khatib and Paulsen, 1984) and prolonged exposure to temperature exceeding 35 °C is not tolerable (Gusta and Chen, 1987 and Blum, 1988). Temperature in the range of 20 to 25 °C has been considered favorable in wheat for germination, seedling emergence and plant establishment (Behl *et al.*, 1993). Greater than 25 °C temperature might depress the rate of leaf appearance (Kirby and Perry, 1987). Mean temperature of 16 to 20 °C is favorable for tillering (Behl *et al.*, 1993). The optimum temperature for reproductive stage of wheat lies with a range of 22 to 26 °C (Al-Khatib and Paulsen, 1990; and Campbell and Read, 1968). However, kernel-filling temperature is the most important for wheat crop (Randall and Moss, 1990).

Heat stress during reproductive stage is recognized as one of the serious problem in early and late seedling wheat and thus limits productivity in many regions of the world, countries between 23 °N and 23 °S latitude (Fischer and Byerlee, 1991) including Bangladesh. Heat tolerance mechanism of wheat is to be investigated for developing heat tolerant genotypes for the tropics. Studies on the physiological aspects of heat tolerance and screening of the heat tolerant wheat genotypes are important component for it. Many works have been done in this area in different wheat growing countries but little work has been done in our country.

In this chapter, attempt has been made to review some of the available information on the effect of sowing time and variety on grain growth and yield of wheat.

2.1 Effect of Sowing Date on Grain Growth and Yield of Wheat

Dagash *et al.* (2014) conducted a field experiments at the College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Khartoum, during winter season in 07-08 and 08-09, to investigate the effect of sowing dates on yield and yield attributes of wheat (*Triticum aestivum* L.), local variety (Wadi Elneel). Three sowing dates namely; early November, mid-November and early December were chosen and applied. Generally, crop sown at mid-November produced higher grain yield, total dry matter and tallest plant for season 07-08. Also higher plant height and harvest index were recorded for season 08-09. The early sown (early November) obtained greater 1000-seed weight and harvest index for season 07-08 and higher amount of 1000-seed weight and total dry matter for season 08-09. The late sown (early December) produced higher grain yield for season 08-09.

Kumar *et al.* (2013) carried out a field experiment at Agronomical Research Farm of Birsa Agricultural University, Ranchi, India to assess the performance of new wheat varieties under timely and late sown condition. The experiment was laid out in split plot design replicated four times. The treatment comprised of 2 dates of sowing i.e. 25th November and 20th December in main plots and five wheat varieties Raj 4229, K 0906, K 0307, HD 2733 and DBW 39 in sub plots. The normal sowing of wheat (25th November) resulted 14.7 per cent higher in spike/m^2 (398 spikes/m^2), 15.15 per cent more number of grain per spike (38 grains/spike), 45.16 per cent higher grain yield (51.04 q/ha), Rs.18629.32 higher net return and 88.73 % higher benefit: cost ratio (1.34) over the 20th December sowing.

Amrawat *et al.* (2013) conducted a field experiment during *rabi* season of 2011 to 2012 at Maharana Pratap University of Agriculture and Technology, Udaipur to study the phenology, accumulated growing degree days, photo thermal unit, Helios-thermal unit, heat use efficiency and performance of wheat varieties grown under different sowing dates. The crop was sown on 5th November took maximum calendar days, growing degree days, photo thermal unit, Helios-thermal unit to attend different phenological stages till maturity which reduced significantly with subsequent delay in sowing time. The grain yield recorded in 5th November was statistically at par with 20th November. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond 20th November. The variety Raj 4037 recorded the highest grain yield at 5th November sowing as compared to all other sowing dates.

Sokoto and Singh (2013) conducted a field experiments during 2009-10 and 2010-11 dry seasons at the Fadama Teaching and Research Farm of the Usmanu Danfodiyo University, Sokoto, in Nigeria to study the effect of water stress, sowing date and cultivar on yield and yield components of wheat (*Triticum aestivum* L.). The treatments consisted of factorial combination of water stress at three critical growth stages which was imposed by withholding water at tillering, flowering, grain filling and control (no stress), four sowing dates (21st November, 5th December, 19th December and 2nd January) and two bread wheat cultivar (Star 11 TR 77173/SLM and Kuaz/Weaver), laid out in a split-plot design with three replications. Results indicated significant ($P < 0.05$) effect of sowing date on length of spike, spikelets per spike, grains per spike and grain yield. Early sown wheat significantly differed from the late sown wheat in all parameters measured. Yield and yield components decreased with delay in sowing date and it was highest at 21st November and 5th December and lowest at 19th December and 2nd January, therefore wheat should be sown in November or at least first week of December in this area and other area with similar climate.

El-Sarag and Ismaeil (2013) stated that agriculture is inherently sensitive to weather and climate especially water supply and heat changes. Adaptation of an appropriate economic management strategy is one of the likely decisions to cope with the impacts of climate changes. The effect of the potential impact of three sowing dates; first sowing date (16th Novembe), second sowing date (1st December) and third sowing date (16th December) on two wheat cultivars (Giza 168 and Sakha 93) under three levels of water stress (irrigation every: 10; 15 and 20 days) was studied at the Farm of Environmental Agricultural Sciences Faculty, El-Arish, during two winter seasons (2009/2010; 2010/2011). Results showed that the Second Sowing Date gave superiority of wheat grain yield and most of its components, in response to increasing heat temperature at anthesis stage.

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

Baloch *et al.* (2012) assessed the effect of planting time (October-20, October-30, November-10, November-20, November-30, December-10, December-20 and December-30) on wheat (var. Zam-04, Gomal-8, Hashim-8, candidate lines DN-62 and DN-76) at the Agricultural Research Institute (ARI), Dera Ismail Khan during the year 2008-09. The results revealed that wheat planted on October-20 and October-30 produced higher spike length, 1000-grain weight, plant height and grain yield with a comparable number of tillers and number of grains per spike. There was 7.2% reduction in grain yield on October-30 as compared to optimum planting time October-20. This reduction was subsequently increased up to 38.9% on December-30 sowing. The interaction between varieties and sowing dates was highly significant on wheat grain yield and its attributes.

Anwar *et al.* (2011) conducted study was planned to determine the proper time of sowing for promising wheat genotypes and to compare their yield behavior with already approved cultivars. Four already approved varieties of wheat i.e. Inqilab-91, Uqab-2000 , Shafaq-2006, Seher-2006 and eight new promising lines i.e. V-03079, V-04188, V-04189, V-03094, V-03138, V-04022, V-04112 and V-04178 were sown at six sowing dates with 10 days interval, i.e. 1-Nov, 10-Nov, 20-Nov, 30-Nov, 10-Dec, and 20-Dec. The experiment was laid out in split plot design keeping sowing dates in main plots and genotypes in subplots. The grain yield of most of the genotypes was highest on the sowing date 20-Nov, except genotypes V-03094 and V-04022, which gave highest yield on 10-Nov and genotypes V-03138 and V-04178, which produced highest yield on sowing date of 1-Nov. Most of the genotypes produced lesser yield at later sowing dates; however, this response was different amongst genotypes.

Nahar *et al.* (2010) evaluated five modern varieties of wheat ‘Sourav’, ‘Pradip’, ‘Sufi’, ‘Shatabdi’ and ‘Bijoy’ under two growing environments; one is normal growing environment (sowing at November 30) and the other is post anthesis heat stressed environment (sowing at December 30). In the normal sowing treatment, the germination period was lower than the late sowing treatment as during that time the temperature was higher as compared to late sowing condition where temperature was lower. Days to anthesis and booting decreased due to late sown heat stress condition regardless the cultivars. Due to heat stress, the yield reduction was 69.53% in 'Sourav', 58.41% in 'Pradip', 73.01% in 'Sufi', 55.46% in 'Shatabdi' and 53.42% in 'Bijoy'.

Tahir *et al.* (2009) conducted a field experiment at Faisalabad, Pakistan conducted during winter 2005-06, the effect of 3 sowing dates December 1, 15 and 30 on three wheat cultivars Inqlab-91, AS-2002 and Bhakkar-2002 was studied. Sowing dates and varieties both significantly affected the number of fertile tillers m^{-2}, plant height, number of spikelets per spike, 1000-grain weight and grain yield. In case of sowing dates significantly maximum grain yield (4289.54 kg ha^{-1}) was obtained when crop was sown on 1 December against the minimum grain yield (2109.50 kg ha^{-1}) in case of late sowing i.e. 30 December.

Qasim *et al.* (2008) conducted a study on growth and yield response of three wheat (*Triticum aestivum* L.) varieties (Suliman- 96, Chakwal-97 and lnqalab-91) to various sowing times at Karakoram Agricultural Research Institute, (Northern Areas) Gilgit, Pakistan during the year 2003-04. Three sowing dates *viz.* November 15, November 30 and December 15 were tested. Early planted wheat yielded maximum grains per spike (44.14), plant height (79 81 cm), 1000-grain weight (39 17 g) grain yield (41G5 7 kg/ha) and straw yield (6814.2 kg/ha). Effect of varieties x sowing dates interaction was highly significant on number of tillers per square meter and grain yield. Suliman-96 produced higher and statistically similar grain yield (4111.00 - 4243 75 kg/ha) at all sowing dates followed by Chakwai-97 (3750 00 to 3825 00 kg), lnqalab- 91 produced the lowest (1955.00 - 2195.00 kg).

Haider (2007) analyzed the effect of three different sowing dates on growth of four varieties of wheat using functional techniques. Crop growth rate (CGR), relative leaf growth rate (RLGR) and specific leaf area (SLA) was higher in the early sown plants compared to late sown plants. Net assimilation rate (NAR) in all the varieties increased slowly at the early stages of growth while it increased sharply at the later stages with fluctuations in most cases.

Singha *et al.* (2006) conducted an experiment on three different sowing dates (first, 18 November 2002; second, 29 November 2002; and third, 10 December 2002) to generate information on the effect of high temperature on yield and yield components which would help in developing high temperature stress tolerant genotypes on a set of 14 diverse genotypes under different temperature regimes in the cropping period. It was found that with the increase in temperature (maximum and minimum) during grain filling period, all the yield components were reduced in mean values ranging from 4.77 to 10.05%. Consequently, maximum reduction in grain yield per plant, grain filling period and 1000-grain weight was observed in the third date of sowing as compared to the first date.

Patil *et al.* (2003) conducted an experiment involving 6 early wheat cultivars and 5 sowing dates, i.e. 15 November, 1 December, 15 December 1999, and 1 January and 15 January 2000. The total biomass at maturity, grain number per spike, 1000-grain weight and yield/m2 decreased significantly with delay in sowing. Amongst cultivars, AKW-381 was found suitable for late sowing, as it exhibited tolerance to high temperature during grain growth phase. The heat unit requirement for flowering varied according to sowing date and cultivars.

Sarkar *et al.* (2001) conducted a study on 15 cultivars sown on 30 November 1996 (early sowing), 16 December 1996 and 14 January 1997 (late sowing), and subjected to high temperature stress during the cropping period. Early maturing genotypes like HD2285, HD2307, Sonalika UP2338, Lok and C306 showed better performance under high temperature stress conditions with less reduction in grain yield, and had relatively higher grain growth rates with more tolerance to heat stress for most of the yield-attributing characters (low S values).

Sikder *et al.* (1999) in a field experiment, ten wheat *(Triticum aestivum)* cultivars were exposed to two sowing times i.e. optimum sowing time (November 30) and late sowing (December 30). In the November 30 sowing, both the tolerant and sensitive cultivars had the similar grain filling duration (40 days). However, in December 30 sowing, the tolerant cultivar had longer grain filling duration (32 days) compared to the sensitive cultivar (28 days). In both sowing times the heat tolerant cultivar had higher grain growth rate compared to the sensitive cultivar. In December 30 sowing both the tolerant and moderately tolerant, cultivars showed lower pre-anthesis stem reserves contribution to the final grain weight compared to November 30 sowing. But the heat sensitive cultivars had higher pre-anthesis stem reserves contribution at December 30 sowing times.

Rasal *et al.* (2006) found that heat stress reduced the grain yield by 17.45%. NIAW 1500, NIAW 1498, NIAW 1501 and NIAW 1502 had low heat susceptibility indexes for grain yield, and were found to be heat-tolerant. The duration and thermal requirements for physiological maturity decreased due to heat stress under late sowing times. The maturity duration of the crop sown on 20 December was reduced by approximately 15 days due to the prevalence of high temperature during the reproductive phase. NIAW 1423, NIAW 1461, N1AW 1422 and NIAW 1417 required the lowest number of heat units, whereas NIAW 1483, NIAW 1428 and NIAW 1429 required the highest number of heat units to attain physiological maturity.

The plant height of barely was significantly influenced by date of sowing. In an experiment carried out by Moula (1999) to study the effect of sowing time on growth and development of barley varieties and reported that the tallest plant was recorded by November 25 sowing (111.8 cm) and the shortest plant was recorded by December 25 sowing (73.8 cm).

A field experiment was conducted by Chowdhury (2002) at four sowing dates viz. sown at November 1, November 15, November 30 and December 15 and reported that the highest grain yield was recorded in November 15 sown plants and the next highest value was recorded in November 30 sown plants and the lowest yield was recorded in December 15 sown plants. He also reported that delay in sowing decreased plant height. At the final harvest highest plant height was observed in November 1 sown plant. However, at 60 DAS highest plant height was recorded in December in 15 sown plants. The highest number of average tillers plant^{-1} were produced by November 15 sown wheat plants and the second highest number were produced by November 30 sown plants, which was at par with November 1 sown plants. The lowest number of tillers plant^{-1} were produced by December 15 sown plants. Spike length, grains spike^{-1} and 1000-grain weight decreased with delay in sowing date from November 15 and the lowest spike length, grains spike^{-1} and 1000-grain weight were recorded in December 15 sown plants.

Haider (2002) conducted experiment with two sowing dates and reported that November 15 sown plants produced significantly higher grain yield in both the years for all the irrigation regimes and varieties of wheat and the lowest yield was recorded in December 5 sown plants. November 15 sown plants of all cultivars of wheat under each irrigation regimes were found to be taller than December 5 sown wheat plants. Early sown plants (November 15) had the highest spike length, grains spike^{-1} and 100-grain weight and late sown plants (December 5) resulted the lowest values of these parameters of wheat.

Many scientists also reported the associations of yield and effective tiller. Shrivastava *et al.* (1998) studied relationship between various traits in wheat. They reported that yield had significant positive correlation with effective tillers per plant.

A field experiment was conducted by Ahmed *et al.* (2006) at Farming System Research and Development (FSRD) site, Chabbishnagar, Godari, Rajshahi under rainfed condition during rabi seasons to find out the suitable variety and sowing time (30 November, 15 December and 30 December). They concluded that number of tiller increased significantly with early sowing (30 November) in all varieties in both the years. Grain and straw yields increased significantly with early sowing (30 November) in all varieties. The results show that early sowing (30 November) gave the highest grain (2.55 t/ha) and straw yield (4.28 t/ha), whereas the lowest grain yield (1.23 t/ha) and straw yield (3.21 t/ha) was obtained from delay sowing.

Zhao *et al.* (1985) conducted experiments on barley in Chinaunder 2 different sowing dates, viz., October 28 and November 17 in 1982-83 and November 7 and November 27 in 1983-84. They 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. The full growth period was shortened with delay in sowing.

Sekhon *et al.* (1991) reported that early sowing decreased the number of spikelets spike^{-1}, grains spike^{-1} but increased 1000-grain weight and yield of wheat. They also reported that late sowing decreased 1000-grain weight and yield.

Ryu *et al.* (1992) concluded that the highest grain weight of barley was reached at 40 days after heading in early and intermediated sowing and 35 days in late sowing.

Eissa *et al*. (1994) observed that spikes m^{-2} and grains spike^{-1} were significantly increased while grain weight non-significantly decreased as sowing date was delayed from November to December.

Zende *et al.* (2005) conducted an experiment during the 2002/03 rabi season in Akola, Maharashtra, India, to evaluate the effects of sowing time (15 November, 1 December and 15 December) on the growth and yield of durum wheat (*Triticum durum)* and concluded that the growth, yield and yield attributes, except for the spike length, showed significant increases when durum wheat crops were sown on 15 November compared with those sown on 1 December and 15 December.

Hossain *et al.* (1990) observed that maximum grain yield was obtained when the wheat was sown November 20 due to higher number of grains $spike^{-1}$ and the highest 1000-grain weight.

Comy (1995) concluded from two years study in Ireland on malting barley cv. Blenhiem sown on March, early April and late April that the earliest sown spring barley generally gave the highest yield and the best quality grain .

BARI (1997) reported from the study in Jamalpur during the rabi season that among the five sowing dates viz. November 5, November 20, December5, December 20 and January 5, the grain yield was statistically different among those sowings. The crop sown on December 20 produced the lowest grain yield which was closely followed by that of January 5 sowing. A drastic reduction in grain yield was observed when the crop was sown on December 5 or later.

Farid *et al*. (1993) conducted an experiment on sowing dates having five sowing times started from November with 15 day intervals with three cultivars. They observed that November 5 was found to be the optimum time for AP-1-20 and November 5 to December 5 for Centinella and AP-1-20, respectively. In general, all the cultivars performed better when sown on November 5. In all cases yield was reduced significantly with delayed sowing beyond December 20.

In a trial with cultivar Balaka in Joydepur and Jessore, BARI (1984) reported that the tallest plant (76.83 cm) was obtained at Jessore when sowing was done on 20 November and shortest with 30 December sowing. They also observed that the highest number of effective tillers $plant^{-1}$ was obtained by 20 November sowing. Similar results have also been observed by Farid *et al.* (1993) and Sarker *et al*. (1999).

Rasal *et al.* (2006) found that heat stress reduced the grain yield by 17.45%. NIAW 1500, NIAW 1498, NIAW 1501 and NIAW 1502 had low heat susceptibility indexes for grain yield, and were found to be heat-tolerant. The duration and thermal requirements for physiological maturity decreased due to heat stress under late sowing times. The maturity duration of the crop sown on 20 December was reduced by approximately 15 days due to the prevalence of high temperature during the reproductive phase.

Singha *et al.* (2006) conducted an experiment on three different sowing dates (first, 18 November 2002; second, 29 November 2002; and third, 10 December 2002) to generate information on the effect of high temperature on yield and yield components which would help in developing high temperature stress tolerant genotypes on a set of 14 diverse genotypes under different temperature regimes in the cropping period. It was found that with the increase in temperature (maximum and minimum) during grain filling period, all the yield components were reduced in mean values ranging from 4.77 to 10.05%. Consequently, maximum reduction in grain yield per plant, grain filling period and 1000-grain weight was observed in the third date of sowing as compared to the first date.

Sial *et al.* (2005) conducted an experiment to evaluate the effects of the time of sowing and heat stress on the yield and yield-associated traits of wheat twenty genotypes under 2 sowing dates, i.e. optimum sowing (9 November) and late sowing (12 December). Heat stress (from 33 to 43 $^{\circ}$C) during the grain filling periods had significant effects on plant height, 1000-grain weight, and grain yield. Delayed planting adversely affected the yield and yield components of wheat genotypes. All the genotypes produced significantly higher grain yields under optimum sowing than under late sowing.

Munjal *et al.* (2004) observed that the mean performance of grain yield and days to heading were significantly higher under optimum conditions than under late sowing times in twenty wheat cultivars.

Patil *et al.* (2003) conducted an experiment involving 6 early wheat cultivars and 5 sowing dates, i.e. 15 November, 1 December, 15 December 1999, and 1 January and 15 January 2000. The total biomass at maturity, grain number per spike, 1000-grain weight and yield/m^2 decreased significantly with delay in sowing. Amongst cultivars, AKW-381 was found suitable for late sowing, as it exhibited tolerance to high temperature during grain growth phase. The heat unit requirement for flowering varied according to sowing date and cultivars.

Sarkar *et al.* (2001) conducted a study on 15 cultivars sown on 30 November 1996 (early sowing), 16 December 1996 and 14 January 1997 (late sowing), and subjected to high temperature stress during the cropping period. Early maturing genotypes like HD2285, HD2307, Sonalika UP2338, Lok and C306 showed better performance under high temperature stress conditions with less reduction in grain yield, and had relatively higher grain growth rates with more tolerance to heat stress for most of the yield-attributing characters (low S values).

Sikder *et al.* (1999) in a field experiment, ten wheat (*Triticum aestivum*) cultivars were exposed to two sowing times i.e. optimum sowing time (November 30) and late sowing (December 30). Based on the cell membrane thermo-stability (CMT) test four cultivars (eg. Ananda, Pavon, Aghrani, and Barkat) took maximum heat killing time and were classified as relatively heat tolerant, three cultivars (eg. Akbar, Kanchan, and Protiva) are moderately heat tolerant and the other three cultivars (eg. Balaka, Sawgat, and Sonora) took the lowest heat killing time and are considered as heat sensitive. In the November 30 sowing, both the tolerant and sensitive cultivars had the similar grain filling duration (40 days). However, in December 30 sowing, the tolerant cultivar had longer grain filling duration (32 days) compared to the sensitive cultivar (28 days). In both sowing times, the heat tolerant cultivar had higher grain growth rate compared to the sensitive cultivar. In December 30 sowing both the tolerant and moderately tolerant .cultivars showed lower pre-anthesis stem reserves contribution to the final grain weight compared to November 30 sowing. Nevertheless, the heat sensitive cultivars had higher pre-anthesis stem reserves contribution at December 30 sowing times.

Cargnin *et al.* (2006) carried out an experiment in the field at summer (heat stress condition) and winter (optimum condition) of 2004. Number of days to heading, plant height, average grain weight, and grain yield were evaluated. In the summer, high temperature reduced the values of all the characters evaluated.

Tyagi *et al.* (2003) evaluated Twenty-five wheat (*Triticum aestivum* L.) genotypes for their yield performance under two sowing dates viz., 20 November (normal) and 21 December (late) during rabi (winter) season of 2000-01 at Agronomy Research Farm of CCS Haryana Agricultural University, Hisar (29°10' N latitude, 75°46' E longitude and 215 M altitude). The results revealed that number of grains spike^{-1}, grain and biological yield were reduced significantly under late sown condition. The 31-day delay in sowing beyond 20 November reduced the grain yield from 5587 to 4410 kg ha.$^{-1}$ i.e. 21.1

percent. Genotypes PBW 484 (6716 kg ha^{-1}), WR 251 (6617 kg ha^{-1}), UP 2425 (6457 kg ha^{-1}), HUW 234 (6358 kg ha^{-1}) and PBW 435 (6235 kg ha^{-1}) were highest grain yielder under normal sown condition. Whereas PBW 483 (5284 kg ha^{-1}), HD 2428 (4926 kg ha^{-1}), NIAW 612 (4915 kg ha^{-1}), NIAW 34 (4864 kg ha^{-1}) and PBW 435 (4815 kg ha^{-1}) were highest grain yielder under late sown condition. The stress tolerance index was highest in genotypes PBW 435 (0.96) followed by UP 2425 (0.95) and HUW 234 (0.94).

Neog *et al.* (2001) conducted a study to know the effect of temperature on grain growth period and grain yield of wheat during the winter season of 1993~94 at Ludhiana. Wheat variety HD. 2329 was sown in five different micro-environments, which were created by manipulating sowing dates. Post-anthesis stages like flowering and grain filling of crop sown on different date were exposed to different temperature environments. Grain growth period (from anthesis to maturity) of the crop was strongly responsive to the air temperature and it was, reduced significantly at high temperature. A linear relationship between average maximum and minimum air temperature and number of days from anthesis to maturity was found which explained 71 percent variation in grain growth period due to variation in maximum and minimum air temperature during this period. High temperature at reproductive growth stage reduced the number of grains per ear and test weight, which were negatively and significantly associated with temperature, which led to reduction in grain yield significantly at high temperature.

Patil *et al.* (2005) conducted a field experiment to study the physiological traits associated with terminal temperature tolerance. Under late sown irrigated wheat results revealed a significant differential genotypic variation for physiological traits with respect to grain yield and its determining attributes under high post anthesis temperature i.e. 4.5-6.8 °C 28°C in late sowing. Genotypes, Halna, K8962, GW 173, HD2189, HD2402 and AKW381 exhibited earliness in their flowering, higher canopy temperature depression (CTD), low membrane thermo-stability index (MTI), greater seed size (1000-grain weight), longer grain growth duration and higher grain yield, thereby showed a greater degree of high temperature tolerance as compared to long duration wheat genotypes. These traits are relatively simple and easily observable and can, therefore, be used to screen large number of wheat germplasm for high temperature tolerance. Based on yielding ability, these genotypes are proposed as suitable donor for crossing program to develop ideal plant type suitable for late sown conditions.

Sardana *et al.* (2005) conducted an investigation to study the effect of planting time and nitrogen application on the yield and quality of durum wheat cultivars. The study revealed significant reduction in grain yield to the extent of 3.2 q ha^{-1} with delay in sowing from 4 November to 19 November.

Dutta *et al.* (2005) conducted a field experiment to study the response of wheat to sowing date-and nutrient level in split plot design on sandy loam alluvial soil of West Bengal. Main-plot consisted of 5 sowing dates, viz., 25 November, 10 December, 25 December, 10 January and 25 January and sub-plot consisted of 5 nutrient levels. Late sowing reduced the grain yield, straw yield, yield attributes, benefit: cost ratio and nutrient-use efficiency of wheat.

Singh *et al.* (2005) conducted a field experiment to study the physiological traits associated with terminal temperature tolerance under late sowing in irrigated wheat. Results revealed a significant differential genotypic variation for physiological traits with respect to grain yield and its determining attributes under high post anthesis temperature i.e.+or-4.5-6.8° C>28° C in late sowing. Genotypes, Halna, K8962, GW 173, HD2189, HD2402 and AKW381 exhibited earliness in their flowering, greater seed size (1000-grain weight), longer grain growth duration and higher grain yield, thereby showed a greater degree of high temperature tolerance as compared to long duration wheat genotypes.

Viswanathan and Chopra (2001) reported that heat susceptibility index (S) revealed that grain weight was less susceptible to heat in Sonalika and PBW 154 than in Hindi62. Heat stress reduced both the grain growth duration (GGD) and the grain growth rate (GGR). The grain weight reduction in PBW 154 and Sonalika was mainly due to a reduction in GGR, while that of Hindi62 was due to a reduction in GGD.

Jhala and Jadon (1989) studied that grain growth rate (mg/spike per day) from the 1^{st} to the 8th week after anthesis (WAA) in 15 wheat cultivars sown on 15 November (optimum date) or 30 November. There were significant differences among cultivars for grain growth rate especially during 1^{st} 4 WAA. Grain growth rate was highest in the 3^{rd} and 2^{nd} WAA for crops sown on 15 November and 30 November respectively. Grain growth rate was higher in crops sown on 15 November and 30 November than in those sown on 30 November. Cv. Lok 1, WH 147, HI 784, Kalyansana and HJ 74- 27 had initial high grain growth rate and could be used for breeding cultivars suitable for late sown conditions.

Schapendonk *et al.* (2007) had conducted an experiment to assess the mechanisms causing genotypic differences in heat tolerance of wheat and concluded that heat shock at the 'end of tillering' strongly reduced the rate of leaf photosynthesis. A similar heat shock during 'grain filling' decreased both rate of photosynthesis (source) and grain growth (sink). The rate of leaf photosynthesis was decreased by 40 to 70%, depending on cultivar and developmental stage. Photosynthesis fully recovered within 4 days after the heat-shock treatment was ended. The effects of the heat shock on biomass yield were more pronounced for treatments at 'early grain filling' than at 'end of tillering'.

2.2 Effect of Variety on Grain Growth and Yield of Wheat

Kumar *et al.* (2013) carried out a field experiment at Agronomical Research Farm of Birsa Agricultural University, Ranchi, India to assess the performance of new wheat varieties under timely and late sown condition. Among the varieties significantly higher grain yield (45.44 q/ha), straw yield (64.44 q/ha) net return (Rs.31093.04) and benefit: cost ratio (1.14) were obtained with wheat variety K 0307 over the rest of the four varieties i.e. Raj 4229, K 0906, HD 2733 and DBW 39.

Amrawat *et al.* (2013) conducted a field experiment during *rabi* season of 2011 to 2012 at Maharana Pratap University of Agriculture and Technology, Udaipur to study the phenology, accumulated growing degree days, photo thermal unit, Helios-thermal unit, heat use efficiency and performance of wheat varieties grown under different sowing dates. Among the varieties highest grain yield of 62.81 q ha^{-1} was recorded in varieties Raj 4037, which was significantly superior over HI-1544 (58.75 q ha^{-1}) and MP-1203 (50.32 q ha^{-1}). Among the varieties MP-1203 took highest calendar days growing degree days, photo thermal unit and Helios-thermal unit to reach the maturity.

El-Sarag and Ismaeil (2013) studied the effect of the potential impact of three sowing dates; first sowing date (16th November), second sowing date (1st December) and third sowing date (16th December) on two wheat cultivars (Giza 168 and Sakha 93) under three levels of water stress (irrigation every: 10; 15 and 20 days) at the Farm of Environmental Agricultural Sciences Faculty, El-Arish, during two winter seasons (2009/2010; 2010/2011). Most of growth characters, grain yield and its components of

Sakha 93 cultivar were greater than Giza 168 under both stressed and non-stressed conditions; this cultivar could be adapted to heat and water stress more than the other one in relation to its genetic stability under unfavorable conditions and its positive response to late sowing date.

Baloch *et al.* (2012) assessed the effect of planting time (October-20, October-30, November-10, November-20, November-30, December-10, December-20 and December-30) on wheat (var. Zam-04, Gomal-8, Hashim-8, candidate lines DN-62 and DN-76) at the Agricultural Research Institute (ARI), Dera Ismail Khan during the year 2008-09. However, there was no statistical difference among wheat varieties for grain yield.

Tahir *et al.* (2009) conducted a field experiment at Faisalabad, Pakistan conducted during winter 2005-06, the effect of three sowing dates December 1, 15 and 30 on three wheat cultivars Inqlab-91, AS-2002 and Bhakkar-2002 was studied. Varieties significantly affected the number of fertile tillers m^{-2}, plant height, number of spikelets per spike, 1000-grain weight and grain yield. Among of varieties Inqlab-91 gave significantly maximum yield (3550.44 kg ha^{-1}) while minimum yield (2932.59 kg ha^{-1}) was obtained by AS-2002.

Qasim *et al.* (2008) conducted a study on growth and yield response of three wheat (*Triticum aestivum* L.) varieties (Suliman- 96, Chakwal-97 and lnqalab-91) to various sowing times at Karakoram Agricultural Research Institute, (Northern Areas) Gilgit, Pakistan during the year 2003-04. Maximum tillers were in lnqalab-91 (302.17) while Suliman-96 topped in grain yield (3387.33 kg/ha). Suliman-96 produced higher and statistically similar grain yield (4111.00 – 4243.75 kg/ha) followed by Chakwai-97 (3750.00 to 3825.00 kg), lnqalab- 91 produced the lowest (1955.00 - 2195.00 kg)

Maiksteniene *et al.* (2006) carried out a field experiment at the Lithuanian Institute of Agriculture’s Joniskelis Experimental Station during 2004-2005 to estimate the changes in productivity and quality indicators of winter wheat varieties. The tests involved: Ada and Bussard (with very good food qualities), Lars and Tauras (with satisfactory food qualities) varieties. The higher grain yield was produced in varieties with satisfactory food qualities compared with those with very good food qualities. The highest contents of protein for grain quality improvement at ripening stage without urea solution application were accumulated by the varieties.

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

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

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

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

Litviurnko *et al.* (1997) produced winter wheat with high grain quality for bread making in Southern Ukraine. Wheat breeding was started more than 80 years ago. Over this time, seven wheat varieties were selected where yield potential increased from 2.73 to 6.74 t ha^{-1}.

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

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

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

Rahman *et al.* (1997) found from a field experiment that Genotypes varied significantly for all traits studied, except spikes/m^2 and biomass at anthesis. Barkat/Buc, Akbar, Fang 60, Kanchan and Fyn/Pvn were identified as the top yielding genotypes. The lowest yielding genotypes Pavon 76 and Seri 82 had relatively high biomass production at harvest, but low values for harvest index. They also produced the lowest sized grains, weighing around 15 g for 1000-grains. Grain yield was positively associated with biomass, harvest index, grain production rate, 1000- grain weight and chlorophyll content, and negatively correlated with CT and days to anthesis.

Sardana *et al.* (2005) conducted an investigation to study the effect of planting time and nitrogen application on the yield and quality of durum wheat cultivars. The study revealed that cultivars differed significantly for grain yield with PDW 233 producing the highest yield. Whereas, 1000-kernel weight was the highest in cultivar PBW 34.

Chapter 3
Materials and Methods

CHAPTER III

MATERIALS AND METHODS

An experiment was conducted at the Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka-1207 during the winter season (November 13 to March 14), 2012 on an upland soil to study on suitable sowing date for different wheat genotypes to optimize the grain filling rate. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1. Location

The study has been conducted in the experimental field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka. The location of the site was 23°74' N latitude and 90°35' E longitude with an elevation of 8.2 meter from sea level.

3.1.2. Soil

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

3.1.3 Climate

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

3.2 Experimental details

3.2.1 Treatments

The experiment comprised of two factors.

Factor A: Variety: 4

i. V_1: BARI Gom-21
ii. V_2: BARI Gom-24
iii. V_3: BARI Gom-25
iv. V_4: BARI Gom-26

Factor B: Sowing date: 3

i. S_1: 20 November
ii. S_2: 1 December
iii. S_3: 12 December

As a whole 12 (3×4) treatment combinations such as S_1V_1, S_1V_2, S_1V_3, S_1V_4, S_2V_1, S_2V_2, S_2V_3, S_2V_4, S_3V_1, S_3V_2, S_3V_3 and S_3V_4.

3.2.2. Experimental design and layout

The experiment was laid out in two factors Randomized Complete Block Design with three replications. There were 36 plots having size 3 m × 2 m. The 12 treatments were randomly assigned in plots of each replication.

3.3. Growing of crops

3.3.1. Seed collection

The seeds of the test crop varieties of this experiment BARI Gom-21, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were collected from Regional Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.3.2. Preparation of the main field

The plot selected for the experiment was opened in the second week of November 2013 with a power tiller, and was exposed to the sun for a week after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally a desirable tilth of soil was obtained for sowing of seed.

3.3.3. Application of fertilizers and manure

The fertilizers N, P, K and S in the form of Urea, TSP, MoP and Gypsum respectively were applied. The entire amount of TSP, MoP and Gypsum, 2/3rd of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation (BARI, 2006). The dose and method of application of fertilizer are shown in Table 1.

Table 1. The doses and methods of application of fertilizer

Fertilizers	Dose (ha)	Application in plot (%)	
		Basal	1^{st} installment
Cowdung	10 t	100%	-
Urea	220 kg	66.66%	33.33%
TSP	180 kg	100%	-
MoP	50 kg	100%	-
Gypsum	120 kg	100%	-

Source: BARI, 2006

3.3.4. Seed sowing

Wheat seeds were sown continuously in the 20 cm apart rows to rows and 4-5 cm depth at the rate of 120 Kg/ha. The rows were thereafter covered with soil and light pre-sowing irrigation water was applied on the rows.

3.3.5. After care

After the germination of seedlings, various intercultural operations such as irrigation and drainage, weeding, top dressing of fertilizer and plant protection measure were accomplished for better growth and development of the wheat seedlings as per the recommendation of BARI (2006).

3.3.5.1 Irrigation and drainage

Flood irrigation was given as per needed. First irrigation was given at three leaf stage (18 DAS), second at spike initiation stage (58 DAS) and third one at grain filling stage (78 DAS). Proper drainage system was also developed for draining out excess water.

3.3.5.2. Weeding

Weeding was done to keep the plots free from weeds which ultimately ensured better growth and development of wheat seedlings. The newly emerged weeds were uprooted carefully at tillering (30 DAS) and panicle initiation stage (55 DAS) manually.

3.3.5.3. Plant protection

The crop was attacked by different kinds of insects during the growing period. Triel-20 ml was applied on 5 January and Sumithion-40 ml/20 liter of water were applied on 25 January as plant protection measure to control leaf blight of wheat.

3.3.6. Harvesting, threshing and cleaning

The crop was harvested manually from each plot through the last week of March 2014 depending upon the maturity of plant. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning of wheat grain. Fresh weight of wheat grain and straw were recorded plot wise. The grains were cleaned and weighted. The weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of wheat grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.4 Data collection

3.4.1. Dry grain weight

Randomly selected five plants per plot were taken just after anthesis and sun dried and then dried in an oven at 48° C for 3 days. The dry weight of five plants were measured individually in g and averaged.

3.4.2. Days to anthesis

The number of days from sowing to anthesis was counted when anthesis was occurred in 50% ears of each plot.

3.4.3. Days to physiological maturity

The number of days from sowing to physiological maturity was determined when the kernel reaches its maximum dry weight and kernel moisture content between 30 and 40 percent.

3.4.4. Days to maturity

The number of days from sowing to maturity was determined by visual observation of loss of green color in 80% of the plant.

3.4.5. Nodes per stem

Total number of nodes was counted by selecting 10 random plants from each plot and averaged. Thus, total number of nodes in a plant was counted.

3.4.6. Plant height

The height of plant was recorded in centimeter (cm) at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.4.7. Internodes length

It was recorded as the distance (cm) from the node to node, twenty random internodes were selected from different plant of a plot and the average was taken.

3.4.8. Spike length

The length of spike was measured with a meter scale from 10 selected spikes and the average value was recorded.

3.4.9. Spikelet spike^{-1}

The total number of spikelet spike^{-1} was counted as the number of spikelet from 10 randomly selected spikes from each plot and average value was recorded.

3.4.10. Number of tiller per plan

The number of tillers plant $^{-1}$ was recorded at the time of harvest. One square meter area was selected from every plot randomly and the obtained data was multiplied into plot size.

3.4.11. Number of fertile tiller

The tiller which can produce the spike with filled grain can be termed as fertile tiller. One square meter area was selected from every plot randomly to collect the data on fertile tiller.

3.4.12. Number of unfertile tiller

The tiller having no spike was regarded as unfertile tiller. One square meter area was selected from every plot randomly and the obtained data was multiplied into plot size.

3.4.13. 1000 Grain weight

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

3.4.14. Grains spike^{-1}

The total number of grains spike^{-1} was counted as the number of grains from 10 randomly selected spikes from each plot and average value was recorded.

3.4.15. Grain weight spike^{-1}

The total grain weight spike^{-1} was weighed in grams from 10 randomly selected spikes from each plot and average value was recorded.

3.4.16. Grain growth

At anthesis three ears were harvested from each plot to quantify grain growth every fourth day beginning from four days after anthesis. The harvesting of ears in all genotypes was continued up to 24 days after anthesis (DAA). The harvested ears were kept in oven 70 °C for 72 hours. Twenty grains of each genotype were separated from the middle two spikelets of every three ear. Then weight of 20 grains of each genotype was taken with an analytical balance.

3.4.17. Grain Yield (t/ha)

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

3.5 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant differences among the treatments. The mean values of all the characters were calculated and analysis of variance was performed, the significance of the difference among the treatment means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

Chapter IV

RESULTS AND DISCUSSIONS

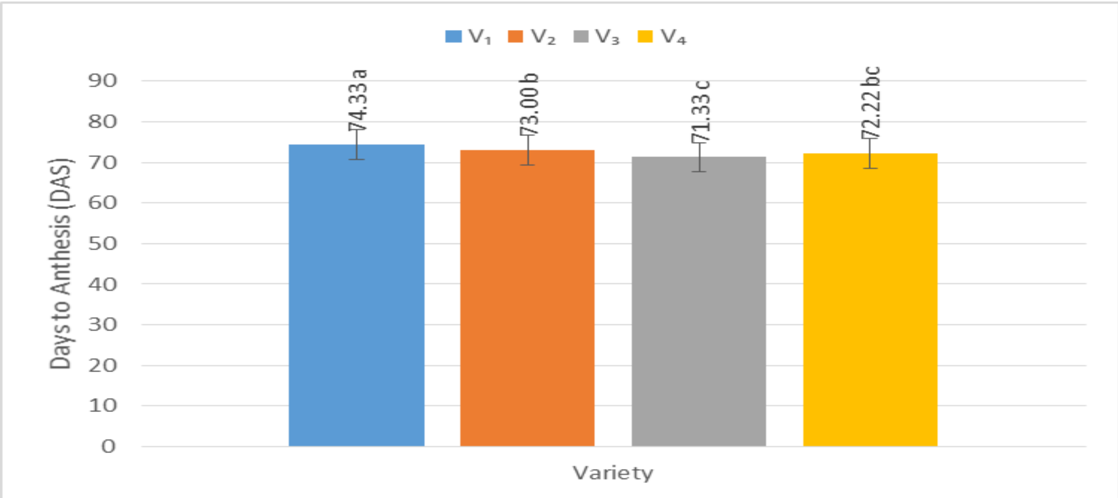
The present study has been conducted to find out the suitable sowing date for the experimental area and to optimize the grain-filling rate by growth study and thus avoid the heat stress. To fulfill these objective four wheat varieties *viz.* V_1: BARI Gom-21 (Shatabdi), V_2: BARI Gom-24 (Prodip), V_3: BARI Gom-25 and V_4: BARI Gom-26 was sown at three different dates *viz.* S_1: 20 November, S_2: 1 December and S_3: 12 December. Performance of different varieties influenced by different sowing date presented in the form of different figures along with adequate discussion and possible interpretation wherever needed.

4.1. Effect of Variety and Sowing Date on Grain Growth and Yield of Wheat

4.1.1. Days to Anthesis

Effect of variety

Considerable varietal difference was observed in days to anthesis (Appendix III & Fig. 1). The maximum time required for anthesis was obtained from BARI Gom-24 (74.33 days), while the minimum (71.33 days) was recorded from BARI Gom-25, which was statistically similar with BARI Gom-26 (72.22 days).



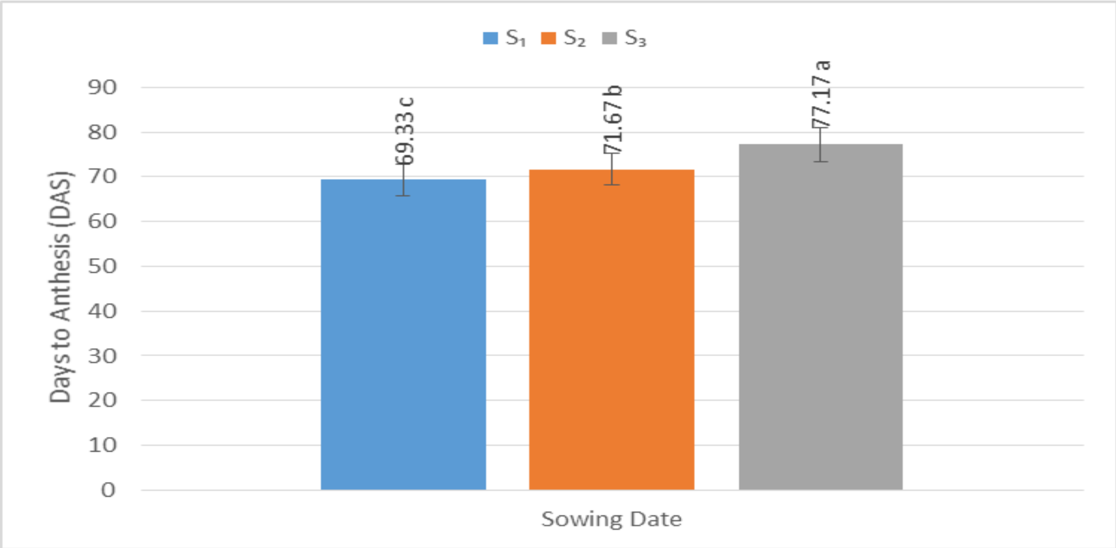
V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 1. Effect of variety on days to anthesis of wheat (LSD 0.05%)

Effect of sowing date

Days to anthesis showed considerable amount of variance due to the sowing date (Appendix III & Fig. 2). The plant those are sown on 20 November (S_1), required lowest amount of time (69.33 days) for anthesis, while the plant which are sown on 12

December (S_3) required the highest amount of time (77.17 days). Normally, delayed sowing shorten the growth period.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 2. Effect of sowing date on days to anthesis of wheat (LSD 0.05%)

Table 2. Interaction effects of variety and sowing date on days to anthesis of wheat

Treatments	Days to Anthesis
$V_1 \times S_1$	71.00 fg
$V_1 \times S_2$	74.00 de
$V_1 \times S_3$	78.00 ab
$V_2 \times S_1$	70.33 gh
$V_2 \times S_2$	70.00 gh
$V_2 \times S_3$	78.67 a
$V_3 \times S_1$	67.00 i
$V_3 \times S_2$	70.33 gh
$V_3 \times S_3$	76.67 bc
$V_4 \times S_1$	69.00 h
$V_4 \times S_2$	72.33 ef
$V_4 \times S_3$	75.33 cd
LSD	1.779
Level of significance	**
CV (%)	1.44

**, *, ^{ns} represent significant at 1%, significant at 5% and non-significant, respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

Interaction effects of variety and sowing date of wheat

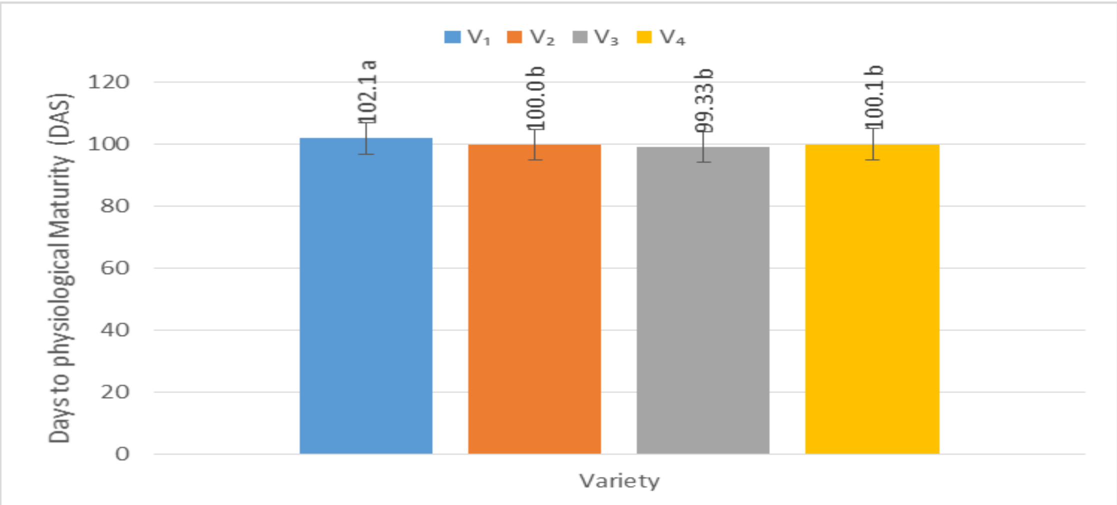
Days to anthesis varied significantly for the interaction effect of variety and sowing date (Appendix III & Table 2). The maximum time required for anthesis were obtained from the combination of V_2S_3 (78.67 days) followed by V_1S_3 (78.00 days). While, V_3S_1 (67.00 days) required minimum time to reach anthesis period (Fig. 3)

Variation among the varieties in respect of days to anthesis appeared due to genotypic variation. Delayed sowing condition may need extended time to reach anthesis period. Similar statements were also observed by Wiegand and Cuellar (1981), Asana and Williams (1965), Begga and Rawson (1977) and Jhala and Jadon (1989).

4.1.2. Days to Physiological Maturity

Effect of variety

The varietal difference due to days required to physiological maturity did not vary widely (Appendix II & Fig. 3). The V_1 required the highest time (102.1 days) to reach physiological maturity. While, V_3 required the lowest time (99.33 days) to reach physiological maturity, which was not significantly different from V_2 (100.0 days) and V_4 (100.1 days).

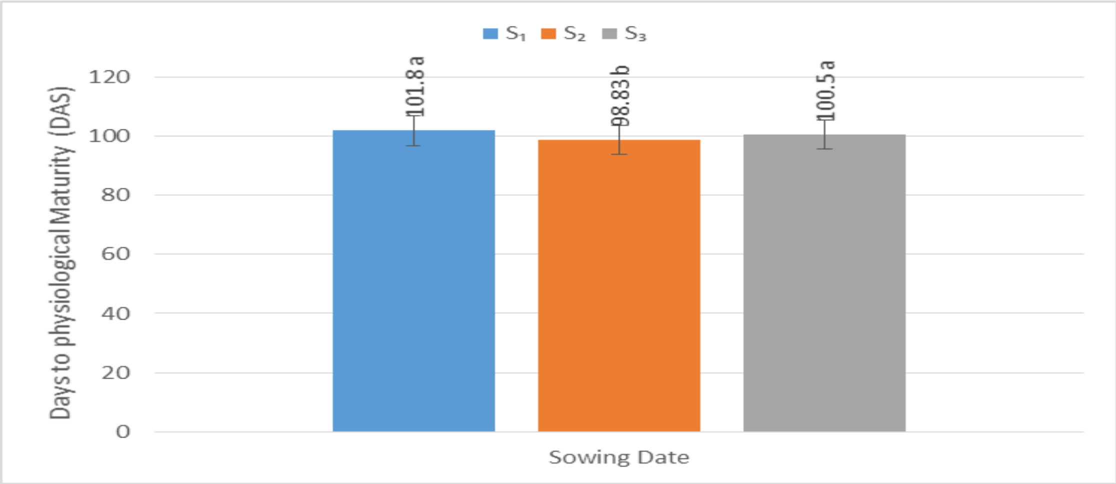


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 3. Effect of variety on days to physiological maturity of wheat (LSD 0.05%)

Effect of sowing date

Different sowing date showed significant variation for days required to obtain physiological maturity (Appendix III & Fig. 4). The V_2 takes minimum time (98.83 days) to reach physiological maturity (fig. 1). On the other hand, V_1 takes maximum days (101.8 days) to obtain physiological maturity, which was statistically similar (100.5 days) with V_3.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 4. Effect of sowing date on days to physiological maturity of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Table 3. Interaction effects of sowing date and variety on days to physiological maturity of wheat

Treatments	Days to physio. Maturity
$V_1 \times S_1$	103.3
$V_1 \times S_2$	101.7
$V_1 \times S_3$	101.3
$V_2 \times S_1$	102.0
$V_2 \times S_2$	97.33
$V_2 \times S_3$	100.7
$V_3 \times S_1$	100.0
$V_3 \times S_2$	97.33
$V_3 \times S_3$	100.7
$V_4 \times S_1$	102.0
$V_4 \times S_2$	99.00
$V_4 \times S_3$	99.33
LSD	-
Level of significance	ns
CV (%)	1.74

**, *, ^{ns} represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

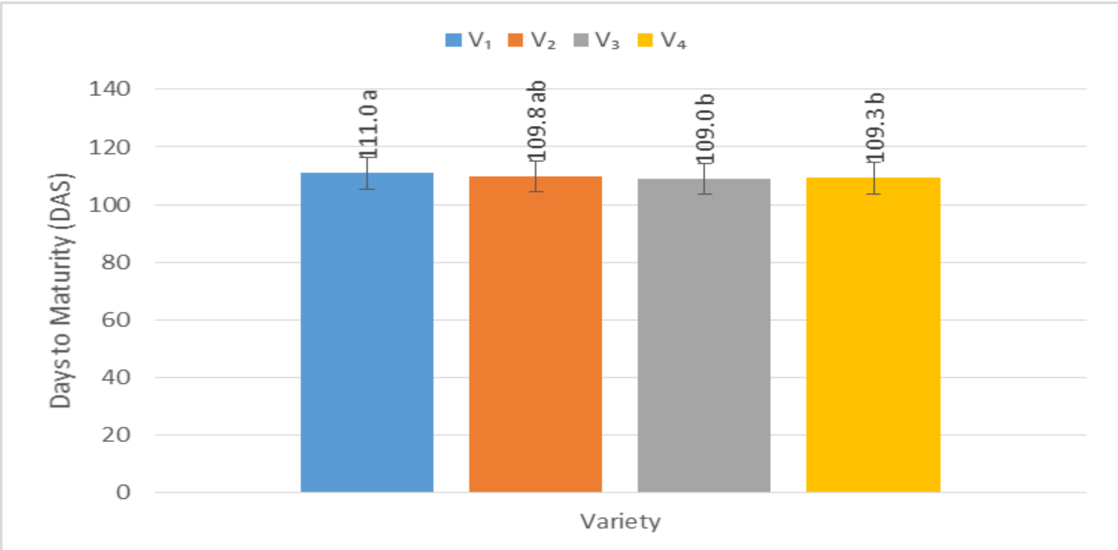
S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

The data pertaining to the days to physiological maturity showed no significant variation among the interaction effect of sowing date and varieties (Appendix III & Table 3). So that no further multiple comparison test were done for this trait.

4.1.3. Days to Maturity

Effect of variety

Days to maturity showed considerable amount of variance among the variety (Appendix III & Fig. 5). The V_3 required lowest duration (109.0 days) to reach maturity, which was statistically similar to V_2 (109.8) and V_4 (109.3 days). On the other hand, V_1 required the highest amount of time (111.0 days) to reach the maturity, which was statistically similar to V_2 (109.8 days).

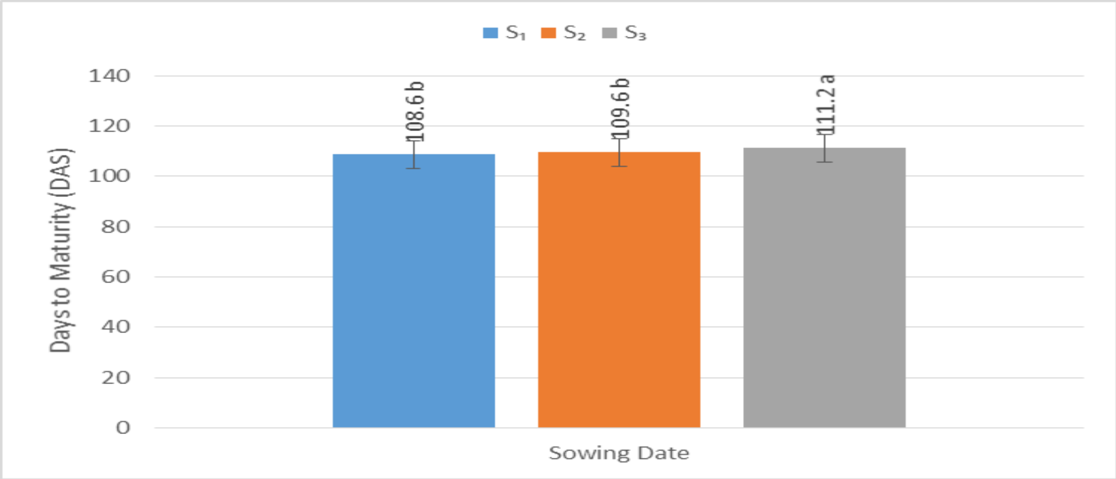


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 5. Effect of variety on days to maturity of wheat (LSD 0.05%)

Effect of sowing date

The days required to maturity, varied significantly due to the sowing date (Appendix III & Fig. 6). The S_3 required the highest time (111.2 days) to reach maturity and differed from that of S_1 and S_2. S_1 and S_2 required statistically similar days (108 days and 109.6 days respectively) to maturity.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 6. Effect of sowing date on days to maturity of wheat (LSD 0.05%)

Interaction effect of variety and sowing date

Interaction effect of variety and sowing date on days to maturity did not differ significantly among the varieties (Appendix III & Table 4). Therefore, LSD test was not applicable for this trait.

Table 4. Interaction effects of sowing date and variety on days to maturity of wheat

Treatments	Days to Maturity
$V_1 \times S_1$	109.3
$V_1 \times S_2$	112.0
$V_1 \times S_3$	111.7
$V_2 \times S_1$	109.7
$V_2 \times S_2$	108.3
$V_2 \times S_3$	111.3
$V_3 \times S_1$	107.3
$V_3 \times S_2$	108.3
$V_3 \times S_3$	111.3
$V_4 \times S_1$	108.0
$V_4 \times S_2$	109.7
$V_4 \times S_3$	110.3
LSD	2.491
Level of significance	ns
CV (%)	1.34

**, *, ^{ns} represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

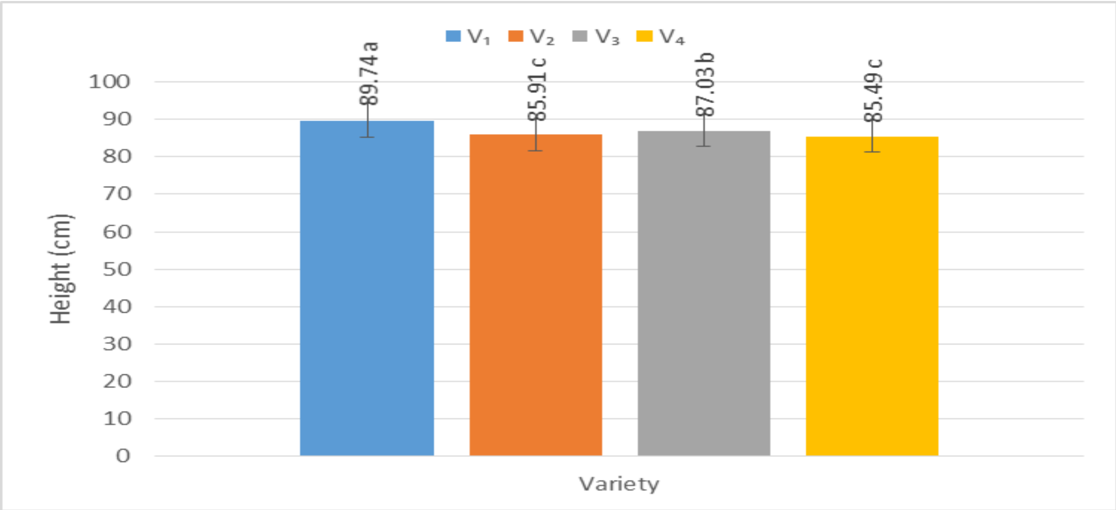
V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

4.1.4. Plant height

Effect of variety

Considerable varietal differences were observed in plant height (Appendix III & Fig. 7). The V_1 (BARI Gom -21) showed the highest plant height (89.74 cm) at harvest and was significantly different from that of others. The V_4 (85.49 cm) exhibited the lowest plant height, which was statistically similar with V_2 (85.91 cm).

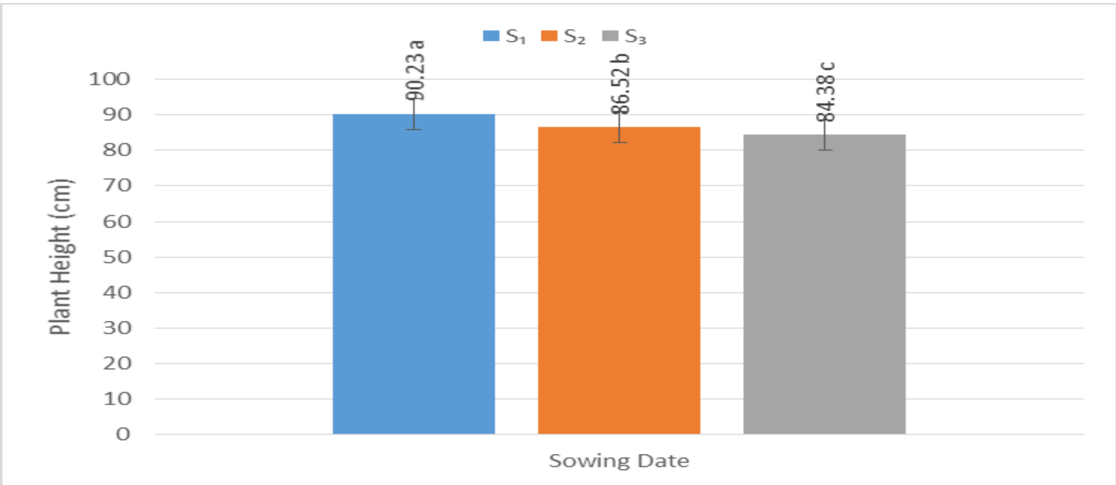


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 7. Effect of variety on plant height of wheat (LSD 0.05%)

Effect of sowing date

Wheat plants were found to be significantly smaller in height due to delayed seeding (Appendix III & Fig.8). The highest plant height (90.23 cm) was recorded in the plant those are planted early (S_1) while late sowing (S_3) produced smallest plant (84.38 cm).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 8. Effect of sowing date on plant height of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Plant height showed significant amount of variation for the interaction effect of variety and sowing date (Appendix III & Fig. 9). The highest plant height (92.27 cm) obtained from V_1S_1 (92.27 cm) followed by V_1S_2 (92.20 cm) and V_3S_1 (91.00 cm). On the other hand, the shortest plant height obtained from V_2S_2 (82.40 cm) followed by V_4S_3 (83.20 cm) and V_3S_3 (83.57 cm).

Wheat plants were found to be significantly smaller in height due to delayed seeding in all genotypes. These finding was also similar to that of Campbell and Read (1968), Bhatta *et al.* (1994) and Begga and Rawson (1977). Decreasing air temperature at vegetative stage due to late sowing might be an environmental factor for reducing plant height.

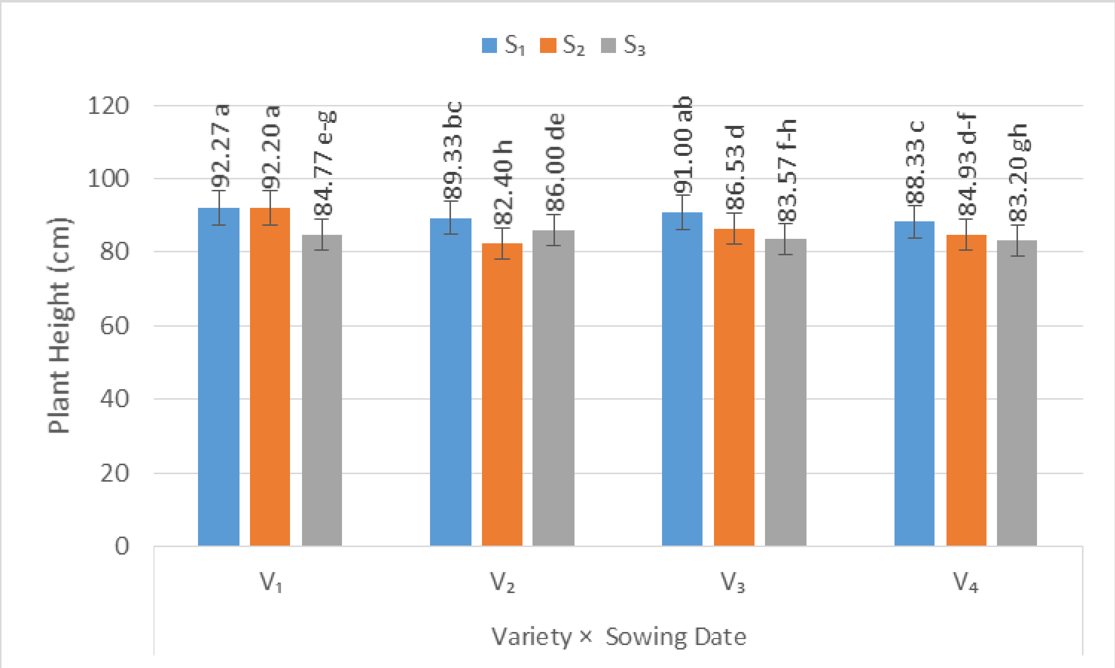


Fig 9. Interaction effects of variety and sowing date on plant height of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

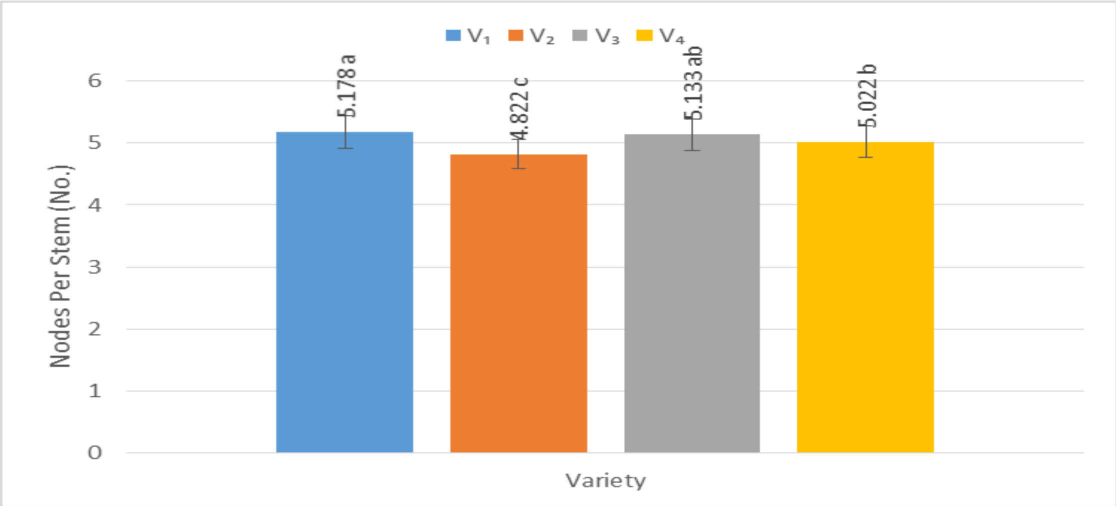
V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

4.1.5. Nodes per stem

Effect of variety

Nodes per stem varied significantly due to varietal variation (Appendix IV & Fig. 10). The V_1 (5.178) showed the highest number of node per stem followed by V_3 (5.133). On the other hand, V_2 (4.822) had the lowest number of nodes per stem.

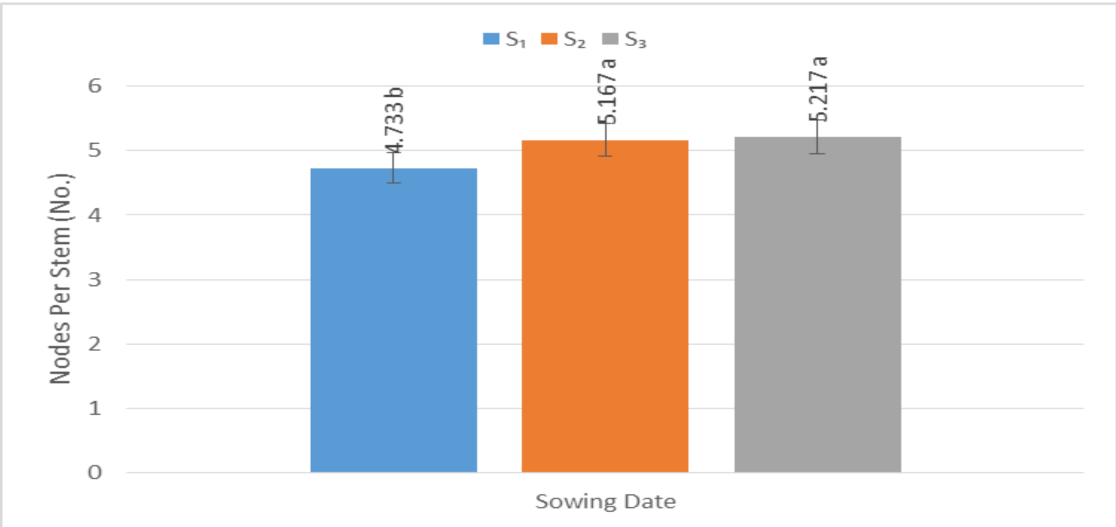


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 10. Effect of variety on nodes per stem of wheat (LSD 0.05%)

Effect of sowing date

Nodes per stem showed considerable variation due to sowing date (Appendix IV & Fig. 11). The highest nodes per stem recorded in S_3 (5.217) followed by S_2 (5.167). Whereas, S_1 (4.733) showed the lowest number of nodes per plant.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 11. Effect of sowing date on nodes per stem of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

The interaction of variety and sowing date showed a considerable amount of variation in case of nodes per stem (Appendix IV & Fig. 12). The combination V_1S_2 (5.467) gives the highest number of nodes per stem followed by V_3S_2 (5.333), V_3S_3 (5.333) and V_4S_3 (5.333). While the lowest number of nodes per stem (4.402) obtained from the combination of V_2S_1.

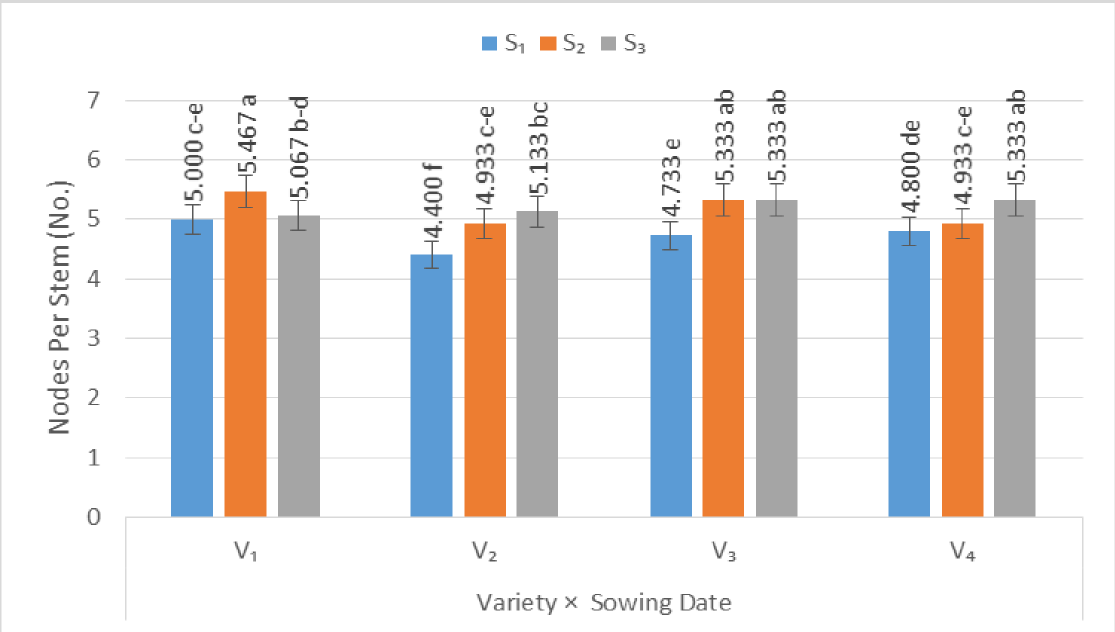


Fig 12. Interaction effects of variety and sowing date on nodes per stem of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

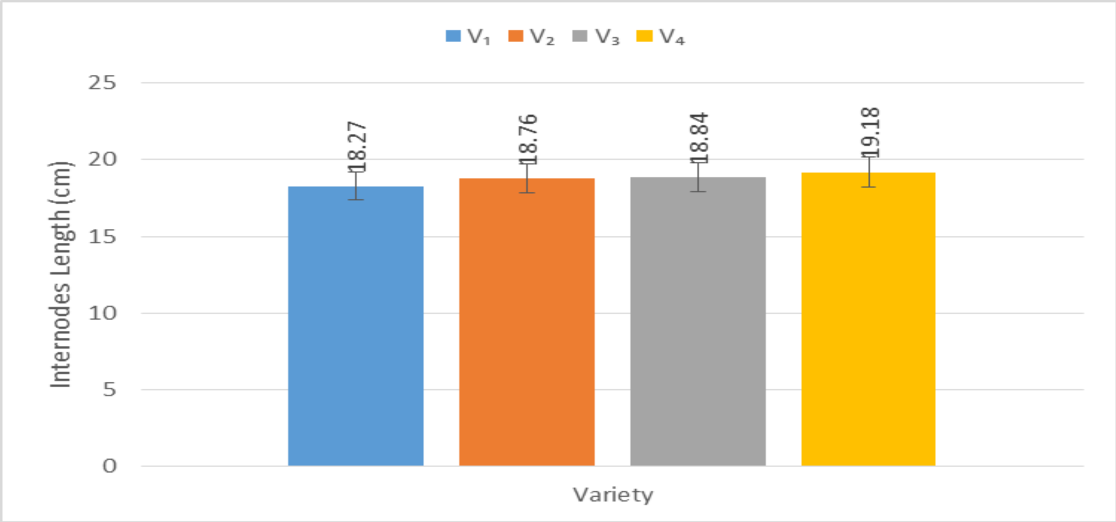
V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

4.1.6. Internodes length

Effect of variety

In case of internodes length, varietal performance did not varied significantly (Appendix IV & Fig. 13). Therefore, no further multiple comparison tests were done for this trait.

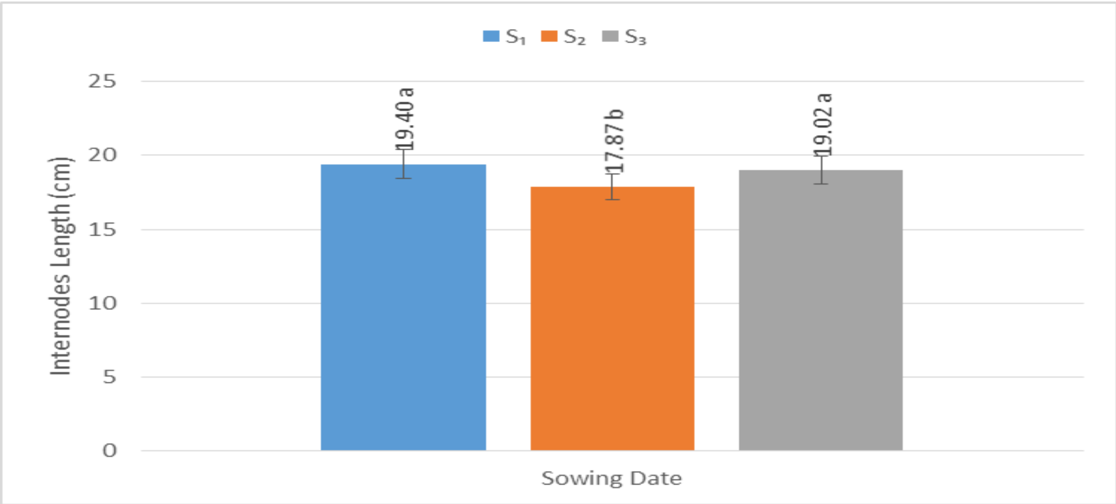


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 13. Effect of variety on internodes length of wheat (LSD 0.05%)

Effect of sowing date

Internodes length showed highly significant variation due to sowing date (Appendix IV & Fig. 14). Early sowing (S_1) showed the highest internodes length (19.40 cm), which was statistically comparable with S_3 (19.02 cm). The lowest internodes length was recorded in S_2 (17.87 cm).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 14. Effect of sowing date on internodes length of wheat (LSD 0.05%)

Interaction effect of variety and sowing date

Internodes length does not demonstrate any significant amount of variation for the interaction of variety and sowing date (Appendix IV & Fig. 15). So no further test was not applicable for this trait.

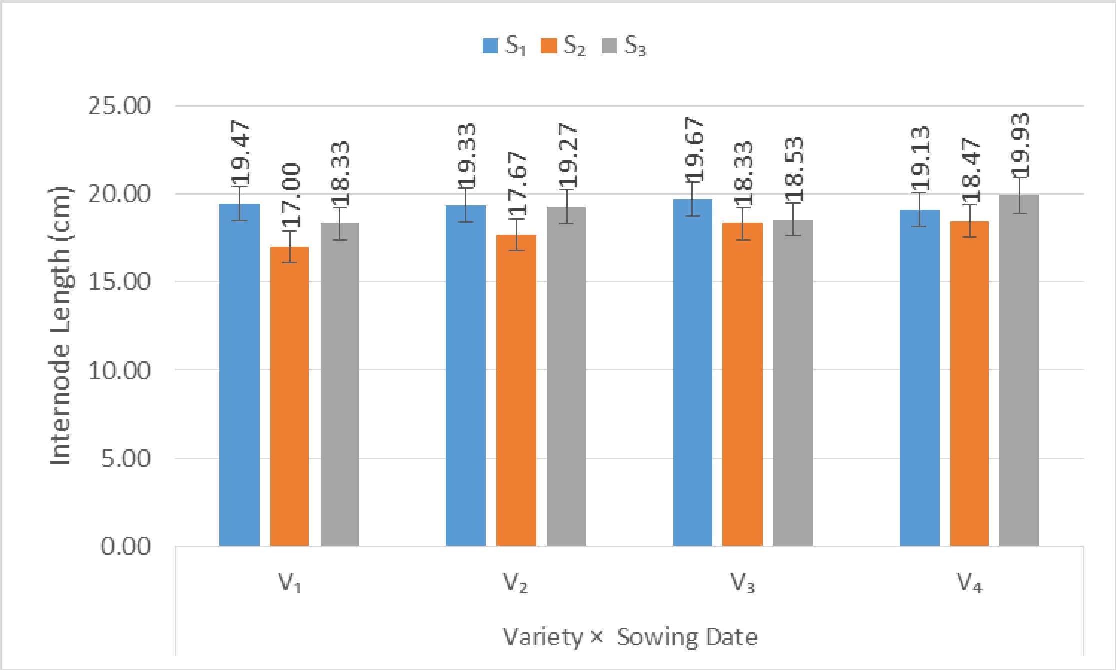


Fig 15. Interaction effects of variety and sowing date on internodes length of wheat (LSD 0.05%)

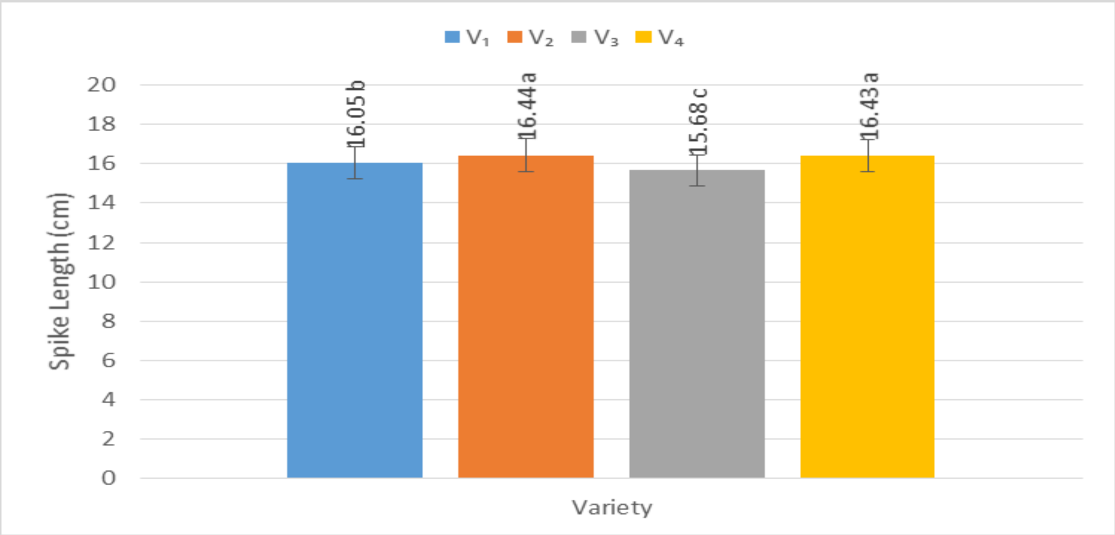
**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

These finding were similar to the reported mean and range values by Begga and Rawson (1977) for internodes length.

4.1.7. Spike length

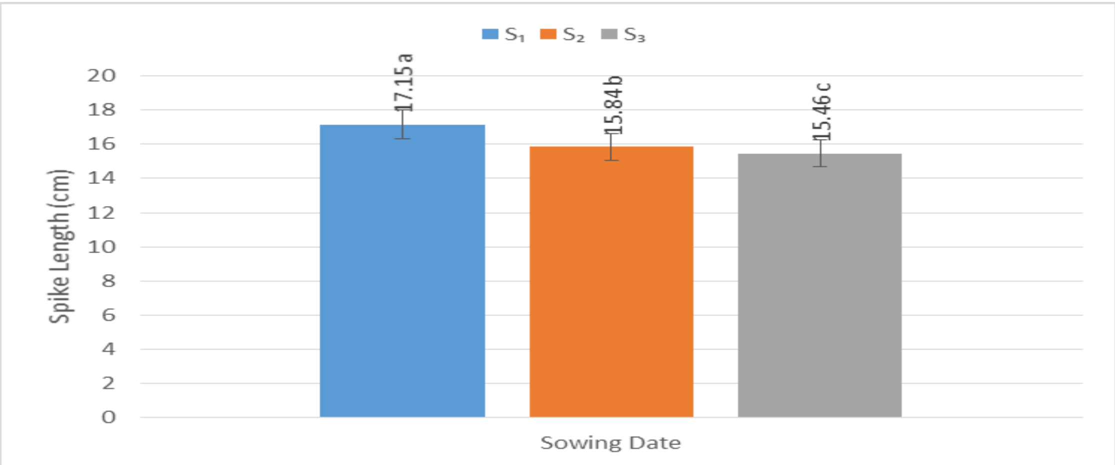


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 16. Effect of variety on spike length of wheat (LSD 0.05%)

Effect of variety

Spike length was significantly influenced by different variety (Appendix IV & Fig. 16). The V_2 (16.44 cm) and V_4 (16.43 cm) both variety exhibited maximum spike length and were statistically similar. While, V_3 (15.68 cm) showed minimum spike length and was statistically different from other varieties.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 17. Effect of sowing date on spike length of wheat (LSD 0.05%)

Effect of sowing date

Different sowing date showed significant variation for spike length (Appendix IV & Fig. 17). It appears that, spike length decrease with delayed sowing. The highest spike length attained by the S_1 (17.15 cm) while sowing at 12 December (S_3) produced the lowest spike length (15.46 cm). All the effects of sowing date on spike length were significantly different from each other.

Interaction effects of variety and sowing date

The interaction effect of variety and sowing date on spike length was significant (Appendix IV & Fig. 18). The highest spike length obtained from the combination V_4S_1 (18.03 cm) followed by the combination of V_2S_1 (17.71 cm). On the other hand, the combination V_4S_3 (15.16 cm) showed the lowest spike length which was statistically similar with V_3S_2 (15.22 cm), V_3S_3 (15.32 cm) and V_2S_3 (15.45 cm).

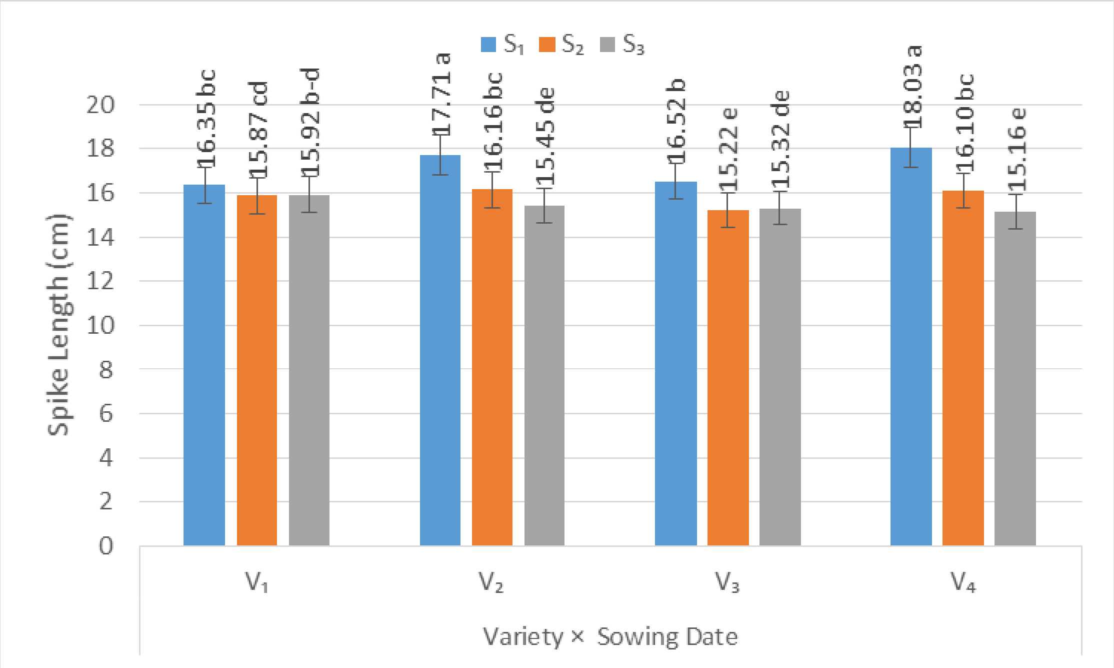


Fig 18. Interaction effects of variety and sowing date on spike length of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

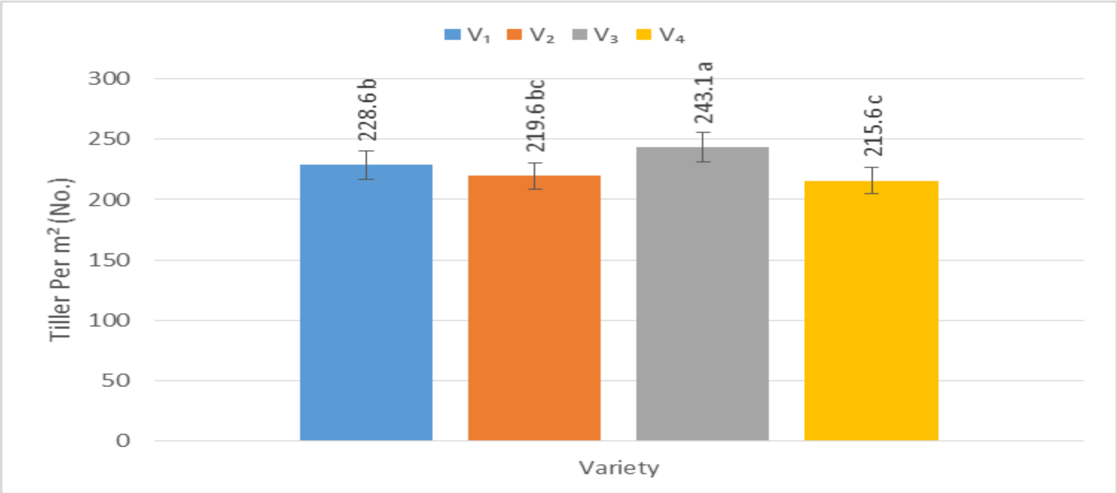
V_1: BARI Gom-21	S_1: Sowing at 20 November
V_2: BARI Gom-24	S_2: Sowing at 1 December
V_3: BARI Gom-25 and	S_3: Sowing at 12 December
V_4: BARI Gom-26	

Spike length was reduced when it was grown under high temperature and high temperature resulted in smaller organ of wheat. Later sowing of wheat made the spike formation under higher temperature. The present finding was in agreement with the findings of Bhatta *et al.* (1994); Begga and Rawson (1977).

4.1.8. Tillers per m²

Effect of variety

Tiller per m^2 showed a significant amount of variation among the varieties (Appendix V & Fig. 19). V_3 produced highest number of tiller per m^2 (243.1). While, V_3 produced lowest number of tiller per m^2 (215.6) followed by V_2 (219.6).

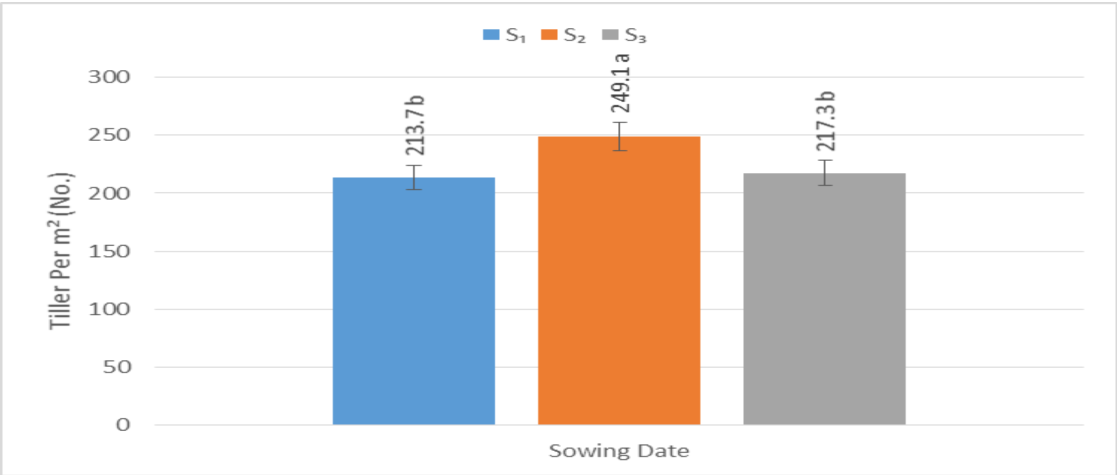


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 19. Effect of variety on tillers per m^2 of wheat (LSD 0.05%)

Effect of sowing date

Sowing date carry out a significant effect on tillers per m^2 (Appendix V & Fig. 20). Both early (S_1) and late (S_3) sowing produced significantly lower number of tillers per m^2 (213.7 & 217.3 respectively) than intermediate (S_2) sowing date (249.1).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 20. Effect of sowing date on tillers per m^2 of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

The combined effect of sowing date and variety significantly affect tiller per m^2 (Appendix V & Fig. 21). The V_3S_2 (274.3) produced highest number of tillers per m^2 in BARI Gom-25 followed by V_1S_2 (264.3). While V_1S_1 (194.0) produced the lowest number of tillers per m^2 followed by V_4S_1 (199.0), V_2S_3 (201.0) and V_4S_3 (214.0).

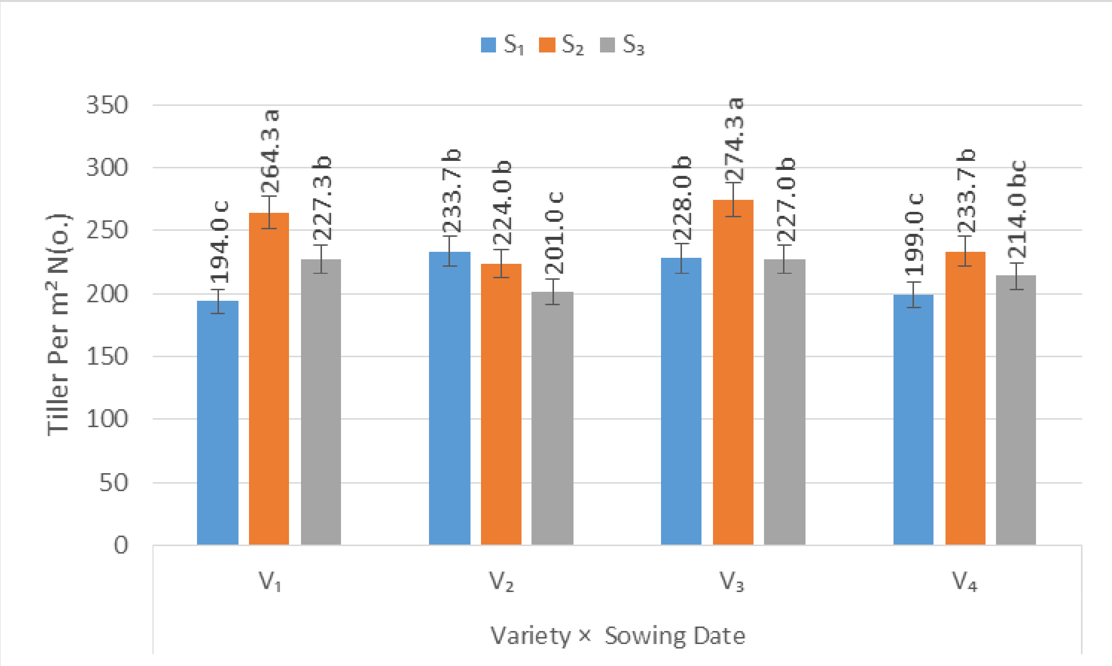


Fig 21. Interaction effects of variety and sowing date on tillers per m^2 of wheat (LSD 0.05%)

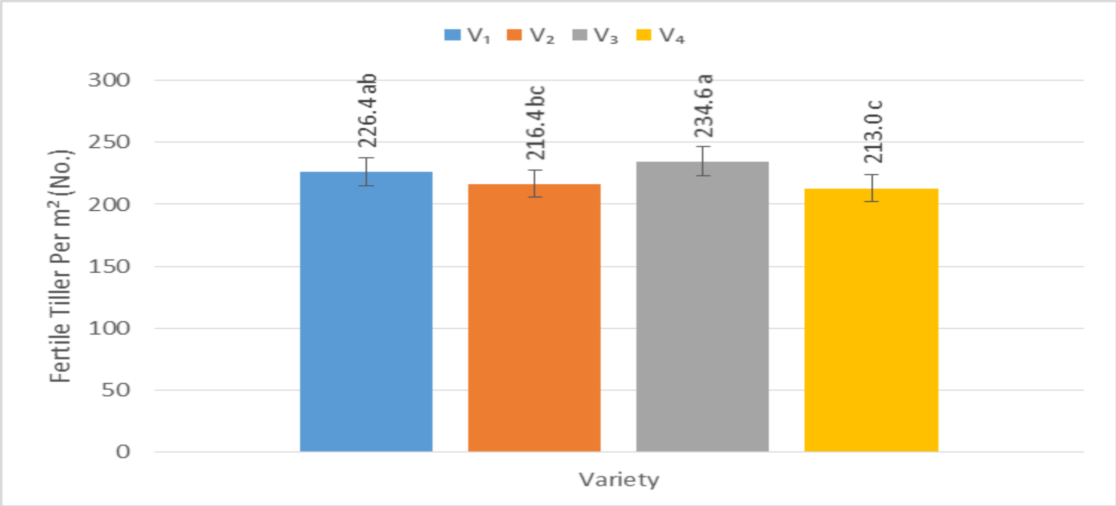
**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21	S_1: Sowing at 20 November
V_2: BARI Gom-24	S_2: Sowing at 1 December
V_3: BARI Gom-25 and	S_3: Sowing at 12 December
V_4: BARI Gom-26	

4.1.9. Fertile Tillers per m^2

Effect of variety

Fertile tillers per m^2 was significantly influenced by the varieties (Appendix V & Fig. 22). The V_3 obtained the highest number of fertile tillers per m^2 (234.6) followed by V_1 (226.4), while V_4 produced the lowest number of fertile tiller per m^2 (213.0) which was statistically similar with V_2 (216.4).

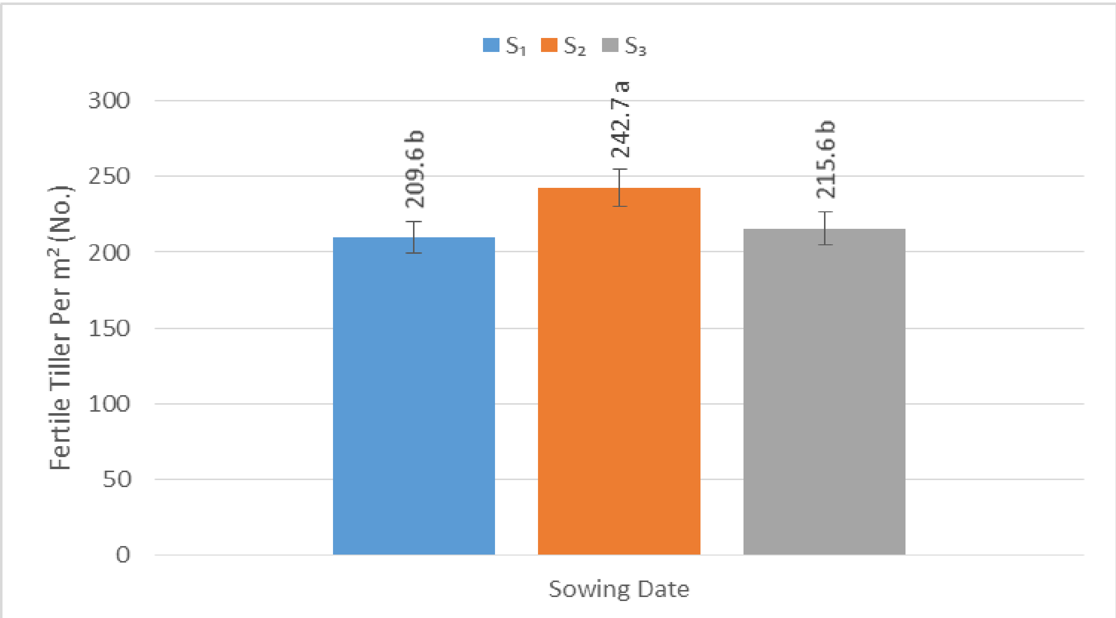


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 22. Effect of variety on fertile tillers per m^2 of wheat (LSD 0.05%)

Effect of sowing date

Sowing date had a significant effect on fertile tillers per m^2 (Appendix V & Fig. 23). The highest number of fertile tillers was obtained from S_2 (242.7). While, the lowest number of fertile tiller was obtained from S_1 (209.6), which was statistically similar with S_3 (215.6).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 23. Effect of sowing date on fertile tillers per m^2 of wheat (LSD 0.05%)

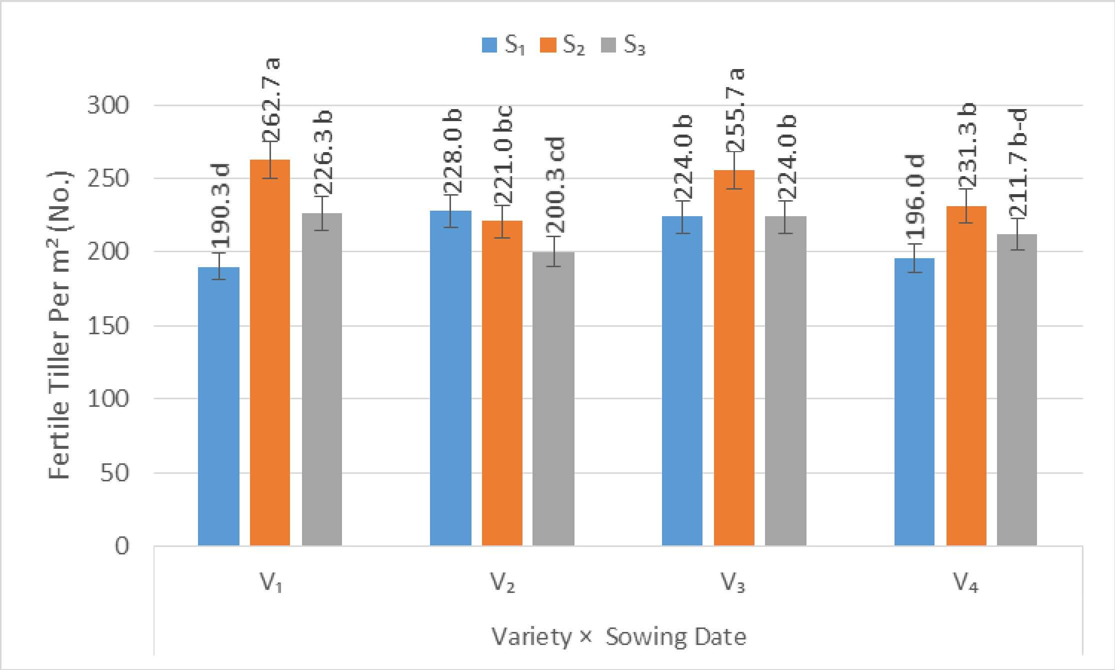


Fig 24. Interaction effects of variety and sowing date on fertile tillers per m^2 of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21	S_1: Sowing at 20 November
V_2: BARI Gom-24	S_2: Sowing at 1 December
V_3: BARI Gom-25 and	S_3: Sowing at 12 December
V_4: BARI Gom-26	

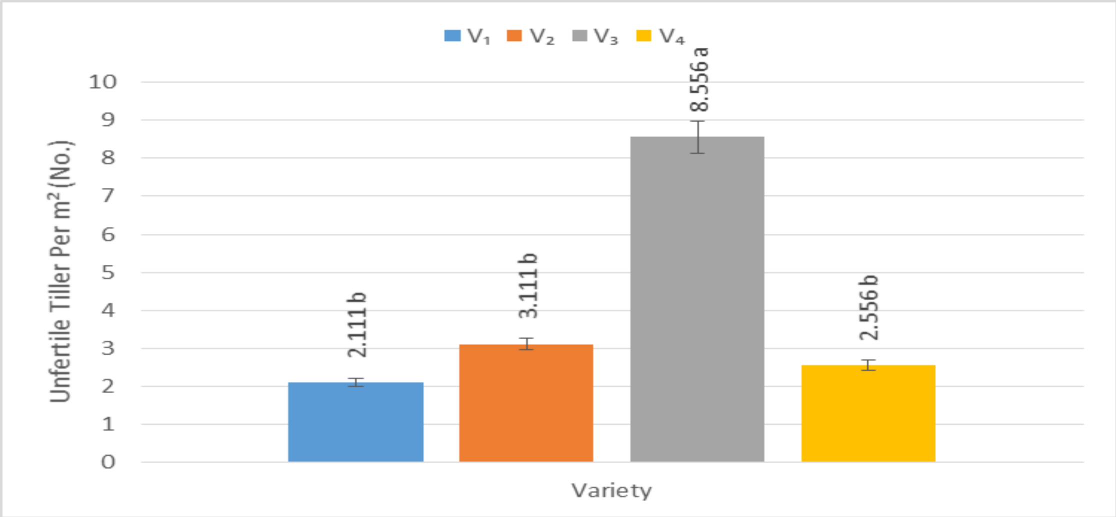
Interaction effects of variety and sowing date

The combined effect of sowing date and variety on fertile tiller per m^2 was significant (Appendix V & Fig. 24). The V_1S_2 (262.7) produced highest number of fertile tillers per m^2 followed by V_3S_2 (255.7). While the combination of V_1S_1 (190.3) produced the lowest number of fertile tillers per m^2, followed by the combination of V_4S_1 (196.0), V_2S_3 (200.3) and V_4S_3 (211.7).

4.1.10. Unfertile Tillers per m^2

Effect of variety

The variety influenced significantly on unfertile tillers per m^2 (Appendix V & Fig. 25). The highest unfertile tillers per m^2 was obtained from the V_3 (8.556). On the other hand, V_1 (2.111) produced the lowest number of unfertile tillers per m^2 followed by V_4 (2.556) and V_2 (3.111).

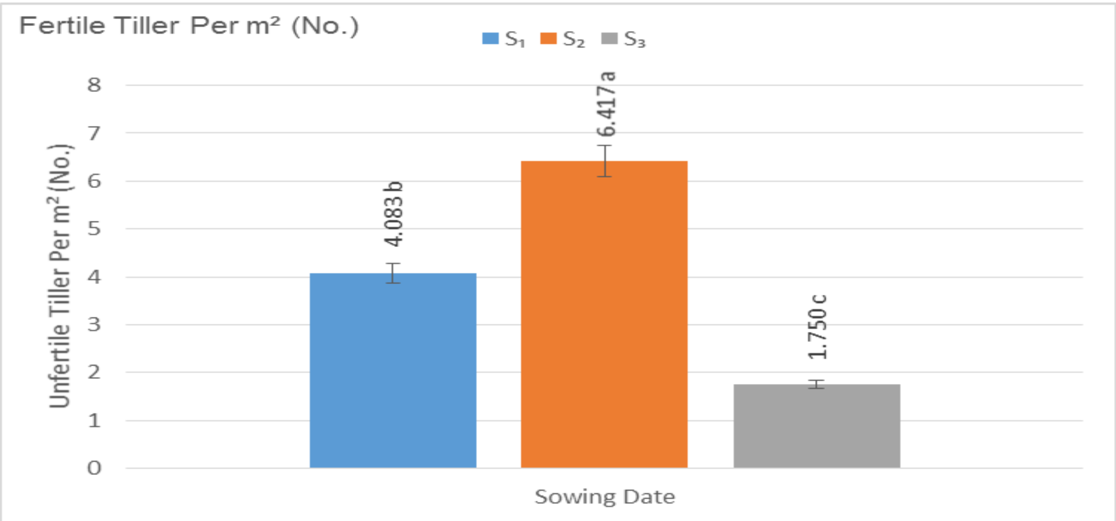


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 25. Effect of variety on unfertile tillers per m^2 of wheat (LSD 0.05%)

Effect of sowing date

Unfertile tillers per m^2 showed significant variation among the sowing date (Appendix V & Fig. 26). In case of sowing date, the maximum unfertile tiller was obtained from S_2 (6.417) while the lowest number of unfertile tiller was obtained from S_3 (1.750).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 26. Effect of sowing date on unfertile tillers per m^2 of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Unfertile tillers per m^2 was significantly influenced by the interaction of sowing date and variety (Appendix V & Fig. 27). The V_3 showed highest number of tillers per plant (18.67) in S_2. On the other hand, V_2S_3 (0.667) produced the lowest number of tillers per plant followed by the combination of V_1S_3 (1.000), V_1S_2 (1.667), V_4S_2 (2.333), V_4S_3 (2.333), V_2S_2 (3.000), V_3S_3 (3.000) and V_4S_1 (3.000).

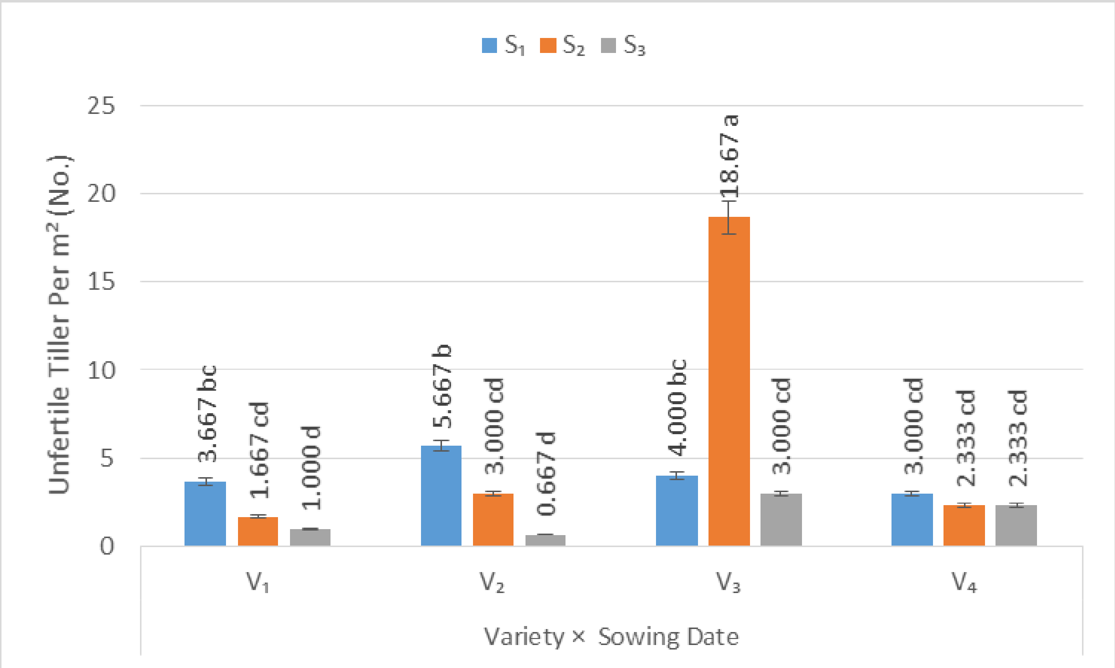


Fig 27. Interaction effects of variety and sowing date on unfertile tillers per m^2 of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

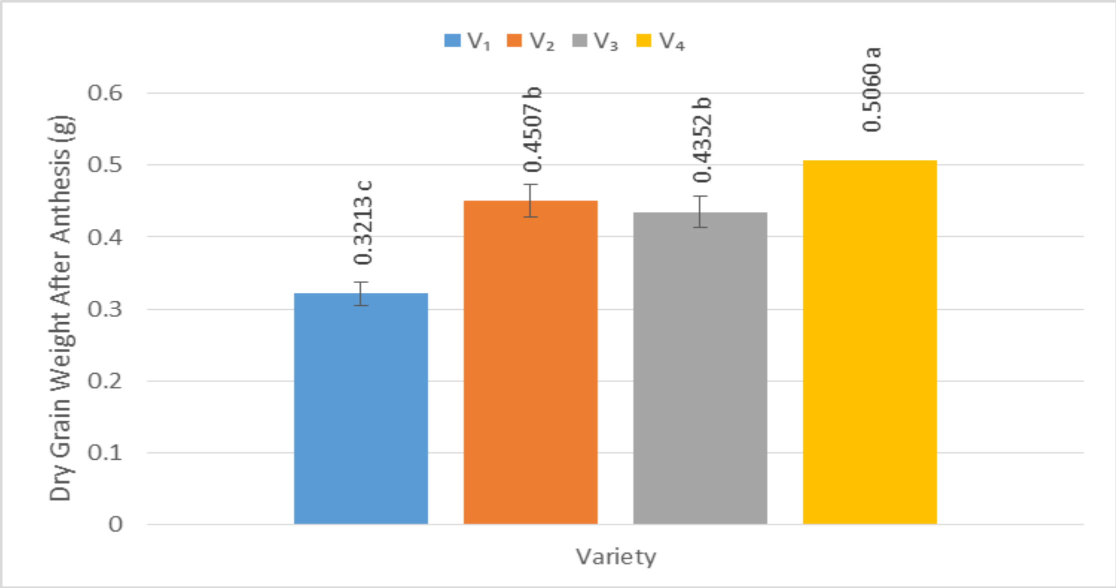
V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

4.1.11. Dry grain weight after anthesis

Effect of variety

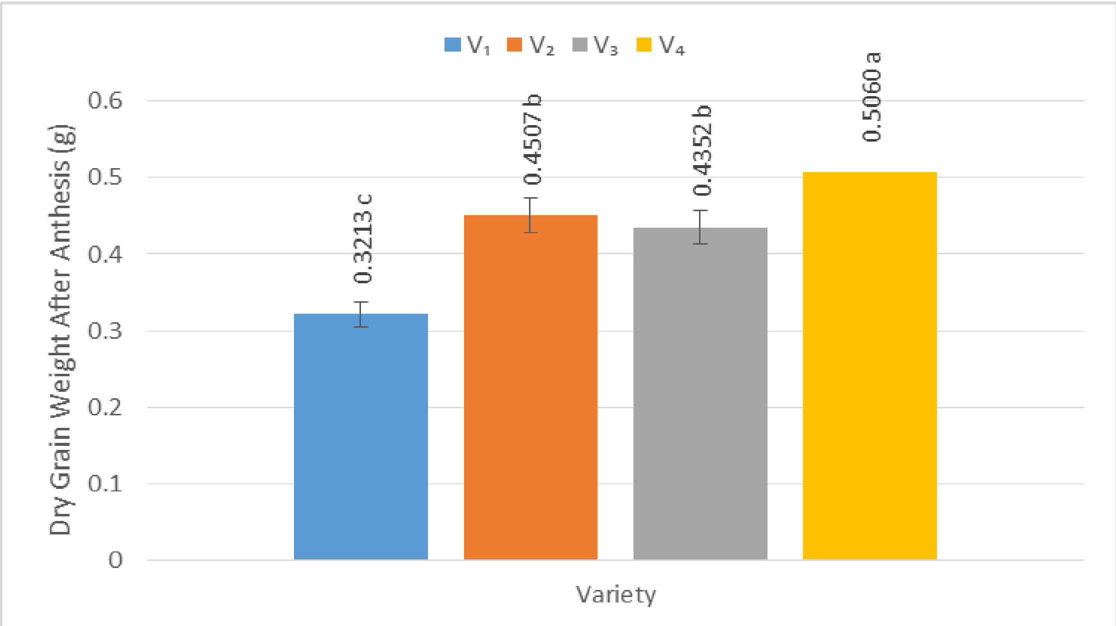
Considerable varietal difference was observed in dry grain weight after anthesis (Appendix VI & Fig. 28). The maximum weight (0.5060g) after anthesis recorded from V_4, while the minimum (0.3213g) was recorded from V_1.



V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 28. Effect of variety on dry grain weight after anthesis of wheat (LSD 0.05%)

Effect of sowing date



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 29. Effect of sowing date on dry grain weight after anthesis of wheat (LSD 0.05%)

Dry grain weight after anthesis showed considerable amount of variance among the sowing date (Appendix VI & Fig. 29). The plant those are sown on 1st December (S_2), gained the highest amount of weight (0.5655g) after anthesis, while the plant which were sown on 12th December (S_3) obtained lowest amount of weight (0.3397g).

Interaction effects of variety and sowing date

Dry grain weight after anthesis varied significantly for the interaction effect of variety and sowing date (Appendix VI & Fig. 30). The maximum dry grain weight after anthesis was obtained from the combination of V_4S_2 (1st December). While V_1S_1 (0.2700g) produced minimum dry grain weight after anthesis period followed by V_1S_3 (0.2858g)

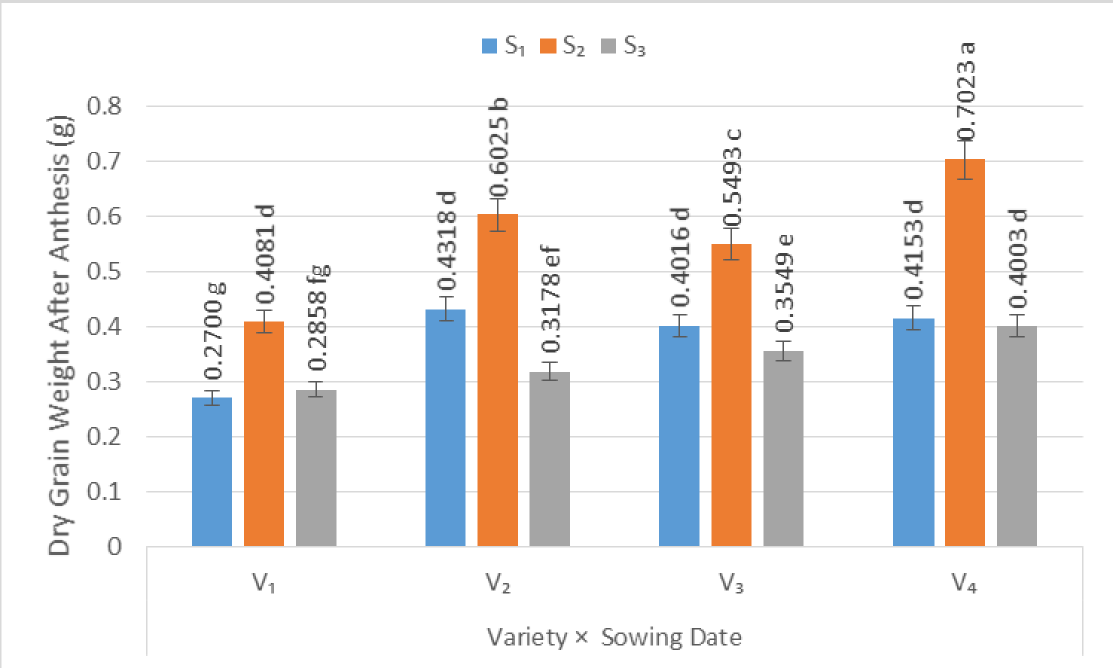


Fig 30. Interaction effects of variety and sowing date on dry grain weight after anthesis (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

Shukla *et al.* (1992) and Ahmad *et al.* (1989) also reported the same trend of dry matter accumulation at grain after anthesis.

4.1.12. Grain growth

Among the genotypes, results indicated that generally the grain growth had an initial lag phase (low growth) just after anthesis to before, the linear increase in dry weight. The linear growth phase (rapid growth) was followed by a decreasing growth rate during maturity. Grain growth rate in different wheat genotypes at different days after anthesis under different sowing conditions shown in Figure 31-34. For BARI Gom-21 all of the three sowing date maintained initial lag phase up to 16 DAA (days after anthesis) .

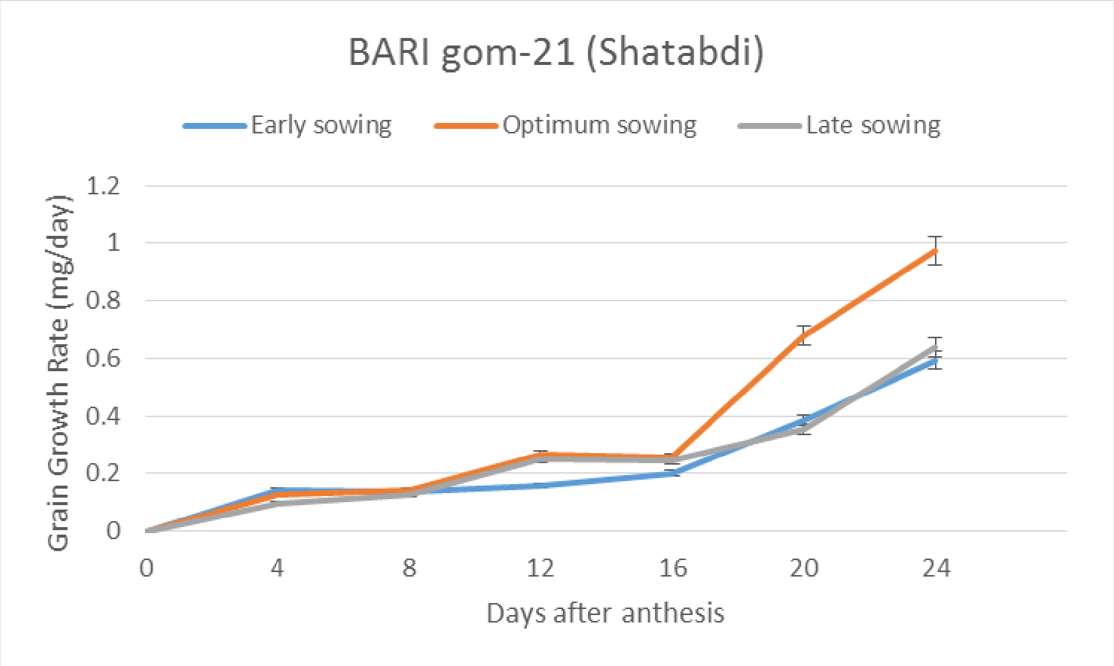


Fig 31. Grain growth rate of BARI Gom-21 (Shatabdi) at different days after anthesis under different sowing conditioin. (Vertical bar indicates the SE value)

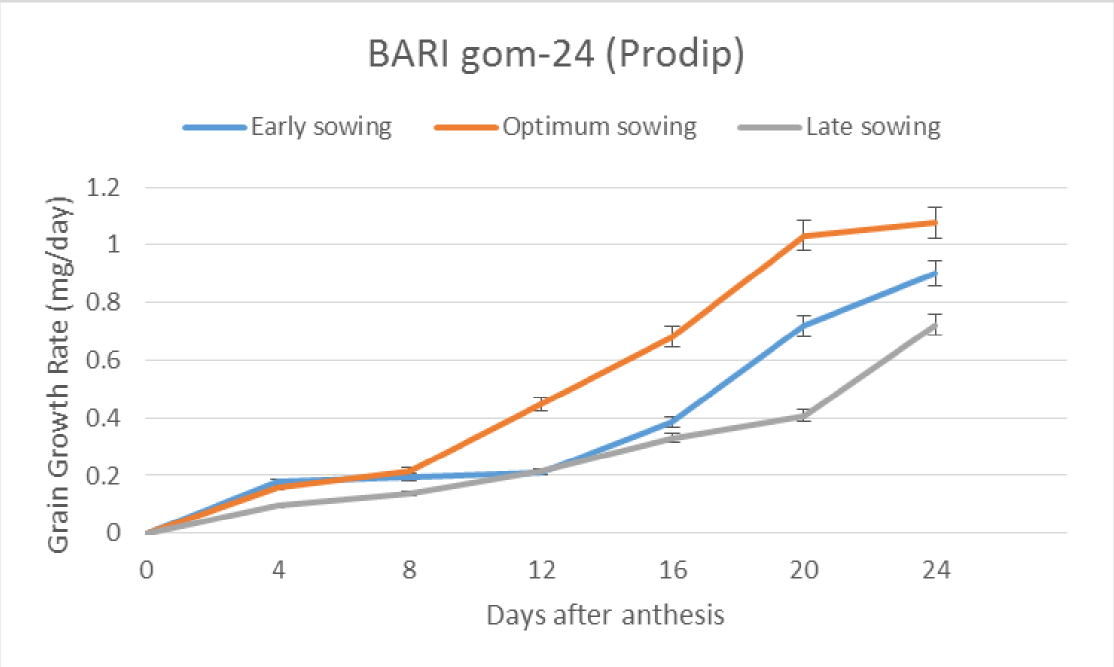


Fig 32. Grain growth rate of BARI Gom-24 (Prodip) at different days after anthesis under different sowing conditioin. (Vertical bar indicates the SE value)

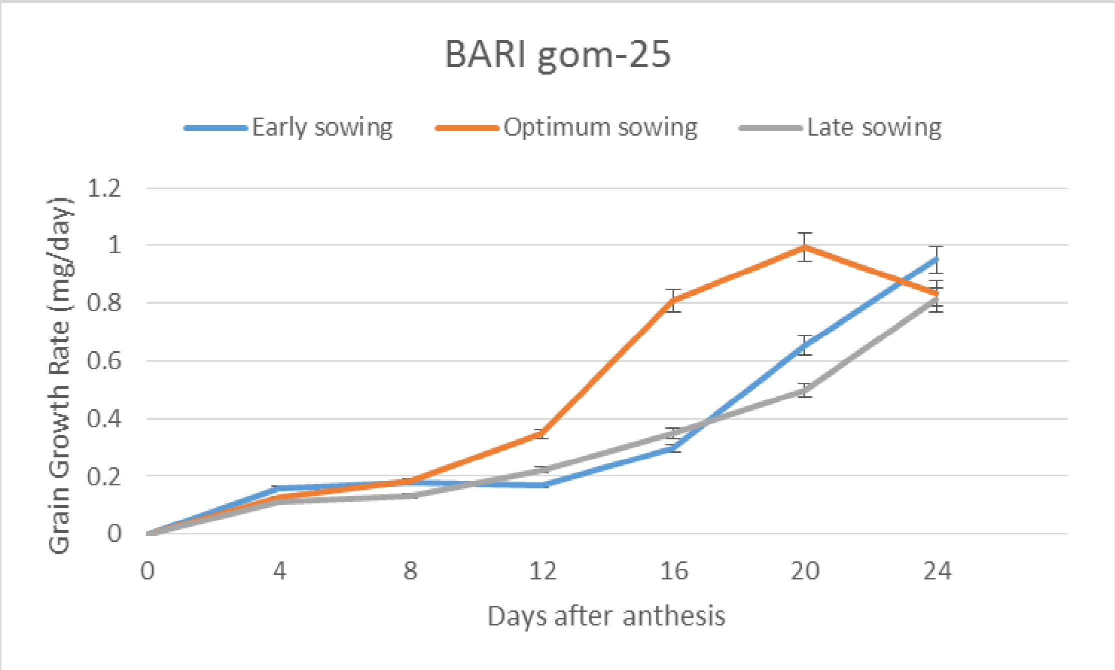


Fig 33. Grain growth rate of BARI Gom-25 at different days after anthesis under different sowing conditioin. (Vertical bar indicates the SE value)

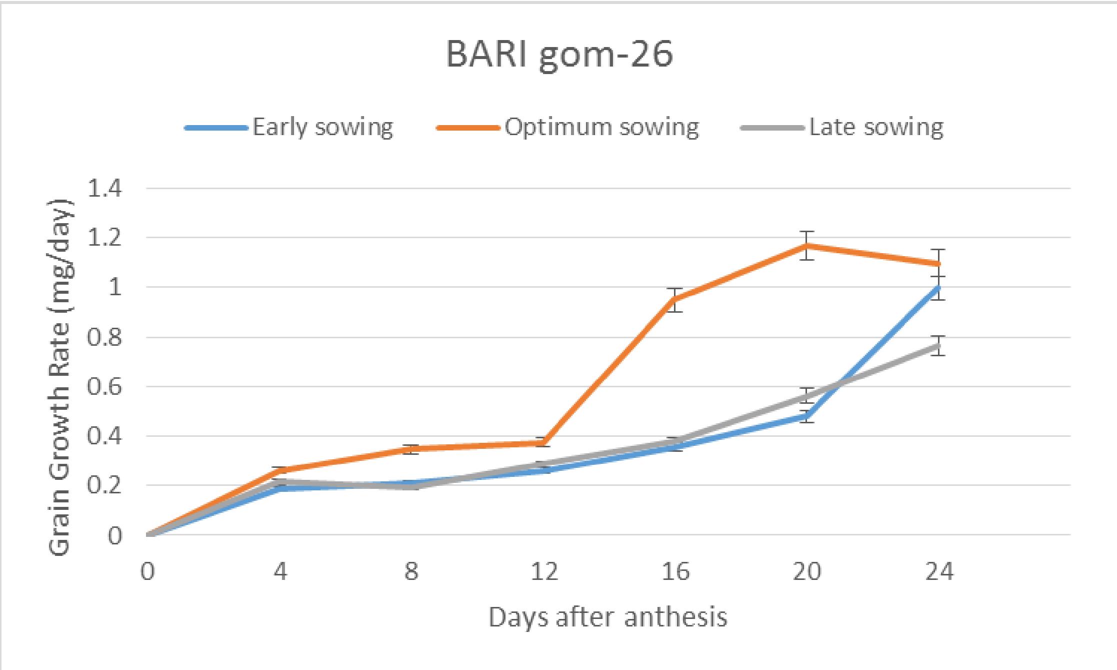
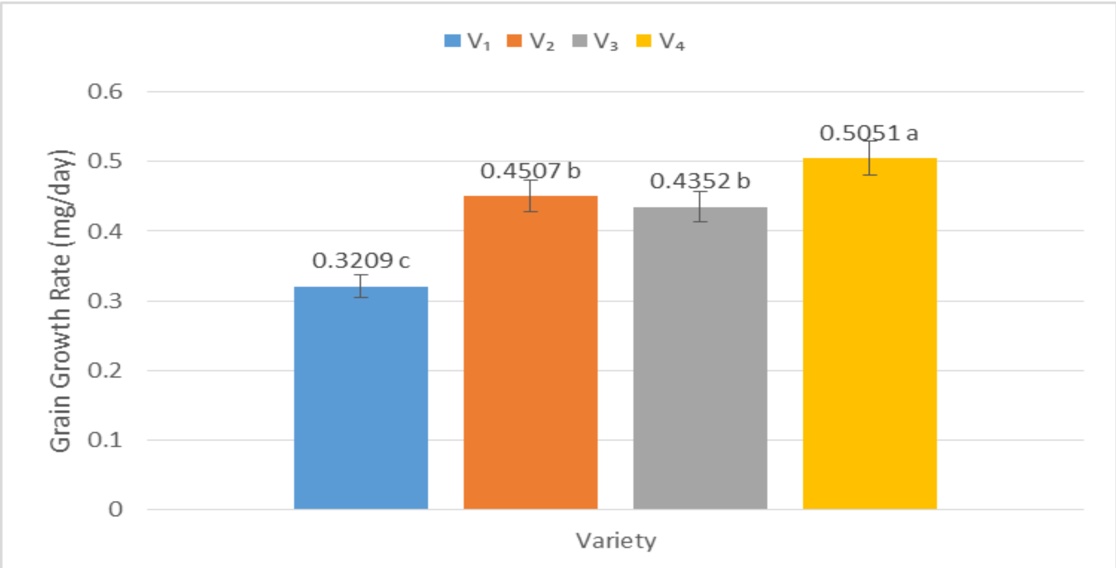


Fig 34. Grain growth rate of BARI Gom-26 at different days after anthesis under different sowing conditioin. (Vertical bar indicates the SE value)

at the same rate and then enter into linear growth phase. In linear growth phase, intermediate sowing showed the highest growth rate than other sowing condition. In case of BARI Gom-24 (Prodip), intermediate sowing condition continued its initial lag phase up to 8 DAA, but other early and late condition kept it up to 12 DAA. The S_2 showed highest growth rate, S_1 showed optimum and S_3 lowest growth rate. For BARI Gom-25, initial lag phase continue until 12 DAA. The S_2 showed highest growth rate during linear growth phase up to 20 DAA. Then its growth rate decreases. However, the other two sowing condition kept linear growth phase up to 24 DAA though the growth rate was lower than S_2. BARI Gom-26 maintain initial lag phase until 12 DAA. The S_2 showed highest growth rate but decrease after 20 DAA. Both S_1 and S_3 condition continued linear phase up to 24 DAA.

Effect of variety

The varietal difference due to average grain growth rate varied significantly (Appendix VI & Fig. 35). The V_4 maintained the highest average growth rate (0.5051 mg/grain). While, V_1 showed lowest average growth rate (0.3209 mg /grain).

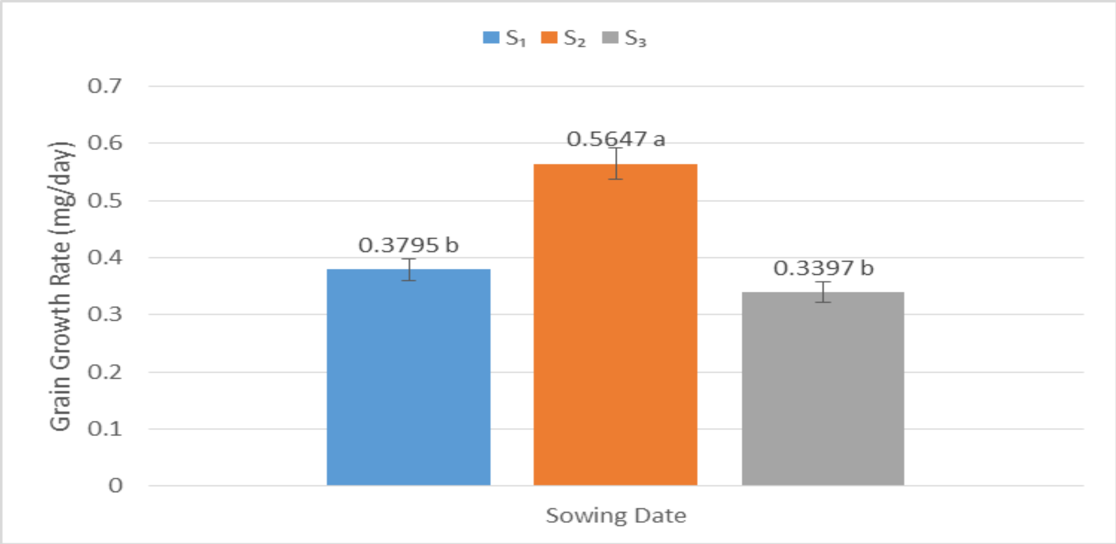


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 35. Effect of variety on average grain growth rate of wheat (LSD 0.05%)

Effect of sowing date

Average growth rate showed significant variation among the sowing date (Appendix VI & Fig. 36). Intermediate sowing (S_2) showed the highest average growth rate (0.5647 mg /grain). The lowest average growth rate was recorded in S_3 (0.3397 mg /grain), which was statistically comparable with S_1 (0.3795 mg/grain).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 36. Effect of sowing date on average grain growth rate of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Average grain growth rate varied significantly for the interaction effect of variety and sowing date (Appendix VI & Table 37). The maximum average grain growth rate were obtained from the combination of V_4S_2 (0.6997 mg/grain). While, V_1S_1 (0.2697 mg / grain) obtained lowest average grain growth rate followed by V_1S_3 (0.286 mg / grain), V_2S_3 (0.3177 mg / grain) and V_3S_3 (0.355 mg / grain).

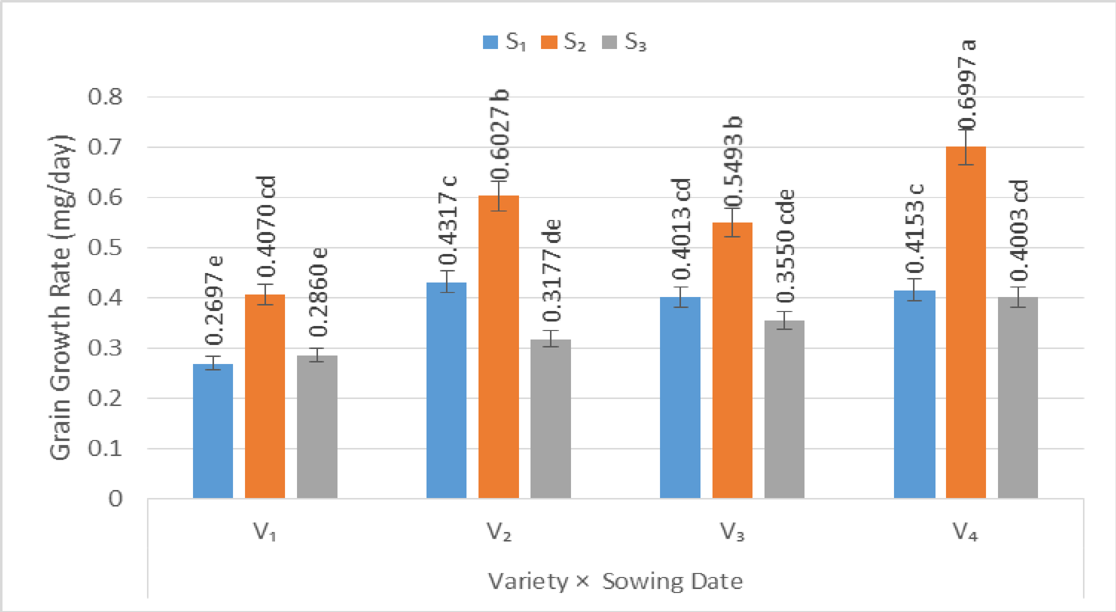


Fig 37. Interaction effects of variety and sowing date on average grain growth rate of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

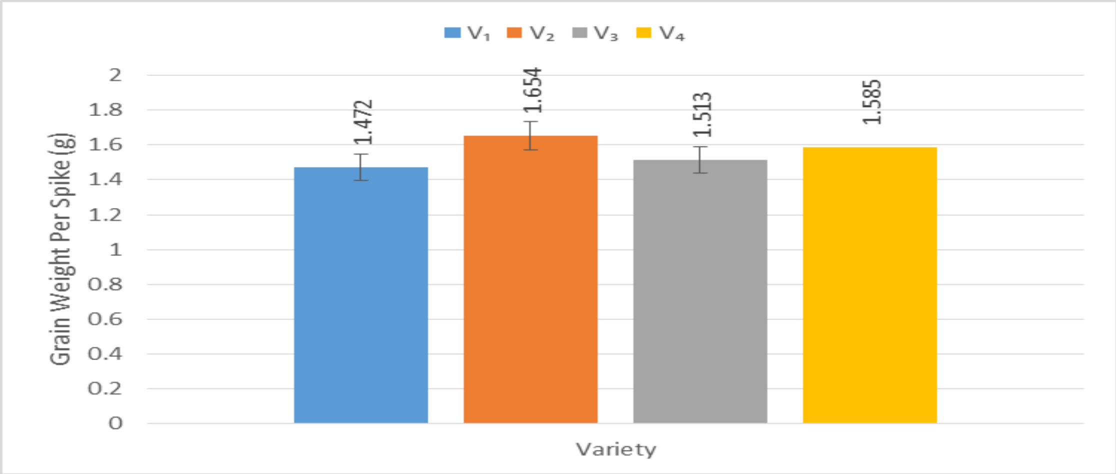
V_1: BARI Gom-21	S_1: Sowing at 20 November
V_2: BARI Gom-24	S_2: Sowing at 1 December
V_3: BARI Gom-25 and	S_3: Sowing at 12 December
V_4: BARI Gom-26	

Similar statements were also made by Wiegand and Cuellar (1981), Asana and Williams (1965), Begga and Rawson (1977) and Jhala and Jadon (1989).

4.1.13. Grain weight per spike

Effect of variety

The varietal difference due to grain weight per spike did not varied significantly (Appendix VI & Fig. 38). Therefore, this trait was not subjected to multiple comparison test.

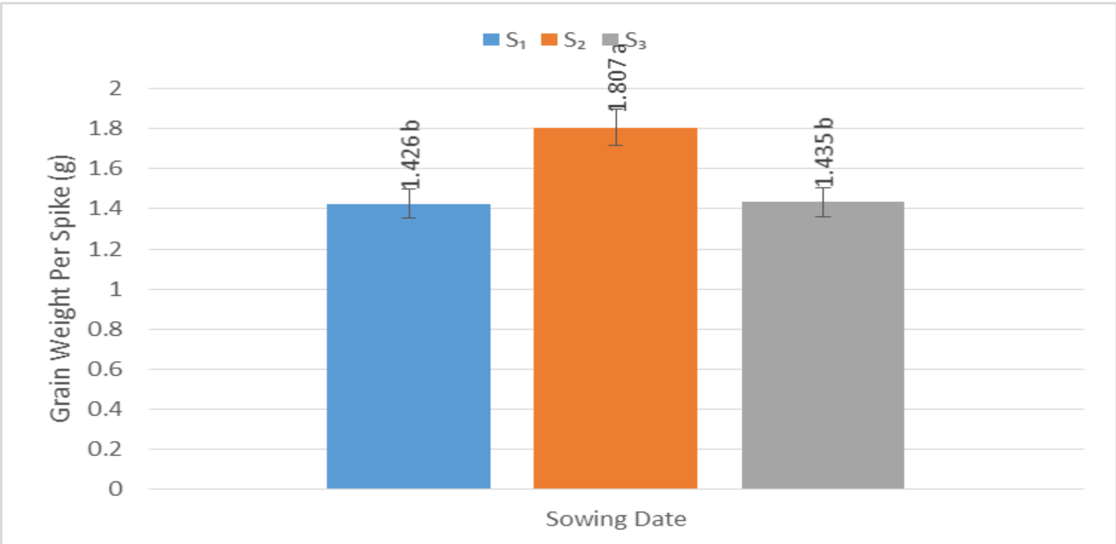


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 38. Effect of variety on grain weight per spike of wheat (LSD 0.05%)

Effect of sowing date

Different sowing date showed significant variation for grain weight per spike (Appendix VI & Fig. 39). The S_2 produced maximum grain weight per spike (1.807 g). On the other hand, S_1 produced minimum (1.426 g) grain weight per spike, which was statistically similar (1.435 g) with S_3.



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 39. Effect of sowing date on grain weight per spike of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

The data pertaining to the grain weight per spike showed no significant variation among the interaction effect of varieties and sowing date (Appendix VI & Fig. 40). So that no further multiple comparison test were done for this trait.

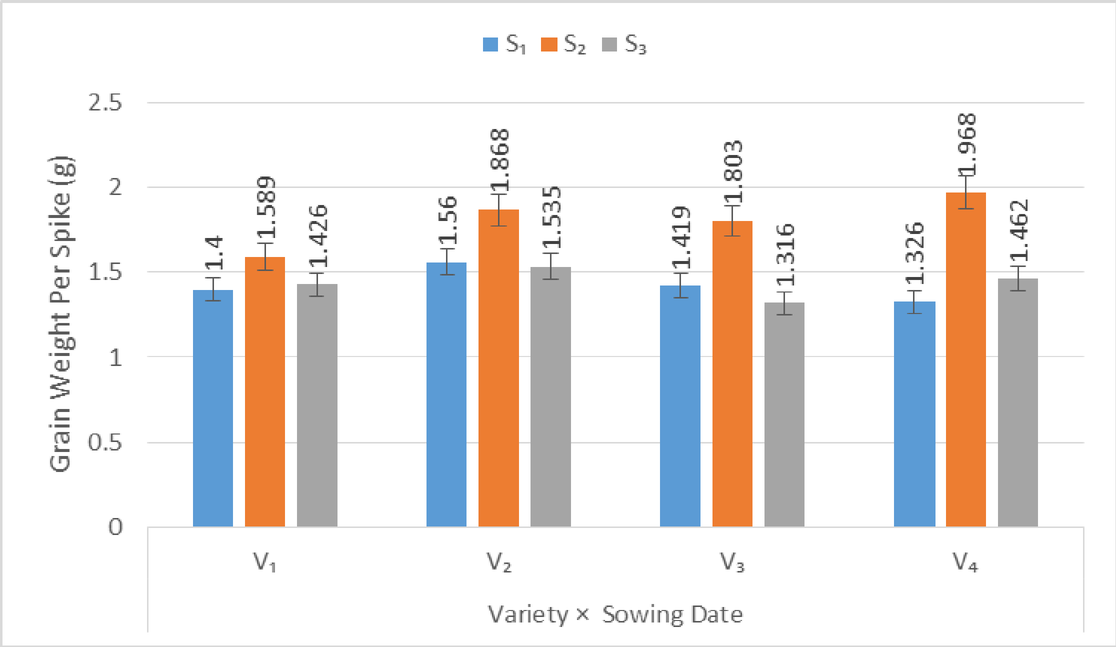


Fig 40. Interaction effects of variety and sowing date on grain weight per spike of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

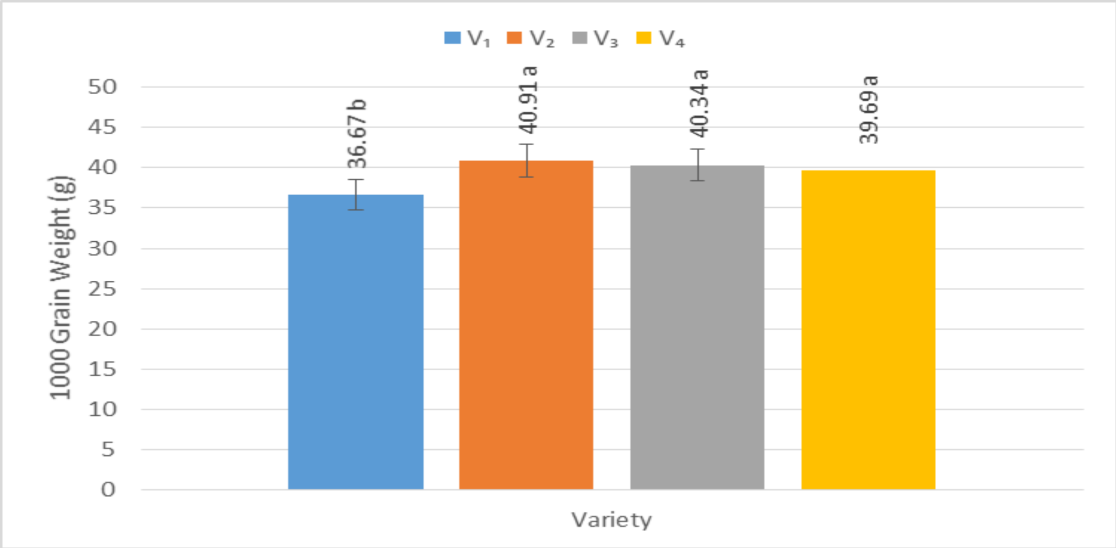
S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

Cargnin *et al.* (2006) also found this kind of grain yield reduction under late sowing condition. Significant variation was observed among cultivars in reduction of grain weight per spike and a single kernel weight under heat stress of 26° C mean temperatures (Fokar *et al.*, 1998). Grain weight per spike was decreased in all cultivars of wheat at high temperature compared to optimum temperature where the degree of decrease was different across the cultivars (Asana and Williams, 1965).

4.1.14. 1000 grain weight

Effect of variety

Weight of 1000 seed was significant for the variety (Appendix VI & Fig. 41). The V_1 achieved lowest amount of 1000-grain weight (36.67g). On the other hand, V_2 (40.91g) attained the highest amount of 1000-grain weight followed by V_3 (40.34g) and V_4 (39.69g).

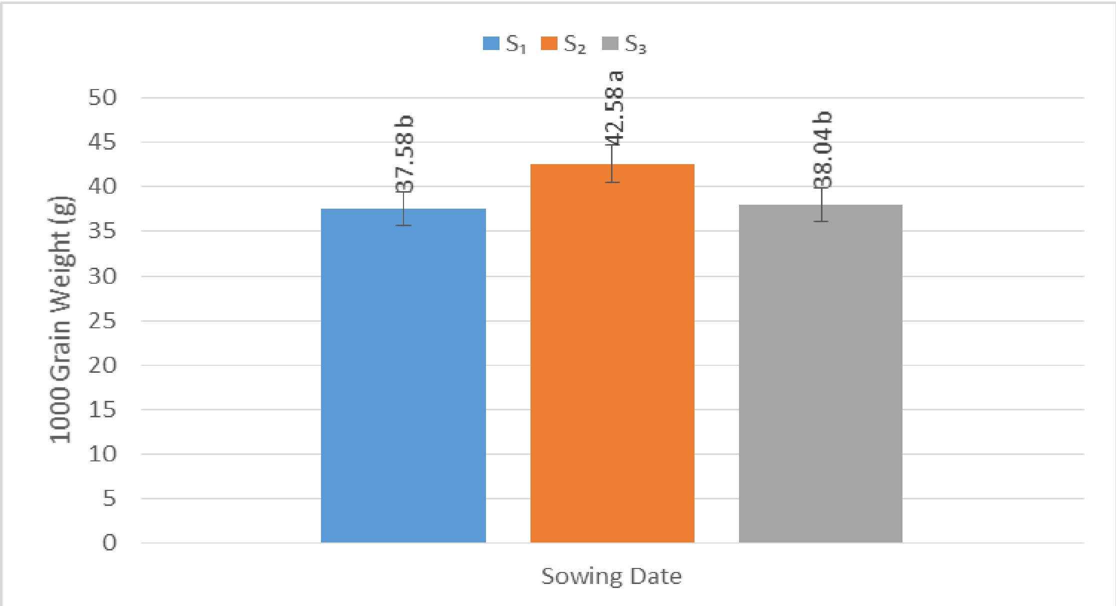


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 41. Effect of variety on 1000-grain weight of wheat (LSD 0.05%)

Effect of sowing date

In case of 1000-grain weight, the difference due to the sowing date varied significantly (Appendix VI & Fig. 42). The highest 1000-grain weight was obtained from S_2 (42.58 g). While S_1 (38.04g) produced lowest 1000 grain weight, which was not significantly different from S_3 (38.04g)



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 42. Effect of sowing date on 1000-grain weight of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

1000-grain weight varied significantly for the interaction effect of variety and sowing date (Appendix VI & Fig. 43). The maximum 1000-grain weight (44.07 g) were obtained from V_3S_2 (44.07g) followed by V_4S_2 (43.83g), V_2S_2 (43.67g), V_3S_1 (42.10g), V_4S_3 (41.93g) and V_2S_3 (40.27g). While V_4S_1 (33.3g) produce minimum 1000-grain weight followed by V_3S_3 (34.87g), V_1S_3 (35.10g) and V_1S_1 (36.13g).

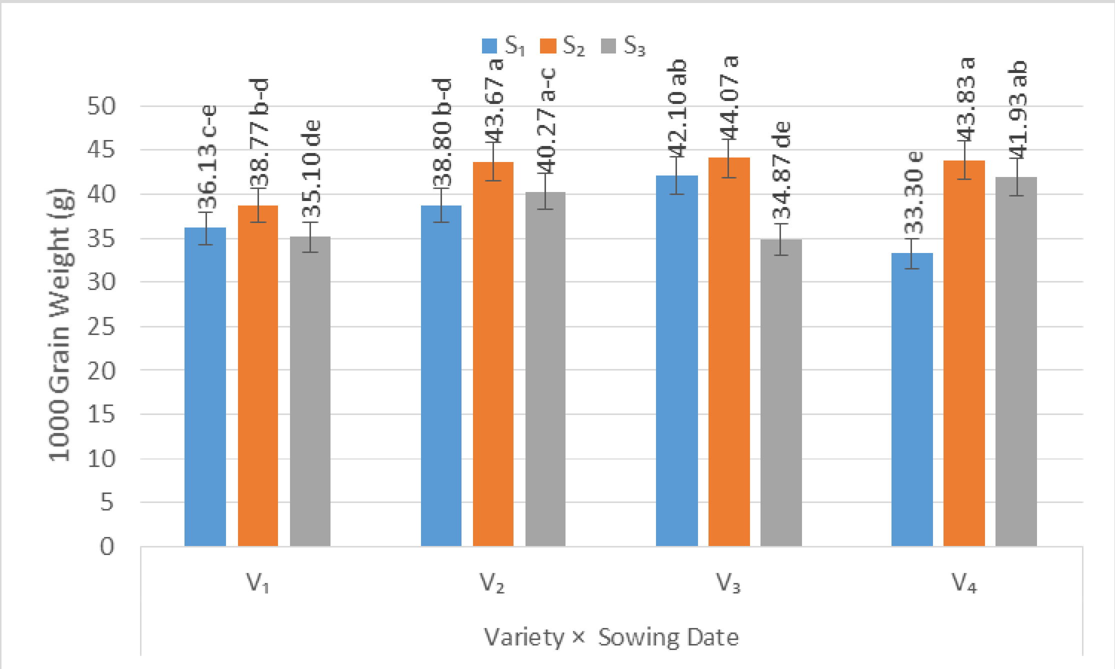


Fig 43. Interaction effects of variety and sowing date on 1000-grain weight of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

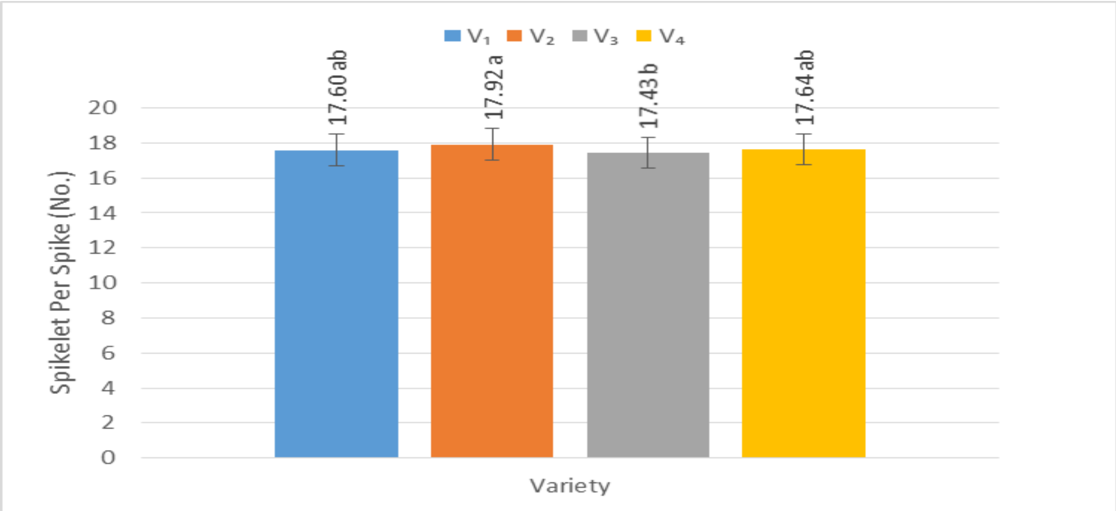
Yield and yield components were significantly reduced under late seeding conditions were also observed by Tyagi *et al*. (2003), Munjal *et al*. (2004). Results apparently indicated that smaller seed size was recorded due to late seeding imposed in all genotypes. As a consequent the reduction of 1000-grain dry weight was obvious. This could be either due to poor metabolic activity of seed or poor rate or quantity supply of metabolites from the leaf.

Different author like Al-khatib and Paulsen (1990), and Asana and Saini (1962) reported genotypic differences in relative grain weight. Grain size is a very stable for all genotypes of wheat to the development and synthetic activity of grain yield (Asana and Williams, 1965).

4.1.15. Spikelet's per spike

Effect of variety

In case of spikelet per spike, varietal performance did not varied significantly (Appendix VII & Fig. 44). Therefore, no further multiple comparison test were done for this trait.

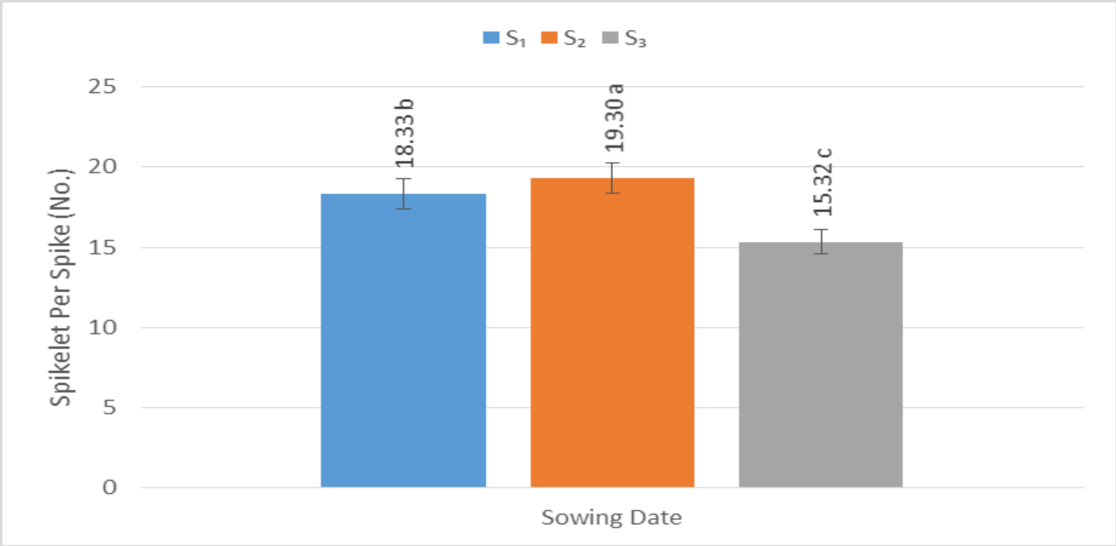


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 44. Effect of variety on spikelet's per spike of wheat (LSD 0.05%)

Effect of sowing date

Spikelet's per spike showed highly significant variation among the sowing date (Appendix VII & Fig. 45). The S_2 (19.30 cm) showed the highest spikelet's per spike. The lowest spikelet's per spike was recorded in S_3 (15.32 cm).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 45. Effect of sowing date on spikelet's per spike of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Interaction effect of variety and sowing date on spikelet's per spike did not differ significantly (Appendix VII & Fig.46). Therefore, LSD test was not applicable for this trait.

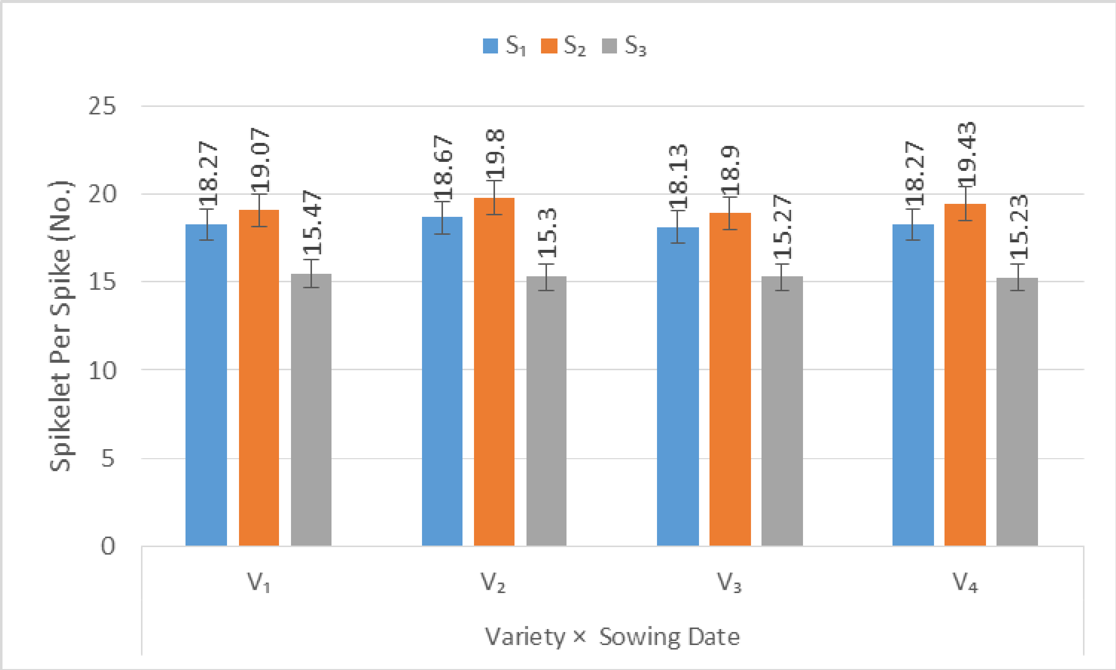


Fig 46. Interaction effects of variety and sowing date on spikelet's per spike of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

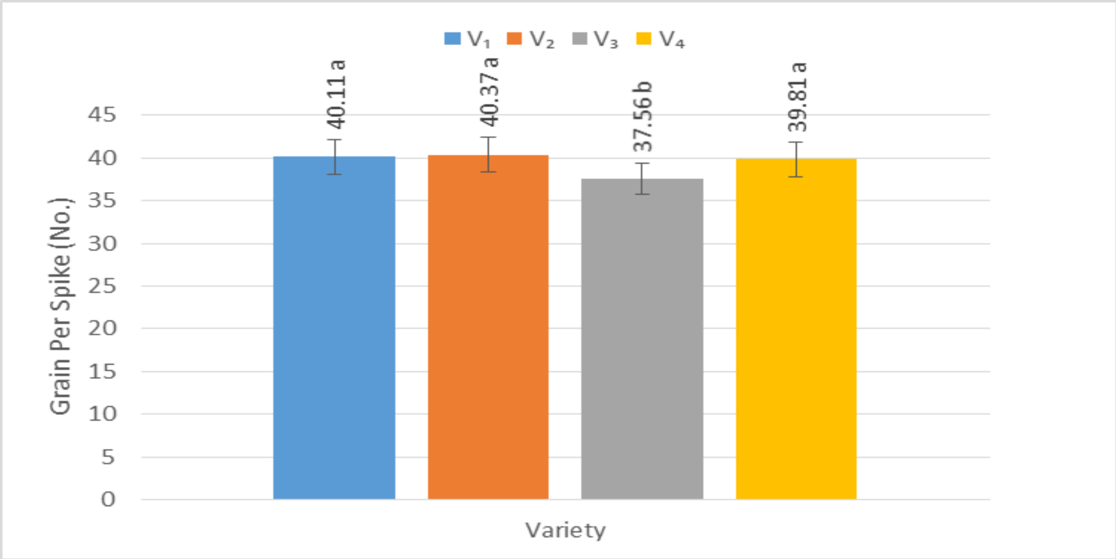
S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

The spikelet's number per spike was reduced under heat stress (Shpiler and Blum, 1986). From the above result, it is clear that both early and late sowing reduced in spikelet's per spike.

4.1.16. Grains per spike

Effect of variety

There was a significant variation among the varieties for grains per spike (Appendix VII & Fig. 47). The highest number of grains per spike was obtained from V_2 (40.37), which was statistically similler with V_1 (40.11) and V_4 (39.81). While, V_3 (37.56) gave the lowest number of grains per spike.

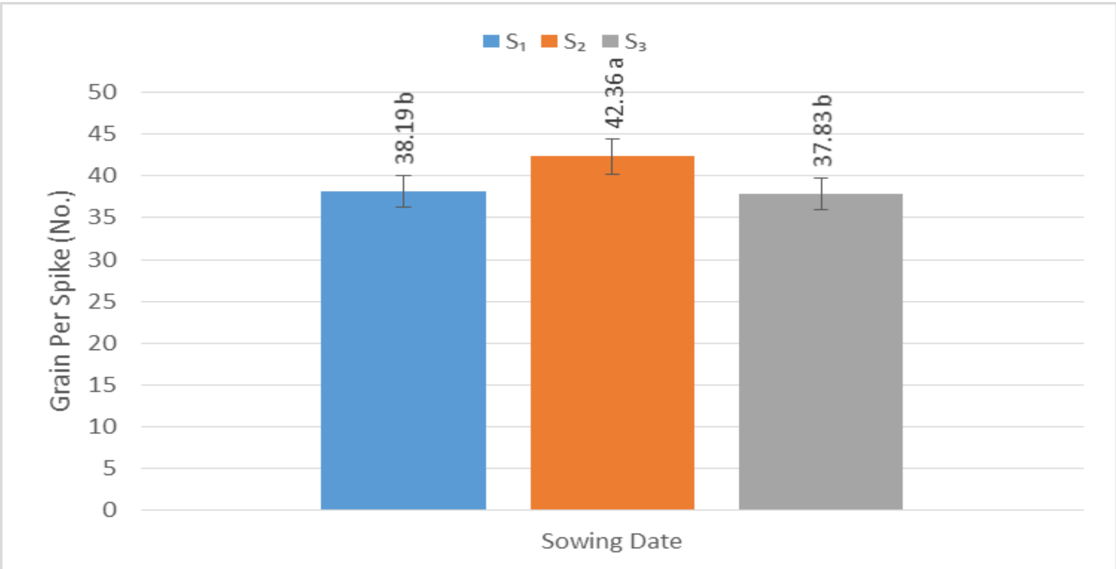


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 47. Effect of variety on grains per spike of wheat (LSD 0.05%)

Effect of sowing date

Different sowing date showed significant variation for grains per spike (Appendix VII & Fig. 48). It appeared that, grains per spike decrease with alteration of optimum sowing time. The highest grain per spike attained by the S_2 (42.36). While, S_3 (37.83) provided the lowest grain per spike which was statistically significant with S_1 (38.19).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 48. Effect of sowing date on grains per spike of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

Grains per spike was significantly influenced by the interaction of sowing date and variety (Appendix VII & Fig. 49). The V_4S_2 (44.78) showed highest number grains per spike followed by V_2S_2 (42.78). On the other hand V_3S_1 (33.78) produced the lowest number of grain per spike followed by the combination of V_4S_3 (34.78).

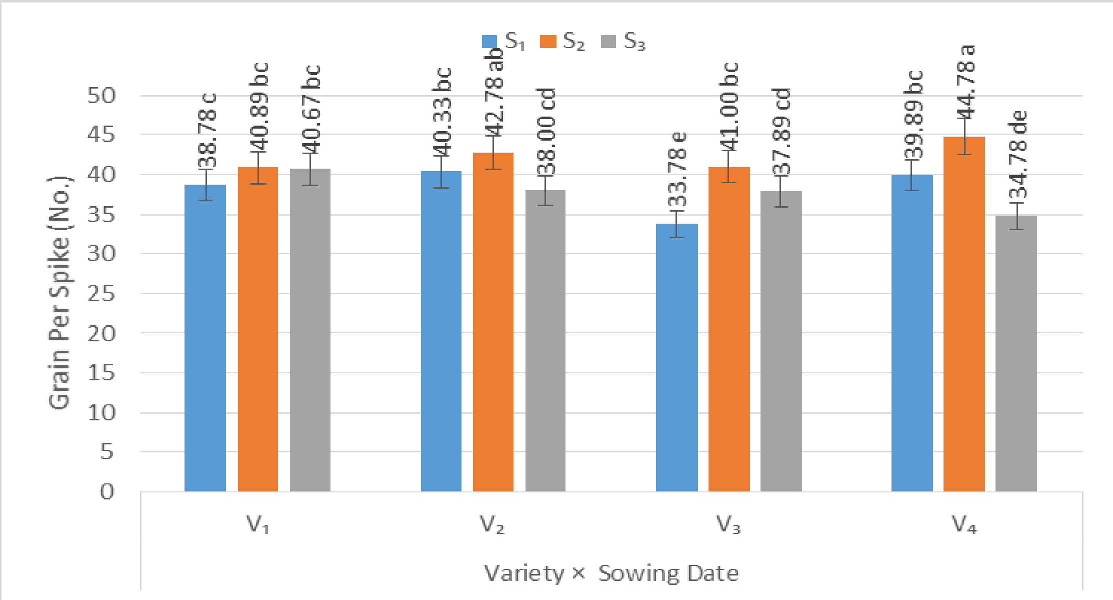


Fig 49. Interaction effects of variety and sowing date on grains per spike of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

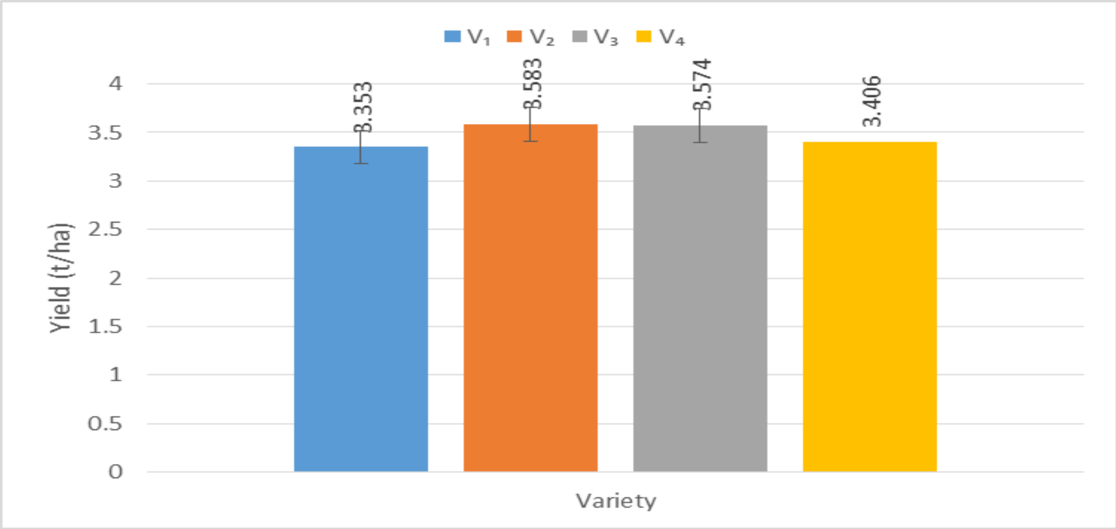
S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

Islam *et al*. (1993), He and Rajaram (1993), Al-khatib and Paulsen (1990) and Bhatta *et al*. (1994) also observed reduced number of grains per spike in different magnitude under late sowing or high temperature condition compared to optimum sowing temperature.

4.1.17. Grain yield (t/ha)

Effect of variety

The varietal difference due to yield did not varied significantly (Appendix VII & Fig. 50). Therefore, this trait was not subjected to multiple comparison test.

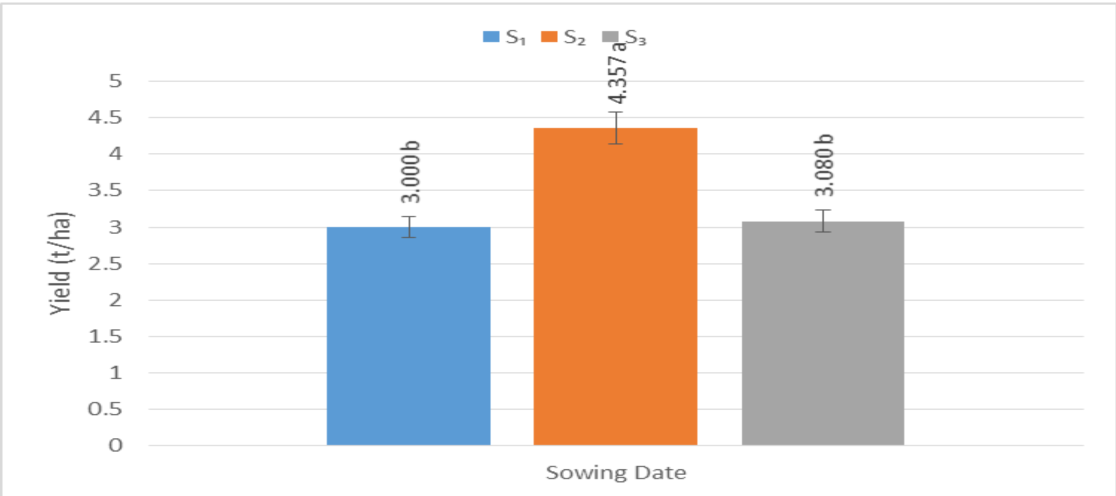


V_1: BARI Gom-21 V_2: BARI Gom-24 V_3: BARI Gom-25 V_4: BARI Gom-26

Fig 50. Effect of variety on grain yield of wheat (LSD 0.05%)

Effect of sowing date

Sowing date had a significant effect on yield (Appendix VII & Fig. 51). The maximum yield was obtained from the S_2 (4.357 t/ha). While the lowest yield was obtained from S_1 (3.00 t/ha) which was statistically similar with S_3 (3.08 t/ha).



S_1: Sowing at 20 November S_2: Sowing at 1 December S_3: Sowing at 12 December

Fig 51. Effect of sowing date on grain yield of wheat (LSD 0.05%)

Interaction effects of variety and sowing date

The interaction effect of variety and sowing date on yield was significant (Appendix VII & Fig. 52). The highest yield was obtained from the combination of V_3S_2 (4.605 t/ha) followed by the combination of V_4S_2 (4.531t/ha) and V_1S_2 (4.162 t/ha). On the other hand, the combination of V_4S_1 (2.601 t/ha) showed lowest yield which was statistically similar with V_1S_1 (2.671 t/ha), V_3S_3 (2.94 t/ha) and V_2S_3 (3.066 t/ha).

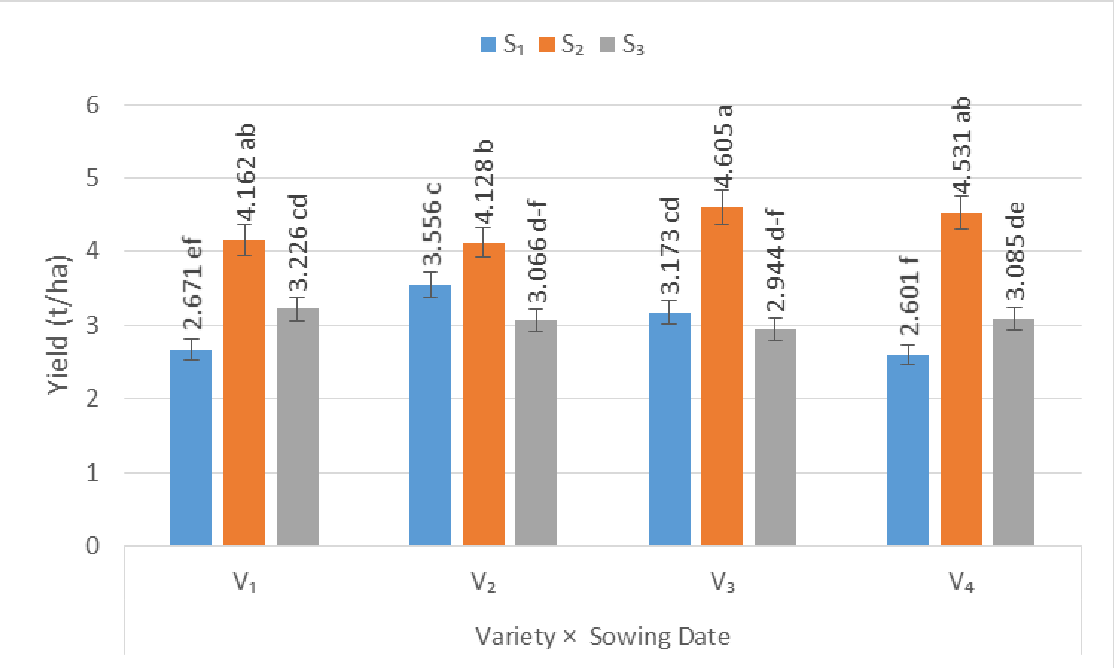


Fig 52. Interaction effects of variety and sowing date on grain yield of wheat (LSD 0.05%)

**, *, ns represent significant at 1%, significant at 5% and non-significant respectively.
In a vertical column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 5% level of significance.

V_1: BARI Gom-21
V_2: BARI Gom-24
V_3: BARI Gom-25 and
V_4: BARI Gom-26

S_1: Sowing at 20 November
S_2: Sowing at 1 December
S_3: Sowing at 12 December

The present finding is in agreement with the findings of the other researchers who work on this field. The late seeding caused lower grain yield in wheat compared to optimum sowing while investigating by Islam *et al*. (1993) and Bhatta *et al*. (1994). Al-khatib and Paulsen, (1990) concluded the high relative grain yield which was the results of stable or long duration of photosynthetic activity at heat stress condition. High temperature reduced the grain yield of wheat. Yield and yield components of wheat were also significantly reduced under early sown condition (Tyagi *et al*., 2003).

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November 2012 to March 2013 to assess the appropriate sowing date and avoiding heat stress in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November 2012 to March 2013. . The experiment comprised two factors; Factor A: Variety (4): i. V_1: BARI Gom-21, ii. V_2: BARI Gom-24, iii. V_3: BARI Gom-25 and iv. V_4: BARI Gom-26; Factors B: Sowing date (3): i. S_1: 20 November, ii. S_2:1 December and iii. S_3: 12 December.Thus, there were altogether twelve treatment combinations.

The two-factor experiment was laid out into RCB design. The size of the unit plot was 3.0 m x 2.0 m. Seeds of four wheat genotypes were sown as per treatment in rows of 20 cm apart as continuous line sowing method. Observations were made on some morpho-physiological and yield contributing characteristics. All collected data were statistically analyzed and the means were compared with Least Significant Difference Test (LSD).

Regarding the effect of variety BARI Gom-21 obtained the highest value for days to anthesis (74.33), days to physiological maturity (102.1) and days to maturity (111.0). While BARI Gom-24 performed better for these traits (73.00, 100.0 and 109.8). In case of plant height, BARI Gom-21 produced the tallest plant (89.74 cm) and BARI Gom-26 provided the lowest (85.49 cm). For yield contributing trait as tillers per m^2, fertile tillers per m^2, unfertile tillers per m^2 BARI Gom-25 showed the highest value (243.1, 234.6 and 8.556 respectively),while BARI Gom-26 obtained the lowest value (215.6, 213.0 and 2.556 respectively).1000-grain weight did not varied widely and yield performance did not differ significantly.

In case of sowing date, days to anthesis, days to physiological maturity and days to maturity was significantly reduced with delayed sowing date. Plant height, internodes length and spike length was smaller in intermediate sowing date than that of both early and late sowing date. All of the yield contributing character *viz.* number of tiller, grain weight per spike, 1000-grain weight, spikelet's per spike, grains per spike and yield varied significantly with sowing date. These traits performed best in December 1 sowing than early or 12 December sowing. December 1 sowing also dominate over other sowing dates in case of dry grain weight after anthesis.

Among the genotypes, BARI Gom-24 and BARI Gom-25 showed lowest initial lag phase duration (8 DAA and 12 DAA, respectively) while BARI Gom-21 showed the highest (16 DAA). Sowing at December 1 exhibited highest grain growth rate than sowing at 20 November and 12 December.

There was a significant variation among the varieties. BARI Gom-26 maintained the highest average grain growth rate (0.5051 mg/grain) and BARI Gom-21 showed lowest (0.3209 mg /grain). Average growth rate showed significant variation among the sowing date. Sowing at December 1 showed the highest average growth rate (0.5647 mg /grain). The lowest average growth rate was recorded in 20 November sowing and late sowing date (0.3795 mg/grain and 0.3397 mg /grain). Average grain growth rate varied significantly for the interaction effects of variety and sowing date. The maximum average grain growth rate was obtained from the combination of BARI Gom-26 with December 1 sowing (0.6997 mg/grain) While, BARI Gom-21 with 12 December sowing obtained lowest average grain growth (0.2697 mg / grain).

The interaction effects of variety and sowing date was significant for all of the traits except days to physiological maturity, days to maturity, internodes length, grain weight per spike and spikelet's per spike. For 20 November sowing, BARI Gom-21 attained the highest plant height (92.27cm). BARI Gom-26 obtained the highest spike length (18.03 cm). The highest 1000-grain weight was obtained by BARI Gom-25 (42.10 g). BARI Gom-24 produced the highest tillers per m^2 (233.7), fertile tillers per m^2 (228.0), unfertile tillers per m^2 (5.667), dry grain weight after anthesis (0.4318 g), grain per spike (40.33) and grain yield (3.56 t/ha). While the lowest spike length (16.35 cm), tillers per m^2 (194.0), fertile tillers per m^2 (190.3), dry grain weight after anthesis (.27 g) was recorded in BARI Gom-21. BARI Gom-24 produced the lowest nodes per stem (4.4). Minimum days to anthesis (67.00) and grains per spike (33.78) were obtained from BARI Gom-25. The lowest plant height (88.33 cm), unfertile tillers per m^2 (3.00), 1000-grain weight (33.30 g) and grain yield (2.60 t/ha) among the 20 November sowing were recorded from BARI Gom-26.

In case of sowing at December 1, the highest days to anthesis (74.00), plant height (92.20 cm), nodes per stem (5.47), fertile tillers per m^2 (262.7) and the lowest unfertile tillers per m^2 (1.67), dry grain weight after anthesis (0.408 g), 1000 grain weight (38.77 g), grains per spike (40.89) was obtained from BARI Gom-21. BARI Gom-24 produced the highest spike length (16.16 cm) and the lowest days to anthesis (70.00), plant height (82.40 cm), nodes per stem (4.93), tillers per m² (224.0), fertile tillers per m² (221.0) and grain yield (4.13 t/ha). BARI Gom-25 attained minimum spike length (15.22 cm) and maximum tillers per m² (274.30), unfertile tillers per m² (255.7), 1000-grain weight (44.07 g) and grain yield (4.61 t/ha).

In respect of late sowing, BARI Gom-21 attained maximum spike length (15.92 cm), tillers per m² (227.3), fertile tillers per m² (226.3), grains per spike (40.67), grain yield (3.23 t/ha) and minimum nodes per stem (5.07), dry grain weight after anthesis (0.286 g), 1000-grain weight (35.10g). BARI Gom-24 required the highest days to anthesis (78.67), highest plant height (86.00 cm) and the lowest tillers per m² (201.0), fertile tillers per m² (200.3), unfertile tillers per m² (0.67). The lowest grain yield (2.94 t/ha)) and the highest nodes per stem (5.33), unfertile tillers per m² (3.00) was obtained from BARI Gom-25. BARI Gom-26 resulted the lowest days to anthesis (75.33), plant height (83.20 cm), spike length (15.16 cm), grains per spike (34.78) and the highest nodes per stem (5.33), dry grain weight after anthesis (0.043g) and 1000-grain weight (41.93 g).

Based on the experimental results, it may be concluded that

i. Sowing of wheat at 1st December was found better than 20 November and 12 December sowing in relation to the crop performance
ii. BARI gom-25 performed better than other wheat varieties in relation to the crop performance.
iii. BARI gom-24 and BARI gom-26 wheat varieties showed lowest initial lag phase duration and BARI gom-26 exhibited the highest grain growth rate at 01 December sowing.

Yet, these findings need to be further investigation and evaluation on different agro-ecological zones before final recommendation to the farmers.

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Appendices

APPENDICES

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the soil before experimentation

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

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

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

* Monthly average

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

Appendix III. Analysis of variance of the data on days to anthesis, days to physiological maturity and days to maturity of wheat influenced by variety and sowing date

Source of variation	Degree of freedom	Days to anthesis	Days to physio. maturity	Days to maturity	Plant Height (cm)
Replication	2	1.861	8.111	5.528	3.222
Variety (A)	3	14.556**	12.926*	6.889*	32.983**
Sowing date (B)	2	194.111**	27.111**	20.361**	105.175**
Interaction (AxB)	6	5.889**	3.704^{ns}	3.361^{ns}	16.371**
Error	22	1.104	3.051	2.164	1.041

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

Appendix IV. Analysis of variance of the data on plant height, nodes per stem internodes length and spike length of wheat influenced by variety and sowing date

Source of variation	Degree of freedom	Nodes/ stem (no.)	Internodes length (cm)	Spike length (cm)
Replication	2	0.030	0.708	0.056
Variety (A)	3	0.226**	1.275^{ns}	1.174**
Sowing date (B)	2	0.848**	7.641**	9.476**
Interaction (AxB)	6	0.122**	0.924^{ns}	0.915**
Error	22	0.025	0.458	0.131

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

Appendix V. Analysis of variance of the data on tiller per m², fertile tiller per m² and unfertile tiller per m² of wheat influenced by variety and sowing date

Source of variation	Degree of freedom	Tiller/m² (no.)	Fertile Tiller/m² (no.)	Unfertile Tiller/m² (no.)
Replication	2	574.528	513.861	3.250
Variety (A)	3	1344.028**	863.296**	81.509**
Sowing date (B)	2	4551.694**	3728.028**	65.333**
Interaction (AxB)	6	1035.806**	919.991**	63.481**
Error	22	167.104	159.861	2.280

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

Appendix VI. Analysis of variance of the data on dry grain weight after anthesis, grain weight per spike and 1000-grain weight of wheat influenced by variety and sowing date

Source of variation	Degree of freedom	Dry grain weight after anthesis (g)	Average grain growth (mg/day)	grain wt./ spike (g)	1000 grain wt. (g)
Replication	2	0.000	0.003	0.012	5.495
Variety (A)	3	0.054**	0.054*	0.059^{ns}	32.190*
Sowing date (B)	2	0.174**	0.173*	0.568**	91.674**
Interaction (AxB)	6	0.007**	0.007^{ns}	0.036^{ns}	34.237**
Error	22	0.001	0.003	0.019	8.132

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

Appendix VII. Analysis of variance of the data on spikelet per spike, grain per spike and yield of wheat influenced by variety and sowing date

Source of variation	Degree of freedom	Spikelet/spike (no.)	Grain/ spike (no.)	Grain yield (t/ha)
Replication	2	0.157	24.703	0.287
Variety (A)	3	0.371^{ns}	14.988*	0.123^{ns}
Sowing date (B)	2	51.803**	75.966**	6.949**
Interaction (AxB)	6	0.152^{ns}	19.856**	0.353**
Error	22	0.123	4.205	0.076

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