STUDY ON GRAIN YIELD AND YIELD COMPONENTS OF WHEAT WHEN SOWN LATE

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CERTIFICATE

*This is to certify that thesis entitled, "**STUDY ON GRAIN YIELD AND YIELD COMPONENTS OF WHEAT WHEN SOWN LATE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **TOMA DEBNATH**, **Registration no. 15-06527** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:

Place: Dhaka, Bangladesh

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DEDICATED TO
MY
BELOVED PARENTS

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STUDY ON GRAIN YIELD AND YIELD COMPONENTS OF WHEAT WHEN SOWN LATE

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2021 to March 2022 in Rabi season, to study on grain yield and yield components of wheat when sown late. The experiment consisted of two factors, and followed Randomized block design with three replications. Factor A. Wheat varieties (2) *viz;* V_1: BARI Gom-32 and V_2: BARI Gom-33 and Factor B. Different sowing date (5) *viz;* S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021. Experimental result showed that in case of different wheat varieties the lowest grain yield (3.96 t ha^{-1}) was observed in V_1 (BARI Gom-32) treatment. Whereas cultivating BARI Gom-33 (V_2) variety gave the highest spike length (10.63 cm), spikelets spike^{-1} (17.59), grains spike^{-1} (46.85), 1000 grains weight (43.51 g), grain yield (4.73 t ha^{-1}), straw yield (5.86 t ha^{-1}), biological yield (10.59 t ha^{-1}) and harvest index (44.66 %). Among different sowing dates, seeds sown on 28th November (S_1 treatment) recorded the highest spike length (10.46 cm), spikelets spike^{-1} (17.49), grains spike^{-1} (52.89), 1000 grains weight (46.20 g), grain yield (4.66 t ha^{-1}), straw yield (5.69 t ha^{-1}), biological yield (10.35 t ha^{-1}) and harvest index (45.01%). In case of combination treatment the V_2S_1 combination treatment gave the highest highest spike length (11.46 cm), spikelets spike^{-1} (18.46), grains spike^{-1} (56.46), 1000 grains weight (47.35 g), grain yield (5.02 t ha^{-1}), grain yield (6.07 t ha^{-1}), biological yield (11.09 t ha^{-1}) harvest index (45.27 %) comparable to other combination treatments. Therefore considering above all facts, it may be concluded that BARI Gom-33 variety seed sown on 28th November (V_2S_1) seems promising for reduction of yield less of late sown wheat than compared to other combination treatment and planting wheat seeds later than 28th November should be discouraged as it reduces wheat yield in both varieties.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum*) a member of family Poaceae is second most important staple food crop of the world after rice and occupies a significant place in world economy. Wheat contributes nearly 35% to the national food basket and plays an important role in food and nutritional security. It contains about 12% protein, 70% carbohydrate, 2.7% minerals, 1.7% fats, 2% fiber and 12% moisture (Javid *et al*., 2022). Because of complex genome nature of wheat it has wider adaptability, therefore it is grown from temperate irrigated to dry and high rainfall areas and from warm humid to dry cold environmental conditions and being a C_3 type crop, it thrives well in cool environment (Saikia *et al*., 2021). As wheat is a thermo-sensitive long-day crop temperature is a major determinant of growth and productivity of wheat. The optimum temperature regime during growing season of wheat crop ranges in between 20-22 ^{o}C at sowing, 16-22 ^{o}C at tillering till grain filling stage and slowly temperature rises to 40 ^{o}C at harvesting time (Hussain, 2021).

Wheat is a major staple food for more than 4.5 billion people (Grote, 2021). It is cultivated in almost every country of the world contributing about 30% of total food grain production (Halecki and Bedla, 2022). Around 780.59 million metric tons of wheat are produced globally from an area of more than 220 million ha, with an average productivity of 3.52 t ha^{-1} (USDA, 2022). Although European Union has maximum production of wheat but among various countries China is the largest producer which is followed by other Asian countries (Statista, 2022). Production of wheat in Bangladesh has increased many folds from the time of independence. During the cropping season of *Rabi* 2021-22, Bangladesh has produced 1.18 million metric tons wheat from an area of 314 thousand hectares with an average productivity of 3.44 t/ha (BBS, 2022). Dinajpur, Rajshahi, and Rangpur are the major wheat producing districts in Bangladesh (Rahman and Miah, 2017).

Suitability of varieties to a particular agro-climate is the most important factor in realizing their yield potential because production efficiency of the plants is determined by genotype and environment. Environmental conditions prevailing over a particular agroclimatic zone cannot be altered. The selection of high yielding wheat

varieties for wide range of adaption to soil and climate condition is essential to increase yield of wheat

(Gupta and Gupta, 2022). Thus, the sowing date and variety are the most important factors that affect grain yield and quality, where the optimum sowing date of wheat cultivars lead to increase 1000-grain weight (Sah *et al*. 2022). The reduction in wheat yield and its components with delayed sowing date was the result of exposure of plants to high temperature, which decreased season length (Shah *et al*., 2020). Improper selection of varieties also affects crop yield because performance of varieties vary correspondingly with their genetic potential and existing environment, so there is scope for increasing yield of wheat with cultivation of multi-character high yielding varieties (Alam *et al*., 2022). Different genotypes have evolved various mechanisms to cope with heat stress which are rolling, shedding and thickening of leaves, reduction in leaf size and duration of growth, transpiration cooling and other adjustments in morphology (Deva *et al*., 2020).

Variety selection may be one major source of productivity gains. In Bangladesh most of the farmers are practicing late sown wheat due to late release of canal water or wheat grown after a catch crop of mustard during September-December. Due to both the reasons productivity of wheat crop get reduced significantly. There are many factors, which are responsible for lower yield levels of wheat crop. Therefore, some efforts have been made to increase the yield by introduction of high yielding new varieties, balanced fertilizer application and optimum use of seed rates in respect to different dates of sowing. But there are certain factors on which attention have not been given to increase the productivity of wheat. One of such environmental factors is date of sowing. This factor affects the yield of wheat crop considerably. The genotypic response of wheat to planting dates varies for yield contributing characters. The decline becomes prominent in the varieties requiring more days for heading (Poudel *et al* 2020). Performance of particular variety under different sowing dates depends upon the genetic makeup of the variety. Varieties with ability to tolerate high temperature perform well under late sown conditions, whereas varieties with no such genetic machinery are good under early sowing. Similarly, susceptible varieties matured earlier when planted late, indicating the forced maturity due to high temperature.

Sowing time governs the Phenological development, yield and effective conversion of biomass into economic yield in wheat. Timely sowing of wheat provides optimum growing period for the crop growth which can accumulate more biomass and finally results in higher grain and biological yield. In case of late sowing, the wheat crop is exposed to low temperature at the time of germination and seedling emergence while exposure to high temperature at the reproductive stage leads to forced maturity and resulted in reduction of the grain yield and biological yield (Gupta *et al*., 2017). Too early sowing produces weak plants with poor root system. Temperature higher than optimum leads to abnormal germination and the embryo frequently dies and the endosperm may undergo decomposition due to activities of bacteria or fungi which impact adversely the emergence of seedlings and the number of tillers, resulted on reduction of economic yield (Fazily, 2021). Delay in sowing results in poor tillering and crop growth is generally slow due to low temperature. In late planting the wheat variety should be of short duration that may escape from high temperature at the grain filling stage (Aryal *et al.,* 2022). Through management of the sowing date, environmental conditions and selection of cultivars the increase in wheat grain by 10% to 80% has been reported by Coventry *et al.,* (2011). Therefore, the optimization of sowing time and selection of well performed wheat variety to a sowing time are significant parameters to attain maximum yield and effective conversion of biomass into economic yield, which can be done through a comprehensive study on days taken to attain different phenophases and yield response of wheat crop during a growing season.

Taking in consideration the above facts an experiment was conducted in *Rabi* season of 2021-22 to "Study on grain yield and yield components of wheat when sown late" with the following objectives:

i. to find out best sowing time of wheat varieties
ii. to study the effect of sowing time on growth, yield and yield attributes of wheat varieties.
iii. To explore interaction effect of sowing time and variety on growth and yield of wheat

CHAPTER II

REVIEW OF LITERATURE

The literature relevant to the present investigation entitled "Study on grain yield and yield components of wheat when sown late, has been reviewed in this chapter. Wherever necessary the references from related crops are also included to make this review more comprehensive and complete. The literature is reviewed under the following heads:

2.1 Effect of varieties

Various varieties responsed differently to abiotic stress through different mechanisms such as rolling, shedding, thickening of leaves, reduction in leaf size, duration of growth, transpiration cooling and other adjustments in morphology. Therefore, determination of different wheat varieties is a significant step to minimize the adverse effects of the abiotic stress on wheat crop growth and yield.

Sah *et al*. (2022) carried out an experiment to evaluate the effect of different sowing times on wheat varieties and reported that variety had no significant effect on plant height and straw yield, but influenced significantly the spike length, effective tillers, 1000 grains weight and grain yield. Among different varieties a promising wheat variety BL 4407 (4017 kg ha^{-1}) produced the highest yield, (20% more) compared with released variety Vijay (3203 kg ha^{-1}).

Shibeshi and Kassa (2021) was carried out an experiment was to identify the most performing durum wheat varieties in the tested environment. The average productivity of the tested genotypes were evaluated at two locations (Alicho and Analimo) using randomized complete block design with four replication for two consecutive years (2016 and 2017). The experimental material consists of seven improved durum wheat genotypes. The Combined analysis of variance showed significant ($P<0.05$) difference among tested genotypes on collected parameter indicating the presence of adequate variability. The highest average grain yield recorded was 4446 kg ha^{-1} from Hitosa variety while the lowest obtained was 3634 kg ha^{-1} from Denbi variety. Grain yield had strong positive correlations ($P<0.01$) with plant height, number of seed $spike^{-1}$ and biomass.

Gupta *et al.* (2020) investigated the influence of planting conditions and nitrogen levels on the performance of three wheat cultivars (HD 2967, RSP 561 and WH 1105) and findings showed that WH 1105 had considerably greater plant height (105.5 cm), LAI (4.43), dry matter accumulation (277 g/m row length) and crop growth rate than the other types.

Yusuf *et al.* (2019) reported that among seven wheat varieties i.e. HS 562, HD 2967, HD 3086, HI 1544, MACS 6222, WR 544 and WH 1105. HI 1544 recorded significantly higher number of effective tillers (94.6 per mrl), grains per spike (48.4), test weight (38.6 g), grain yield (4920 kg ha^{-1}) harvest index (39.2%), while variety WH 1105 resulted in longer spike (11.5 cm).

Bachhao *et al.* (2018) reported that all the growth attributing were increased with the advancement in age of the wheat crop. Plant count (33.36), plant height (81.49 cm), number of functional leaves per plant (1.83), total number of tillers per meter length (101.97), leaf area (0.75 dm^2) and dry matter per plant (12.15 g) were found significantly higher in variety Tapowan over Trimbak and Godawari.

Kamboj (2018) reported that among four wheat varieties i.e. WH 1105, HD 2967, HD 3086 and DBW 88, highest yield attributes were recorded with HD 3086 except number of grains per earhead which was highest in WH 1105. Maximum grain yield (5822 kg/ha), biological yield (14023 kg/ha), were obtained from HD 3086. The highest harvest index (41.6) was attained by WH 1105.

Mahajan *et al.* (2018) reported that the highest values of grain yield (39.90 q ha^{-1}), straw yield (61.58 q ha^{-1}) and protein content (11.30%) were recorded in variety NIAW-1994 (Phule Samadhan) as compare to NIAW-301 (Trimbak), NIAW917 (Tapovan), NIAW-34 (Niphad -34).

Gupta *et al.* (2017) reported that wheat varieties HD 2967, HD 3086, HS 562, WH 1105, MACS 6222 and HI 1544 recorded 101 cm, 99.6 cm, 98.1 cm, 96.2 cm, 94 cm and 98 cm height, days taken to 75 per cent ear head emergence was 99 days, 92 days, 103 days, 95 days, 101 days and 89 days and ear length was 10.4 cm, 10 cm, 11 cm, 11.5 cm, 10.8 cm and 11.3 cm, respectively.

Kaur and Kaur (2017) observed that among different varieties in relation to yield and yield contributing parameters like effective tillers (m^{-2}), number of grains per spike

and 1000 grain weight (g) HD 3059 was the top yielder (48.11q ha^{-1}) which proved significantly superior over PBW 590, PB W550 and WH 1021 and was statistically at par with WH 1124, DBW 90 and WH 1129.

Sandhu *et al*. (2017) conducted an experiment by taking nine different wheat varieties (PBW 725, PBW 677, HD 3086, WH 1105, HD 2967, PBW 621 and PBW 550 are timely sown and PBW 658 and PBW 59 are late sown varieties) to evaluate their performance. They reported that varieties HD 3086, WH 1105 and PBW 550 took comparatively less days for maturity as compared to rest of the varieties. Variety PBW 677 recorded significantly higher plant height than rest of the varieties.

Shirinzadeh *et al.* (2017) revealed that the Chamran cultivar with the yield of 6948 kg ha^{-1} and Morvarid cultivar with the yield of 5875 kg/ha produced the highest and lowest yield, respectively.

Yadav *et al*. (2017) reported that under normal sowing condition numerically recorded values of plant height and accumulated dry matter in variety HD 2967, HD 3086 and WH 105 was 95.52 cm, 93.83 cm and 92.89 cm and 1.04 kg m^{-2}, 1.07 kg m^{-2} and 1.01 kg m^{-2}, respectively.

Verma *et al.* (2016) obtained significantly higher grain yield (5320 kg/ha) and straw yield (6171 kg/ha) of wheat genotype DBW 39 over the rest of the three varieties *i.e.* HD 2967, HD 2733 and PBW 502.

Singh and Uma (2015) conducted an experiment with three sowing dates and seven wheat genotypes (DBW 88, DBW 17, SD 2967, BPW 621-50, HD 3086, WH 1105 and PBW 550) and observed that BPW 621-50 produced significantly more number of effective tillers, longest spikes, more number of spikelets per spike, higher number of grains per spike, higher grain weight per spike and higher 1000 grain weight than the rest of the genotypes under all sowing times.

Gill *et al*. (2014) conducted an experiment at two zones of Punjab state i.e. Central plain zone, Ludhiana and South-Western zone, Bathinda to study the phenological behaviour of wheat varieties *viz*. PBW 343 and PBW 621 under different environmental conditions. They reported that the variety PBW 621 took significantly less time for initiation and completion of the various phenological stages than PBW 343.

Alam *et al.* (2013) observed superiority of K 0307 in total number of tillers (492/m^2) and dry matter accumulation (1120.6 g/m^2) over rest of the four varieties *i.e*. Raj 4229, K 0906, HD 2733 and DBW 39.

Chourasiya *et al*. (2013) reported that yield attributes and yield of wheat crop showed significant variation due to wheat varieties. Among varieties, HI 8498 produced significantly maximum grain (60.82 q ha^{-1}) and straw yield (80.63 q ha^{-1}); whereas, GW 366 recorded the lowest grain and straw yield. The higher grain yield with wheat variety HI 8498 was attributed to more yield attributes, i.e. number of tillers m^{-2}, ear head m^{-2}, number of grains $spike^{-1}$ and test weight as compared to rest of the varieties, which might have contributed higher leaf area responsible for accumulating more photosynthesis.

Kumar (2013) reported that wheat variety K 0307 produced significantly higher total number of tillers (490.1/m^2) and higher dry matter accumulation (1118.6 g/m^2) over other varieties *viz.* Raj 4229, K 0906, HD 2733 and DBW39.

Al-Musa *et al*. (2012) worked in Bangladesh using four varieties i.e. BARI ghom-23, BARI ghom-24, BARI ghom-25 and BARI ghom-26. Among the varieties BARI ghom-26 recorded superior germination at 13 days after sowing as compared to the other varieties and also the tallest plant, maximum total dry matter, maximum effective tillers, grains per spike, highest grain and straw yield and highest test grain weight were recorded by this variety comparable to over other wheat varieties (BARI ghom-23, BARI ghom-24 and BARI ghom-25).

Basu *et al.* (2012) conducted an experiment on five wheat varieties i.e. PBW 343, HD 2733, HW 2045, PBW533 and K 9107 under three sowing dates in Nadia (West Bengal). They reported K 9107 with minimum growing days required during vegetative and reproductive stages.

Mukherjee (2012) reported that HS 473 gave significantly higher mean grain yield (2930 and 2740 kg ha^{-1}) than HS 365 (2000 and 2170 kg/ha) but was at par with VL 875 (2860 and 2500 kg ha^{-1}) and PBW 343 (2890 and 2610 kg ha^{-1}) during both the years.

Ram *et al*. (2012) conducted an experiment using three wheat varieties *viz.* PBW 550, PBW 343 and DBW 17 at Ludhiana (Punjab) with four seed rates and reported the

highest grains ear^{-1} in variety PBW 550 which was significantly higher than PBW 343 and DBW 17.

Singh *et al*. (2012) observed performance of HI 1544 cultivar sown on 25th November and reported that the variety attained botting stage, spike emergence, anthesis and physiological maturity at 66, 82, 92, and 132 DAS, respectively.

Ali *et al*. (2010) conducted an experiment in which two wheat varieties viz. SH 2002 and AS 2002 along with a standard Uqab 2000 were subjected to different sowing times starting from 1st November to 30th December at ten days interval and revealed that wheat variety AS 2002 proved better than SH 2002 and Uqab 2000 in growth parameters.

Bhardwaj *et al.* (2010) conducted an experiment using five wheat varieties and reported that PBW 343 had vigorous growth in terms of plant height and dry matter accumulation as compared to other varieties.

2.2 Effect of sowing date

Wheat is the most important food crop grown during *Rabi* season in India. Variation in weather conditions during crop season is one of the most significant constraint affecting growth and yield potential of wheat crop. Therefore, one of the requirements for obtaining high yield is the selection of the appropriate sowing date.

Sah *et al*. (2022) carried out an experiment to evaluate the effect of different sowing times on wheat varieties and reported that there was a significant effect of date of sowing on spike length, tillers, grain yield and 1000 grains weight, but the plant height and straw yield were not affected significantly by sowing dates. The 25th November sown wheat crop gave a significantly higher grain yield (3925 kg ha^{-1}) and straw yield (8044 kg ha^{-1}) but declined in grain yield noted by 11-14% in the 10th November and 10th December sown wheat. It can be concluded that proper time of sowing and selecting appropriate variety enhanced the grain yield of wheat.

Singh *et al*. (2022) conducted an experiment during Rabi seasons of 2019-20 and 2020-21 at Krishi Vigyan Kendra, Maharajganj, Eastern U.P. conducted 30 acre sowing date demonstration on wheat crop at farmers field of three adopted villages to study the effect of sowing dates of sowing (15th November and 15th December) on growth, yield attributes and yield of wheat variety (K 1317) on a sandy loam soil at

Maharajganj district, eastern Uttar Pradesh, India. Wheat sown on 15th November recorded significantly highest plant height, tillers m^{-2}, grain yield. The results of sowing date revealed that average yield of 41.46 q ha^{-1} was first sowing and second sowing grain yield was recorded 36.11q ha^{-1}, village obtained in Bisohhor, Basuli and Raipur blocks of Nichlol district Maharajganj. The yield was found to be 14.82 percent higher over the second sown. The lowest values of technology gap indicate the more feasibility of the technology gap from 13.55 percent.

Galdi *et al*. (2021) carried out an experiment to study the effects of sowing date and spring wheat cultivars on yield and yield components. The experiment was laid on with randomized complete blocks design with three replications in the Research Farm of Gonbad University, Iran in 2013-2014, 2014-2015. Sub-plots included planting dates (4th and 19th of November, 3rd, and 18th of December, 2nd, and 18th of January, 8th, and 23rd of February, and 9th of March). The main plots were spring wheat cultivars (Khazar 1, Falat, Zagros, Kuhdasht, and Kareem). The results showed that a delayed planting date reduced the number of days from planting to flowering, therefore plant height and removable storage material reduced in the seed. Delay in planting reduced number of spike, number of seeds per plant, grain weight per spike and grain weight, also reduced yield. The highest grain yield was obtained from the planting date i.e. 4th November in the year 2013-2014 with 4,178.3 kg ha^{-1} per hectare and in the year 2014-2015 with 3,194.13 kg ha^{-1}. The lowest grain yield was obtained from the delayed sowing date i.e. 9th March in the year 2013-2014 with 762.2 kg ha^{-1} and in the year 2014-2015 with 920.58 kg ha^{-1} respectively.

Ahmed *et al.* (2022) showed that the values of grain yields and yields attributed were highly significantly affected by planting dates and methods during two consecutive winter seasons of 2017-18 and 2018-19. Planting wheat at the optimal date (20th November) was better than sowing at the late date (20th December) for all values i.e., plant height, no. of grains per spike, spike length, 1000-grain weight and grain yield from the studied parameters in both seasons of the study.

Yusuf *et al.* (2019) reported that among four sowing dates viz. 5th November, 25th November, 15th December and 5th January. 5th November sowing is the most economical and suitable than rest of the sowing dates. 5th November sown crop recorded significantly longer spike (11.7 cm), higher number of effective tillers (98.3

per mrl), grains per spike (48.6), test weight (39.9 g), grain yield (5432 kg ha-1) and harvest index (39.0%) compared to rest of the sowing dates.

Dar *et al.* (2018) results revealed that the growth characters like plant height (94.94 cm), dry matter accumulation (110.7 g m^{-2}), number of tillers (311.5 m^{-2}) and leaf area index (3.60) were recorded highest with 15th October sowing.

Kamboj (2018) reported that among four sowing dates viz. 5th November, 15th November, 25th November, 5th December, sowing of wheat on 5th November resulted in significantly higher effective tillers, grains per earhead and 1000 grain weight resulting in 27.4, 9.7 and 20.5 % higher, respectively as compared to 5th December sowing.

Madhu *et al.* (2018) results showed that the highest number of effective tillers m^{-2} (4.15), the highest number of total spikelets $spike^{-1}$ (15.68), the highest spike length (10.13 cm), the highest number of grains $spike^{-1}$ (35.43), and the highest 1000-grain weight (27.47 g) were found on 15th November sowing.

Singh *et al*. (2018) reported that number of effective tillers m-2 were reduced under delayed sown which might be due to unfavourable climatic condition during crop growth period which resulted in reduction of the total wheat yield. They further added that the test weight of wheat crop was reduced by delay in sowing time which might be due to less production of photosynthates, due to shorter growth period of the crop and shrivelled grains which was attributed to prevailing hot winds during milking and grain filling stages of the wheat crop. There was adverse relationship during reproductive period between temperature and grain yield of wheat (under late sowing time the temperature rises and grain yield decreases and vice versa).

Ali *et al*. (2017) reported that the significant maximum grain yield was recorded (5196 kg ha^{-1}) and (5008 kg ha^{-1}) for October 25th and November 5th against the minimum grain yield of (3366 kg ha^{-1}) for December 5th sown crop.

Gupta *et al*. (2017) reported that the number of days taken to different phenological stages (emergence, heading, anthesis, milking, dough and maturity), leaf area index, dry matter, grain yield as well as biological yield was significantly influenced by different dates of sowing. The crop sown under late condition took less number of days to attain maturity as compared to the crop sown timely.

Kaur and Kaur (2017) revealed that germination count was significantly affected by date of sowing. The January sown crop recorded significantly lower germination count (173.3 m^{-2}) as compared to December sown crop (234.7 m^{-2}).

Shirinzadeh *et al*. (2017) revealed that the highest and lowest grain yields were recorded from 21st November (7322 kg ha^{-1}) and 21st December (5176 kg ha^{-1}) sowing dates, respectively. Higher yield was observed from 21st November sowing due to the superiority of some traits, including 1000 grain weight, grain number, grain weight per spike, optimum density, harvest index and grain filling period as compared to 21st December sowing.

Yadav *et al.* (2017) conducted a field experiment with two dates of sowing *i.e.* 15th November and 25th November to study the performance of newly released wheat varieties at different sowing dates under NWPZ of UP and reported that maximum plant height, dry matter and number of tillers per m2 was observed with first sowing date (15th November).

Singh (2016) reported that the number of effective tillers, 1000-grain weight, ear length, number of grains per spike, spikelets per spike, grain yield and harvest index increases under early and timely sown crop, which were due to favourable growing conditions and allocation of long growing period and favourable temperature at reproductive stage of wheat crop as compared to late sown conditions.

Ahmed (2015) observed that delay in sowing decreased values of all the parameters except harvest index. Maximum biological yield was recorded with 25th October sowing while minimum biological yield was recorded in crop sown on 15th December.

Kaur *et al*. (2015) reported that wheat growth duration depends on the sowing time. The wheat crop sown during 2nd fortnight of November gets 7-10 more days (growth duration of 137-145 days) for its growth as compared to the crop sown in December whose growth duration was shorted by 7-10 days (growth duration of 124-135) in Punjab condition.

Mumtaz *et al*. (2015) conducted an experiment with six sowing dates (1st November, 11th November, 21st November, 1st December, 11th December and 26th December) to study the effect of various sowing dates on growth, yield and yield components of different wheat genotypes and reported that the wheat varieties sown on 11th

November performed better with respect to days taken to booting, heading, anthesis and maturity stages; germination count m^{-2}, number of tillers m^{-2} and plant height compared to the other sowing dates.

Shroti and Chauhan (2015) stated that at harvest, the reduction in plant height of wheat crop was to the tune of 10.1 and 20.9%, and reduction in dry matter accumulation was to the tune of 7.0 and 13.2% with late (12th December) and very late (2nd January) sowings, respectively over normal date of sowing (18th November). The increase in spike length with normal sowing was to the tune of 23.4 and 36.3%, respectively over late and very late sowing dates.

Suleiman *et al.* (2014) concluded that the yield and yield components decreased with delay in sowing date from 1st November to 15th December and the highest values were obtained when cultivars were sown on 1st November followed by 15th November.

Alam (2013) revealed that sowing of wheat on 25th November resulted in significantly more total number of tillers (420 tillers m^{-2}) and higher dry matter accumulation (1190 g m^{-2}) as compared to 20th December sowing.

Amrawat *et al*. (2013) reported that the wheat crop sown on 5th November produced the highest grain (64.9 q ha^{-1}) and straw (108.8 q ha^{-1}) yield followed by 20th November than that of the 5th December and 20th December which might be due to higher growing degree days, photo thermal unit and days taken to attain physiological maturity stages. There is negative relationship between mean temperature and reproductive period of the crop, as an increase in mean temperature during reproductive period by 1°C, reduces the reproductive period by about 4 days, which results in reduction of grain yield of the wheat crop.

Chourasiya *et al*. (2013) stated that sowing dates significantly affected the yield and yield attributes of wheat crop. The crop sown on 18th November (normal sowing) produced significantly higher yield and yield attributes over the 11th (early sowing) and 25th November (late sowing) sown crop. They further added that too early (11th November) and delayed (25th November) sowings produced 6.37% and 13.35% less grain yield, respectively than that of normal sowing (18th November).

Dogiwal *et al*. (2013) observed that total plant biomass and its partitioning into different plant parts were reduced significantly at all growth stages with each 30 days successive delay in sowing from 10th November to 10th January.

Jat *et al*. (2013) reported that yield attributes like ear length, grains per ear, ear weight and test weight were significantly influenced by the dates of sowing. All yield attributes were reduced with delay in sowing time of the wheat crop. Lower grain yield under late-sown wheat could be due to less favourable period for maturity. High temperature and hot winds caused forced maturity of the crop which resulted in shorting the maturation period.

Kumar (2013) reported that sowing of wheat on 25th November produced higher plant height (97.3 cm) with more total number of tillers m^{-1} (416.3) and higher dry matter accumulation (1180.9 g m^{-2}) as compared to 20th December sown crop.

Aslani and Mehrvar (2012) revealed that with optimum sowing date all wheat varieties recorded higher number of spikes m^{-2}, 1000-grain weight, biological yield and final grain yield than that of the delayed sowing dates.

Mukherjee (2012) conducted an experiment on six wheat varieties under five sowing dates *viz*. 1st November, 15th November, 30th November, 15th December and 30th December and reported that crop growth characters like plant height and dry matter accumulation were significantly influenced by date of sowings. He observed that in mid-November sowing time, plant height and dry matter accumulation were more than the rest of sowing dates which was followed by late-November sowing. The reduction in plant height and dry matter accumulation under late sowing was due to shorter growing period.

Chakrabarti *et al*. (2011) conducted an experiment on five wheat varieties with seven sowing dates (7th October, 21st October, 7th November, 25th November, 7th December, 27th December and 7th January) and reported that low temperature during the crop growth period enhanced crop duration while higher temperature hastened anthesis and maturity of the crop. They further added that air temperature below 15 °C was not suitable for the growth and development (germination, seedling stand establishment and tillering) of spring wheat.

Hossain *et al*. (2011) conducted a field experiment with 8 existing wheat varieties of Bangladesh and reported that wheat varieties which were sown under late condition (27^{th} December) faced low temperature stress (<10 °C) at germination up to vegetative stage and high temperature stress at the reproductive stage which resulted in delayed seed germination and reduced seedling establishment, plant population m^{-2} and tillers/effective tillers $plant^{-1}$.

Baloch *et al*. (2010) reported that the wheat crop sown on 25th October and 10th November recorded maximum number of effective tillers as compared to the wheat sown on 25th December. They further stated that the wheat crop sown on 25th October and 10th November produced the tallest plant with longest spike which were reduced by delay in sowing time of the crop.

Nahar *et al*. (2010) evaluated five wheat varieties with two dates of sowing (30^{th} November and 30^{th} December) and reported that the heat stress significantly changed the phenology of wheat varieties and the yield as well. Generally due to high temperature stress the phenologyical stages of wheat crop were reduced which resulted in short life cycle of the wheat crop.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study on grain yield and yield components of wheat when sown late. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from November 2021 to March 2022 in Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the Central laboratory and Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level.

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For a better understanding ofthe experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with pH 5.56. The morphological, physical, and chemical characteristics of the experimental soil have been presented below Appendix-II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April, and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity, and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Planting material

BARI Gom-32 and BARI Gom-33 were used as planting materials for this experiment. The important characteristics of these are

BARI Gom -32

BARI Gom -32 Developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and released in year of 2017. The main characteristics of this variety are high yielding, early in maturity and tolerant to terminal heat stress. The variety is resistant to leaf rust and tolerant to BpLB disease. The variety also shows tolerance to wheat blast. Grains are white amber in colour and large in size (50-58g). Spikes are long with 42-47 average grains per spike. Leaves are broad and recurved. Glaucosity is medium in spike, culm and flag leaf sheath. Few hairs present in upper culm node. Lower glume beak (LGB) length is medium in length (7.0 mm). LGB spicules- numerous, LGB shoulder medium in width and elevated. Its Resistant to leaf rust and Bipolaris leaf blight. The variety also shows tolerance to wheat blast disease. and give an average yield of 4.6-5.0 t ha^{-1}.

BARI Gom -33

BARI Gom -32 Developed by Wheat Research Centre (WRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and released in year of 2017. The Main characteristics of this variety are stem and leaf are dark green color, tillers are semi erect during heading. Flag leaf is wide and droopy. Glaucosity is weak in spike. Zn-enrich variety. and give an average yield of 4.0-5.0 t ha^{-1}.

3.4 Land preparation

Only one pre-sowing irrigation was applied and then the whole field was prepared by two ploughing with harrow followed by cultivator and planking on 28th November (first sowing date). For the rest sowings the field was ploughed on 5th December, 15th December, 21th December and 28th December after application of pre-sowing irrigation respectively for second, third, fourth and fifth sowings.

3.5 Experimental treatment

There were two factors in the experiment namely different wheat varieties and sowing date as mentioned below:

Factor A: Wheat varieties (2) *viz;*

V_1: BARI Gom-32 and
V_2: BARI Gom-33

Factor B: Different sowing date (5) *viz;*

S_1: 1st sowing date : 28th November, 2021
S_2: 2nd sowing date : 5th December, 2021
S_3: 3rd sowing date : 15th December, 2021
S_4: 4th sowing date : 21th December, 2021
S_5: 5th sowing date : 28th December, 2021

3.6 Experimental details

The present experiment was laid out by using Randomized block design with three replications. The layout consisted of 30 experimental units in three replications with 10 experimental units in each replication. The unit plot size was 5.1 m^2 (3 m × 1.7 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was done at 26 November 2021.

3.7 Detail of experimental preparation

3.7.1 Seed collection and sprouting

The seeds were collected from Wheat Research Center at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Healthy and disease free seeds were selected, following standard technique.

3.7.2 Fertilizer management

On the basis of gross plot size, a uniform dose of nitrogen @ 120 kg ha^{-1} through Urea, phosphorus @ 60 kg ha^{-1} through TSP, potassium @ 40kg ha^{-1} through MoP, sulphur @ 22 kg ha^{-1} through Gypsum were applied to all treatment. The half quantity of nitrogen and full quantity of phosphorus, potassium and sulphur were broadcasted in the field during final field preparation. The rest half dose of nitrogen was top-dressed in two splits, after first and second irrigation of the crop.

3.7.3 Sowing and seed rate

Sowing was done on 28th November, 5th December, 15th December, 21th December and 28th December, 2021 using 120 kg seed ha^{-1}. Line sowing was done at 20 cm apart row opened through the manual labor and seeds were placed at 4 to 5 cm depth. Planking was done after sowing.

3.7.4 Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after sowing followed by second weeding at 15 days after first weeding.

3.7.5 Irrigation:

Field was irrigated as per requirement of the crop maintained proper moisture throughout the crop season.

3.7.6 Plant protection measures

The wheat crop was infested by Aphid and rodent. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied in some times because wheat field was highly infested by rodent.

3.8 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.9 Harvesting

Wheat was harvested when the leaves and stems turn yellow and become finally dry. Two rows of border from both the side of the plot and 0.5 m^2 wide from each side border was first harvested and rest net plot was harvested to record the yields.

3.10 Threshing, cleaning and bagging

The total produce of net area was weighed plot wise after complete sun drying before threshing. Threshing of wheat was done manually. After cleaning, grain yield was weighed from net area and finally expressed in t ha^{-1}. To obtain straw yield, grain yield was deducted from total bundle weight.

3.11 Data collection

The data were recorded on the following parameters

i. Plant height (cm)
ii. Number of tillers $plant^{-1}$
iii. Spike length (cm)
iv. Number of spikelet $spike^{-1}$
v. Number of grains $spike^{-1}$
vi. 1000-grain weight (g)
vii. Grain yield (t ha^{-1})
viii. Straw yield (t ha^{-1})
ix. Biological yield (t ha^{-1})and
x. Harvest index (%)

3.12 Procedure of data collection

i. Plant height (cm)

Five plants were randomly selected from each plot. The plant height was measured in cm from the soil surface to basal portion to flag leaf at 30^{th}, 60^{th}, 90^{th} DAS and at harvest stage.

ii. Number of tillers $plant^{-1}$

Number of tillers $plant^{-1}$ were counted at15 days interval up to harvest from pre selected hills and finally averaged as their number $plant^{-1}$. Only those tillers having three or more leaves were considered for counting.

iii. Spike length (cm)

The five spikes were selected randomly from each net plot area and their lengths were measured in cm from the base of spike to the tip of the last spikelet and average values were taken.

iv. Number of spikelet spike^{-1}

Five randomly selected spikes were threshed and their spikelet were counted and averaged and expressed as number of spikelet spike^{-1}.

v. Number of grains spike^{-1}

Five randomly selected spikes were threshed and their seeds were counted and averaged and expressed as number of grains spike^{-1}.

vi. 1000-grain weight (g)

Random grain samples were collected from the produce of each net plot and 1000-grains were counted and weighed in gram with the help of electronic balance.

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

The grains ware obtained after threshing of the net plot area was weighed as grain yield kg plot^{-1} and finally converted into t ha^{-1}.

viii. Straw yield (tha^{-1})

The straw yield for each net plot was obtained after subtracting the grain yield from total biological yield and converted in to t ha^{-1}.

ix. Biological yield (qha^{-1})

All the above ground biomass of experimental crop of each plot was harvest sun dried and weighed in kg plot^{-1} and finally converted in to t ha^{-1}.

v. Harvest index (%)

The ratio of grain to biological yield (dry matter) was considered as harvest index which expressed in percentage and calculated with the help of following formula.

$$\text{Harvest index (HI \%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.13 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

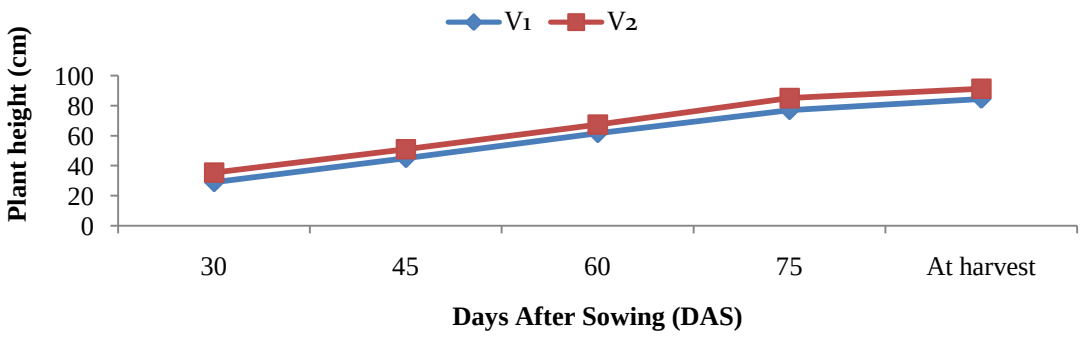
RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study on grain yield and yield components of wheat when sown late. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Plant height (cm)

Effect of variety

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants (Fig. 1). Different variety significantly influenced on plant height of wheat at different days after sowing (DAS). It was seen that height increased gradually with the age of the crop up to Harvest. Experimental result revealed that the highest plant height (35.47, 51.03, 67.38, 85.01 and 91.27 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed in V_2 (BARI Gom-33) treatment. Whereas, the lowest plant height (28.90, 44.99, 61.61,76.98 and 84.58 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed in V_1 (BARI Gom-32) treatment. The variation of plant height is probably due to the genetic make-up of the varieties. Shibeshi and Kassa (2021) reported that in wheat varieties height of a plant is determined by genetical character and under a given set of environment different varieties will acquire their height according to their genetical makeup.

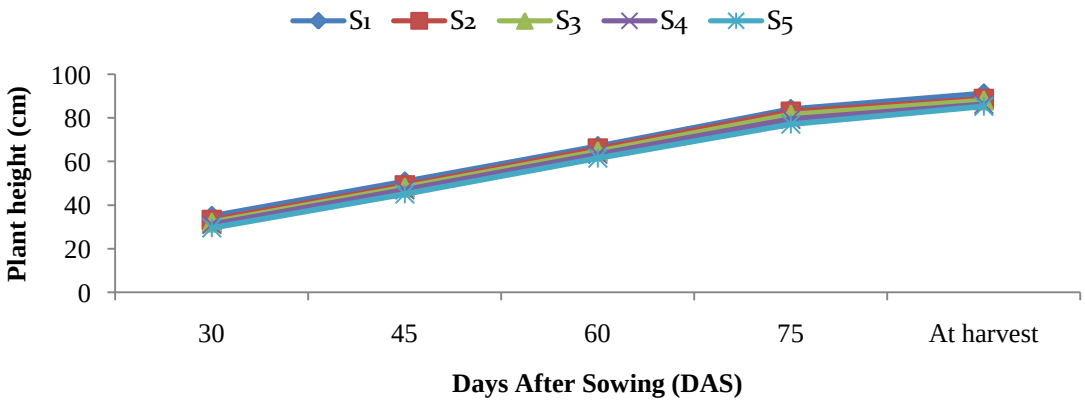


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 1. Effect of variety on plant height of wheat at different days after sowing ($LSD_{(0.05)}$: 1.45, 1.60, 2.21, 1.02 and 1.22 at 30, 45, 60, 75 DAS and at harvest, respectively).

Effect of sowing date

Significant variance in wheat plant height was observed as a result of various sowing dates (Fig. 2). Experimental result showed that the highest plant height (34.94, 50.77, 67.05, 84.07 and 91.25 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed in S_1 (1^{st} sowing date : 28^{th} November) treatment which was statistically similar with S_2 treatment (33.18, 49.09, 65.87 and 82.77 cm) at 30, 45, 60, 75 DAS respectively and with S_3 treatment (64.66 cm) at 60 DAS. Whereas the lowest plant height (29.56, 45.11, 61.62, 77.22 and 85.38 cm) at 30, 45, 60, 75 DAS and at harvest, respectively) was observed in S_5 (5^{th} sowing date : 28^{th} December, 2021) treatment which was statistically similar with S_4 treatment (31.12, 46.97, 63.29 and 86.24 cm) at 30, 45, 60 DAS at harvest, respectively. In present experiment reduction in plant height was recorded at all growth stages when sowing was delayed by each 7-10 days from 28^{th} November up to 28th December (Table 5). Highest plant height in 28th November sown crop might be due to availability of optimum environmental conditions specially temperature and solar radiation which positively influenced nutrient absorption capacity and conversion of radiant energy to chemical energy in presence of chlorophyll. The results are in line with those of Ahmed *et al.* (2022). In case of delayed sowing beyond 28_{th} November the reduced plant height in spite of higher temperature can be due to prevailing of hot dry winds which affected adversely cell expansion. The result is at par with that of Yusuf *et al.* (2019).



Here, S_1: 1^{st} sowing date : 28^{th} November, 2021, S_2: 2^{nd} sowing date : 5^{th} December, 2021, S_3: 3^{rd} sowing date : 15^{th} December, 2021, S_4: 4^{th} sowing date : 21^{th} December, 2021 and S_5: 5^{th} sowing date : 28^{th} December, 2021.

Fig. 2. Effect of sowing dates on plant height of wheat at different days after sowing ($LSD_{(0.05)}$: 2.29, 2.53, 3.49, 1.62 and 1.94 at 30, 45, 60, 75 DAS and at harvest, respectively).

Combined effect of variety and sowing dates

Variety and sowing dates had shown significant effect on wheat plant height at different days after sowing (Table 1). Experimental result showed that the highest plant height (38.76, 54.18, 70.34, 88.10 and 94.67 cm) at 30, 45, 60, 75 DAS and at harvest, respectively was observed in V_2S_1 treatment combination which was statistically similar with V_2S_2 treatment combination (36.51, 51.73, 69.19, 86.27 and 92.25 cm) at 30, 45, 60, 75 DAS and at harvest, respectively; with V_2S_3 treatment combination (35.65, 51.06 and 67.92 cm) at 30, 45, 60 DAS and with V_2S_4 treatment combination (65.57 cm) at 60 DAS. While V_1S_5 combination treatment showed the lowest plant height (26.93, 41.91, 59.34, 72.75 and 81.75 cm) at 30, 45, 60, 75 DAS and at harvest, respectively which was statistically similar with V_1S_4 combination treatment (28.00, 44.05, 61.00 and 83.12 cm) at 30, 45, 60 DAS and at harvest, respectively; with V_1S_3 combination treatment (28.60, 45.18 and 61.40 cm) at 30, 45and 60 DAS and with V_1S_2 (29.86 cm) and V_2S_5 (32.19 cm) combination treatment at 30 DAS.

Table 1. Combined effect of variety and sowing dates on plant height of wheat at different days after sowing

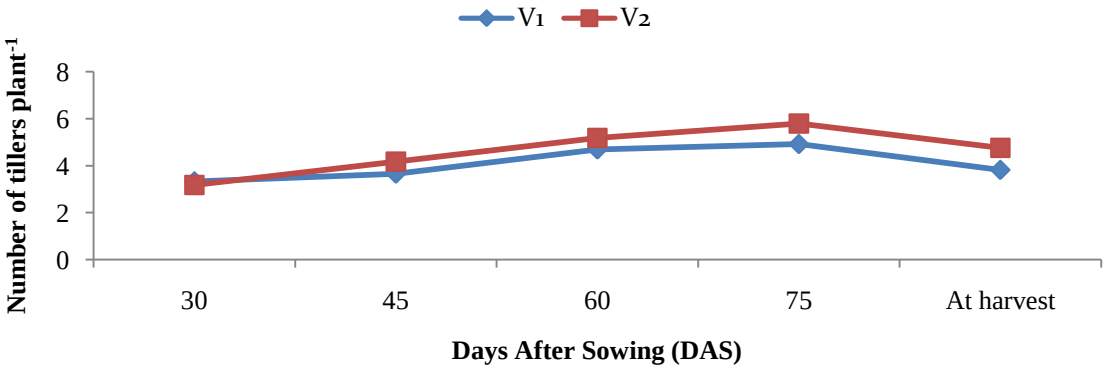
Treatment combinations	Plant height (cm) at different days after sowing				
	30	45	60	75	At harvest
V_1S_1	31.11 c-e	47.36 c-e	63.75 b-d	80.03 de	87.83 de
V_1S_2	29.86 d-f	46.45 c-e	62.55 cd	79.26 ef	85.19 ef
V_1S_3	28.60 ef	45.18 d-f	61.40 cd	77.33 fg	85.00 f
V_1S_4	28.00 ef	44.05 ef	61.00 cd	75.52 g	83.12 fg
V_1S_5	26.93 f	41.91 f	59.34 d	72.75 h	81.75 g
V_2S_1	38.76 a	54.18 a	70.34 a	88.10 a	94.67 a
V_2S_2	36.51 ab	51.73 ab	69.19 a	86.27 ab	92.25 ab
V_2S_3	35.65 ab	51.06 ab	67.92 ab	85.68 b	91.11 bc
V_2S_4	34.23 bc	49.89 bc	65.57 a-c	83.32 c	89.33 cd
V_2S_5	32.19 cd	48.31 b-d	63.89 b-d	81.69 cd	89.00 cd
$LSD_{0.05}$	3.24	3.58	4.94	2.30	2.74
CV%	5.93	4.39	4.51	3.67	4.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1: BARI Gom-32 ,V_2: BARI Gom-33, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

4.2 Number of tillers plant^{-1}

Effect of variety

Number of tillers plant^{-1} influenced significantly by wheat varieties at all growth stages (Fig. 3). At 30 DAS V_1 treatment recorded significantly higher number of tillers plant^{-1} (3.33) than rest of the varieties, while the lowest number of tillers plant^{-1} (3.18) was recorded in V_2 treatment. At 45, 60, 75 DAS and at harvest, respectively the V_2 treatment showed the highest number of tillers plant^{-1} (4.18, 5.19, 5.80 and 4.76). Whereas the lowest number of tillers plant^{-1} (3.66, 4.69, 4.92 and 3.82) was observed in V_1 treatment. The variation of number of tillers plant^{-1} was due to the genetic background of the varieties and the conditions to which the crop is exposed during growth and also it could be due to higher LAI of the variety which provided better source sink relationship. The result was similar with the findings of Sah *et al*. (2022) who reported that variety had significant effect on tillers number of wheat plant.



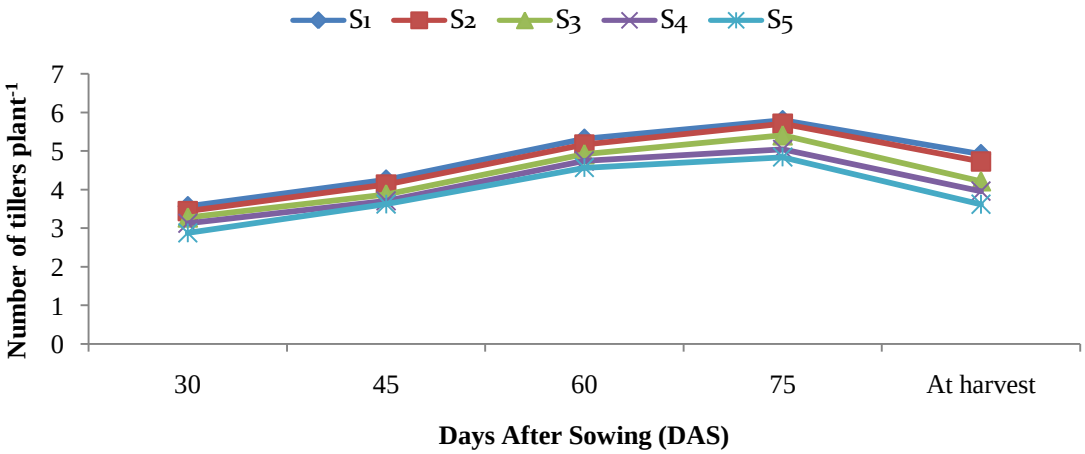
Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 3. Effect of variety on number of tillers plant^{-1} of wheat at different days after sowing ($LSD_{(0.05)}$: 0.09, 0.10, 0.05, 0.11 and 0.08 at 30, 45, 60, 75 DAS and at harvest, respectively).

Effect of sowing date

Number of tillers plant^{-1} were influenced significantly by sowing dates (Fig. 4). Experimental result showed that 28th November sown crop (S_1 treatment) resulted in significantly higher number of tillers plant^{-1} (3.57, 4.26, 5.32, 5.80 and 4.92) at 30, 45, 60, 75 DAS and at harvest, respectively as compared to rest of the sowing dates and it was statistically similar with S_2 treatment (3.44, 4.13 and 5.71) at 45, 60, 75 DAS and

at harvest, respectively. Reduction in number of tillers plant^{-1} occurred when sowing was delayed. As a result 28th December sown crop (S_5 treatment) recorded the lowest number of tillers plant^{-1} (2.88, 3.63, 4.57, 4.84 and 3.62) at 30, 45, 60, 75 DAS and at harvest, respectively. Higher number of tillers with 5th November sowing might be due to favourable climatic condition which prolonged vegetative period and resulted in more interception of solar radiation which affected positively number of total tillers plant^{-1}, higher the total tillers more the spike density and more will be the effective tillers. Also, it could be due to longer reproductive stage which affected positively the translocation of assimilated photosynthates from source (leaves and stalk) to sink (grain) which caused the plant to produce viable pollen which affected directly grain set up which is in link with elongation and viability of the spike. The results are in line with Alam (2013) who revealed that sowing of wheat on 25th November resulted in significantly more total number of tillers (420 tillers m^{-2}) and higher dry matter accumulation (1190 g m^{-2}) as compared to 20th December sowing.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 4. Effect of sowing dates on number of tillers plant^{-1} of wheat at different days after sowing ($LSD_{(0.05)}$: 0.14, 0.16, 0.09, 0.18 and 0.13 at 30, 45, 60, 75 DAS and at harvest, respectively).

Combined effect of variety and sowing dates

Wheat tiller number plant^{-1} at various days after sowing had shown a significant impact depending on the variety and sowing dates (Table 2). Experimental result showed that at 30 DAS the highest tiller number plant^{-1} (3.74) was observed in V_1S_1

combination treatment whereas the lowest tiller number plant^{-1} (2.80) was observed in V_2S_5 combination treatment which was statistically similar with V_1S_5 (2.96) combination treatment at 30 DAS. At 45, 60, 75 DAS and at harvest, respectively highest tiller number plant^{-1} (4.46, 5.50, 6.33 and 5.50) was observed in V_2S_1 combination treatment which was statistically similar with V_2S_2 combination treatment (4.35 and 6.20) at 45 and 75 DAS. Whereas the lowest tiller number plant^{-1} (3.32, 4.27, 4.44 and 3.14) at 45, 60, 75 DAS and at harvest, respectively was observed in V_1S_5 combination treatment which was statistically similar with V_1S_4 combination treatment (3.40 and 4.65) at 45 and 75 DAS.

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

Treatment combinations	Number of tillers plant^{-1} at different days after sowing				
	30	45	60	75	At harvest
V_1S_1	3.74 a	4.06 cd	5.14 cd	5.27 cd	4.34 d
V_1S_2	3.51 b	3.90 d	5.00 e	5.21 cd	4.21 de
V_1S_3	3.30 c-e	3.63 e	4.60 g	5.01 d	3.84 f
V_1S_4	3.16 d-f	3.40 f	4.44 h	4.65 e	3.54 g
V_1S_5	2.96 fg	3.32 f	4.27 i	4.44 e	3.14 h
V_2S_1	3.40 bc	4.46 a	5.50 a	6.33 a	5.50 a
V_2S_2	3.36 b-d	4.35 ab	5.33 b	6.20 a	5.24 b
V_2S_3	3.26 c-e	4.13 bc	5.23 bc	5.80 b	4.60 c
V_2S_4	3.10 ef	4.02 cd	5.04 de	5.43 c	4.37 d
V_2S_5	2.80 g	3.93 cd	4.86 f	5.23 cd	4.10 e
$LSD_{0.05}$	0.20	0.22	0.13	0.26	0.18
CV%	3.63	3.42	3.56	2.89	2.55

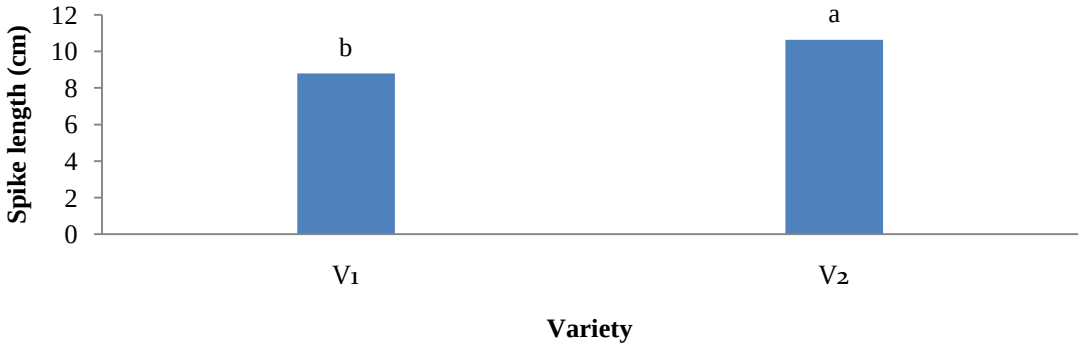
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1: BARI Gom-32 ,V_2: BARI Gom-33, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

4.3 Spike length (cm)

Effect of variety

The spike length of wheat was significantly influenced by different varieties (Fig. 5). Experimental result revealed that the highest spike length of wheat (10.63 cm) was found in V_2 (BARI Gom-33) treatment. Whereas the lowest spike length of wheat (8.80 cm) was found in V_1 (BARI Gom-32) treatment. Different wheat varieties had different spike length was due to the genetic makeup of the variety however physiological variations in wheat varieties at different growth stages can exhibit

variations in physiological traits to growing conditions, resulting in influenced spike length, which may then result in variations in wheat yield. The result was similar with the findings of Al-Musa *et al*. (2012 who reported that the spike length of wheat varies among varieties of wheat.

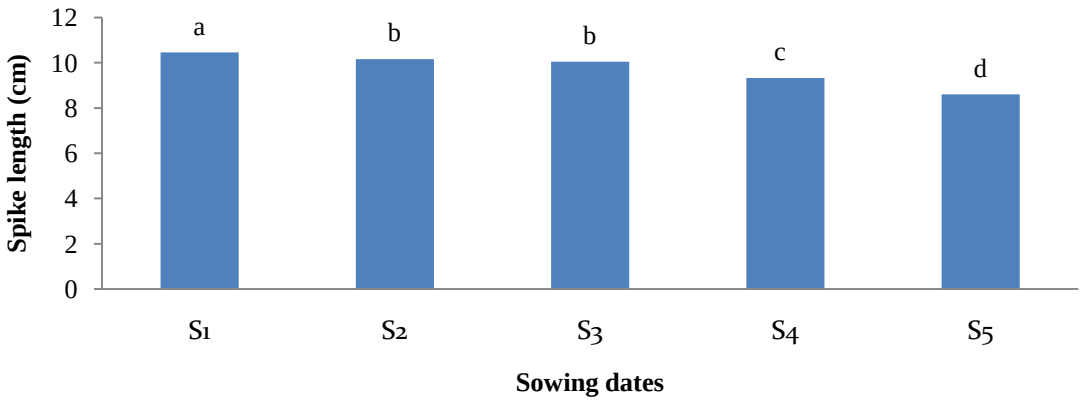


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 5. Effect of variety on spike length of wheat ($LSD_{(0.05)}$: 0.11)

Effect of sowing date

Sowing dates influenced significantly on spike length of wheat (Fig. 6). Maximum spike length (10.46 cm) was recorded with 28th November sowing (S_1 treatment) which was significantly higher than rest of sowing dates, while the lowest spike length (10.46 cm) was recorded with 28th December sowing (S_5 treatment). Reduction in spike length with sowings beyond 28th November might be due prevailing of higher temperature which shorten vegetative and reproductive phases, forced crop to complete its life span earlier which hasten senescence of leaves and flag leaf (responsible for solar radiation interception) resulted in inadequate assimilates absorption and translocation through source for development of reproductive organs. The results are supported by Baloch *et al*. (2010), who reported that early sown crop produced maximum spike length than delayed sown crops.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 6. Effect of sowing dates on spike length of wheat ($LSD_{(0.05)}$: 0.17)

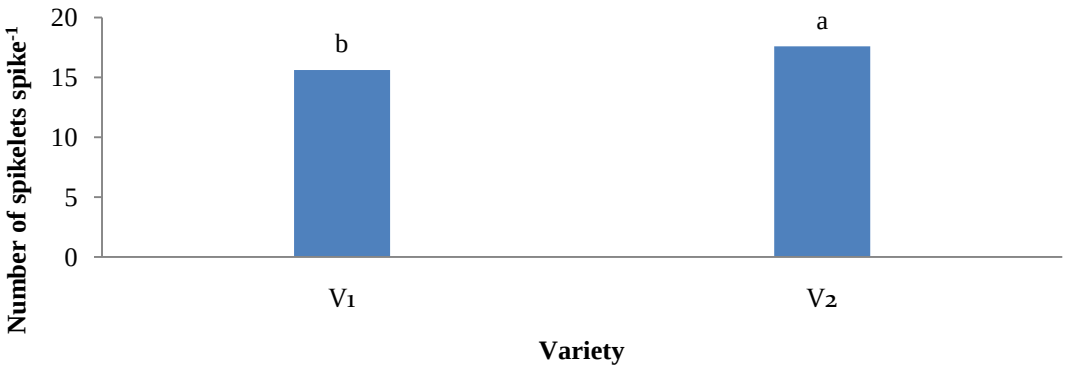
Combined effect of variety and sowing dates

Combined effect of wheat varieties and sowing dates with respect to spike length was found significant (Table 3). Experimental result showed that BARI Gom-33 wheat variety sown on 28th November (V_2S_1) recorded the maximum spike length (11.46 cm) comparable to the rest of the treatment combination. While BARI Gom-32 wheat variety sown on 28th December (V_1S_5) recorded minimum spike length of wheat (8.03cm) which was statistically similar with V_1S_4 (8.06 cm) combination treatment.

4.4 Number of spikelets spike^{-1}

Effect of variety

Different wheat varieties had shown significant affect on the number of spikelets spike^{-1} of wheat (Fig. 7). The result of the experiment showed that the V_2 (BARI Gom-33) treatment had the highest number of spikelets spike^{-1} of wheat (17.59). However the V_1 (BARI Gom-32) treatment had the lowest number of spikelets spike^{-1} of wheat (15.61). The genetic makeup of the varieties might be the possible reasons for these variations. The result was similar with the findings of Kaur and Kaur (2017) who reported that spikelets spike^{-1} of wheat varied among different genotypes of wheat.

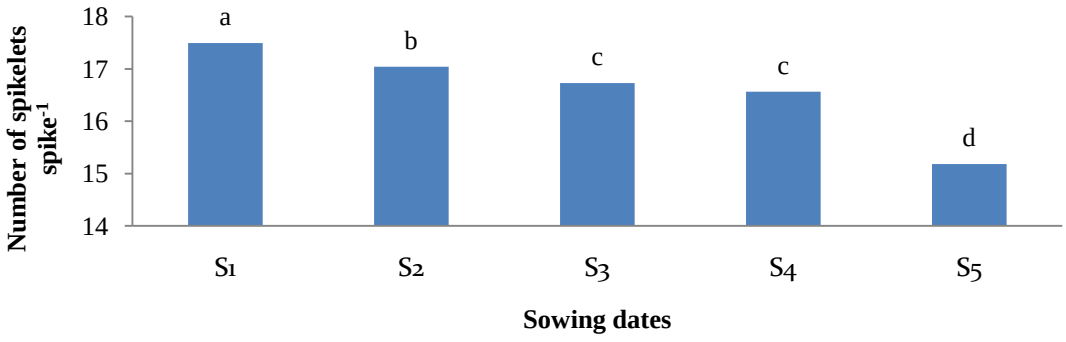


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 7. Effect of variety on number of spikelets spike^{-1}of wheat (LSD$_{(0.05)}$: 0.15)

Effect of sowing date

Different sowing date of wheat had shown significant effect on the number of spikelets spike^{-1} of wheat (Fig. 8). According to the experimental findings the highest number of spikelets spike^{-1} of wheat (17.49) was observed in S_1 treatment. It might be due to availability of suitable temperature during anthesis stage (fertilization) which resulted in viable pollens and longer grain filling period (translocation of assimilates from source to sink) which ultimately induced production of higher grains per spike. While the lowest number of spikelets spike^{-1} of wheat (15.18) was observed in S_5 treatment. The result was supported by Galdi *et al*. (2021) who reported delay in sowing reduced number of spike, number of spikelets spike^{-1}, grain weight per spike and grain weight, also reduced yield of wheat.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 8. Effect of sowing dates on number of spikelets spike^{-1}of wheat (LSD$_{(0.05)}$: 0.25)

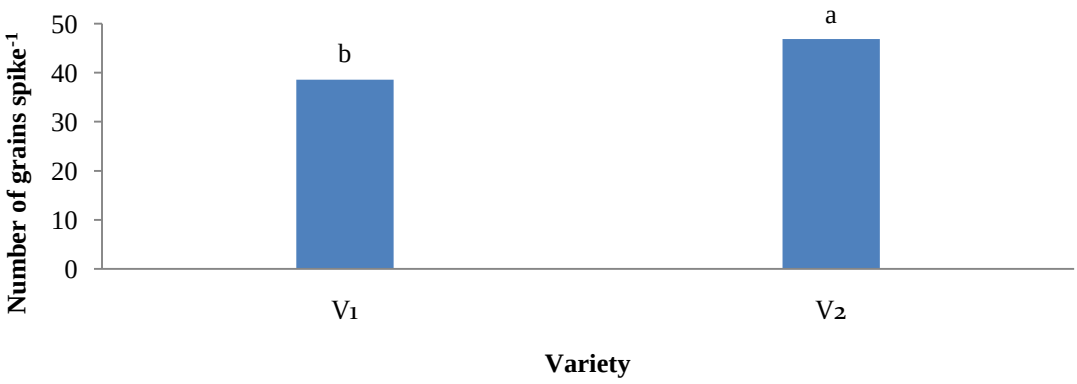
Combined effect of variety and sowing dates

The combined effects of variety and sowing dates significantly influenced the number of spikelets spike^{-1} of wheat (Table 3). Experimental result showed that the highest number of spikelets spike^{-1} of wheat (18.46) was observed in V_2S_1 combination treatment while the lowest number of spikelets spike^{-1} of wheat (14.40) V_1S_5 combination treatment.

4.5 Number of grains spike^{-1}

Effect of variety

Different wheat varieties had a significant impact on the number of grains spike^{-1} of wheat (Fig. 9). The V_2 (BARI Gom-33) treatment had the highest number of grains spike^{-1} of wheat (46.85). However, the V_1 (BARI Gom-32) treatment had the number of grains spike^{-1} of wheat (38.57). This may be due to genetic characteristic of the variety. Similar results are in conformity to the findings of, Singh and Uma (2015) reported that BPW 621-50 wheat genotype produced significantly higher number of grains per spike, higher grain weight per spike and higher 1000 grain weight comparable to other wheat genotypes.



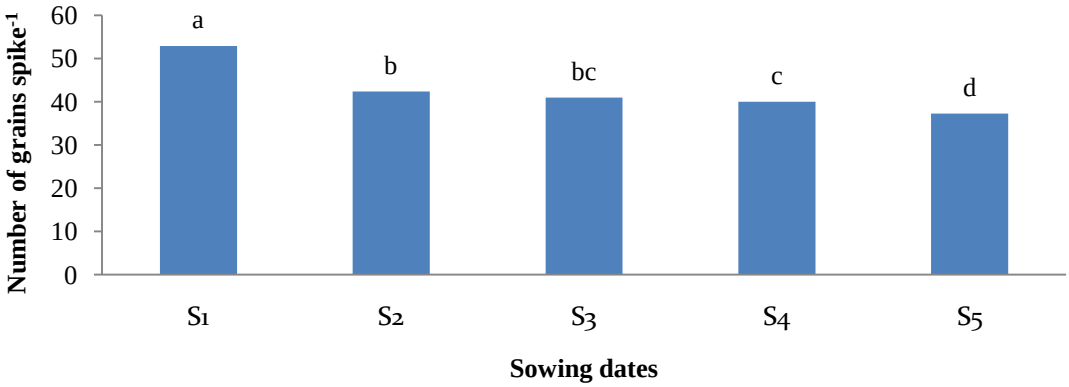
Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 9. Effect of variety on number of grains spike^{-1} of wheat ($LSD_{(0.05)}$: 0.96)

Effect of sowing date

The number of grains spike^{-1} of wheat was significantly affected by the wheat sowing date (Fig. 10). According to the experimental findings the S_1 treatment produced the highest number of grains spike^{-1} of wheat (52.89).While the lowest number of grains spike^{-1} of wheat (37.23) was observed in S_5 treatment. Higher grains spike^{-1} of wheat

observed with 28th November sowing could be attributed to favorable climatic conditions, which prolonged the crop's vegetative and reproductive phases, resulting in more interception of solar radiation and translocation of assimilated photosynthates from source (leaves and stalk) to sink, causing the plant to produce higher grains spike^{-1} of wheat and ultimately resulting in higher grain yield. Ahmed *et al.* (2022) reported that planting wheat at the optimal date was better than sowing at the late date for all values i.e., plant height, no. of grains per spike, spike length, 1000-grain weight and grain yield.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 10. Effect of sowing dates on number of grains spike^{-1}of wheat ($LSD_{(0.05)}$: 1.52)

Combined effect of variety and sowing dates

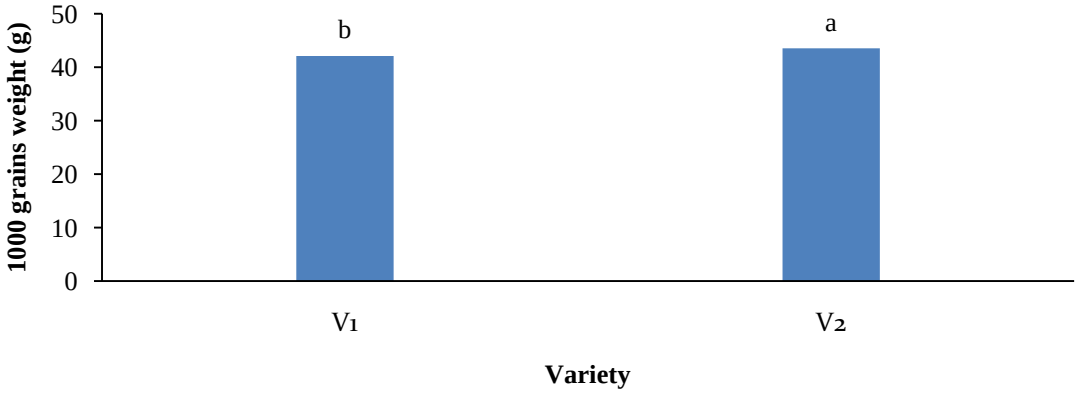
The combined effects of variety and sowing dates significantly influenced the number of grains spike^{-1} of wheat (Table 3). Experimental result showed that the highest number of grains spike^{-1} of wheat (56.46) was observed in V_2S_1 combination treatment while the lowest number of grains spike^{-1} of wheat (34.00) V_1S_5 combination treatment which was statistically similar with V_1S_4 (34.66) combination treatment.

4.6 1000 grains weight (g)

Effect of variety

The 1000 grains weight was significantly influenced by various wheat varieties (Fig. 11). According to the experimental findings, the V_2 (BARI Gom-33) treatment had

the highest 1000 grains weight of wheat (43.51 g). While the lowest 1000 grains weight of wheat (42.11 g) was found in the V_1 (BARI Gom-32) treatment. The genetic makeup of the varieties might be the possible reasons for these variations. Sandhu *et al*. (2017) discovered a similar effect, reporting that variety had a substantial impact on 1000-grain weight of wheat. Because the performance of varieties varies inversely with their genetic potential and adaptability to the environment, there is potential for enhancing wheat output through the cultivation of climate resilient varieties.

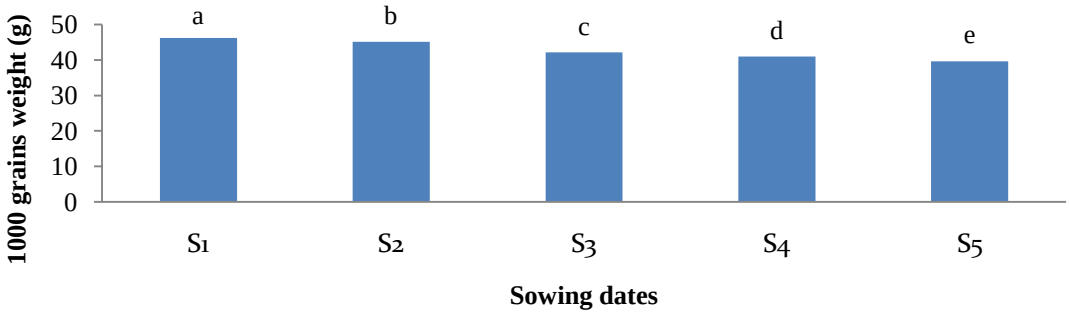


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 11. Effect of variety on 1000 grains weight of wheat ($LSD_{(0.05)}$: 0.52)

Effect of sowing date

The sowing dates of wheat had shown a significant impact on the 1000 grains weight of wheat (Fig 12). According to the experimental results, the S_1 treatment recorded the highest 1000 grains weight of wheat (46.20 g). While The S_5 treatment had the lowest 1000 grain weight of wheat (39.64 g). Reduction in 1000 grains weight of wheat weight beyond 28th November sowing might be due to prevailing of higher temperature and hot winds during grain filling period which resulted in faster senescence of leaves, poor assimilate synthesis, poor photosynthates translocation to developing grain and greater respiratory losses and it could be due to short grain filling period, reduced grain filling rate or combined effect of both which ultimately resulted in reduced grain size and shriveled grains. The results are attributed to those of Aslani and Mehrvar (2012) who revealed that with optimum sowing date all wheat varieties recorded higher 1000-grain weight than that of the delayed sowing dates.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 12. Effect of sowing dates on 1000 grains weight of wheat ($LSD_{(0.05)}$: 0.82)

Combined effect of variety and sowing dates

The combined effects of variety and sowing dates had a significant impact on wheat 1000 grain weight (Table 3). The highest 1000 grains weight of wheat (47.35 g) was observed in the V_2S_1 combination treatment, which was statistically similar to the V_2S_2 combination treatment (46.48). While the lowest 1000 grains weight of wheat (39.27 g) was observed in V_1S_5 combination treatment was statistically similar to V_2S_5 (40.00 g) combination treatment.

Table 3. Combined effect of variety and sowing dates on spike length, number of spikelets spike^{-1}, number of grains spike^{-1} and 1000 grains weight of wheat

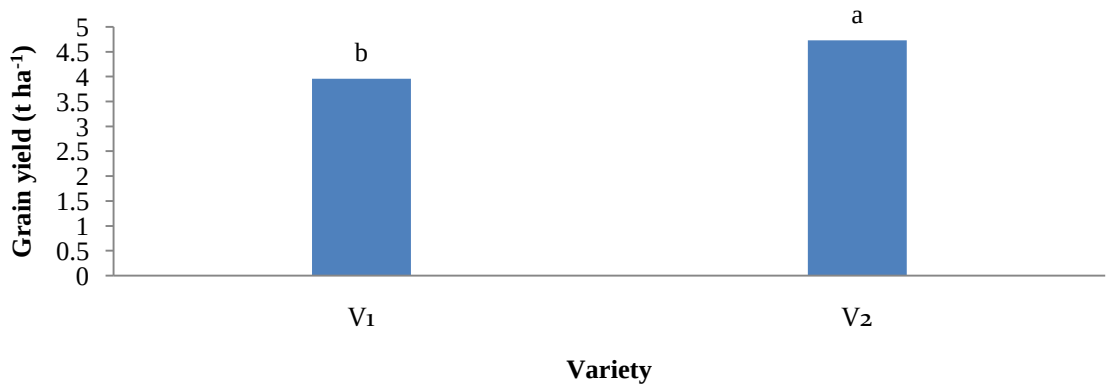
Treatments combinations	Spike length (cm)	Number of spikelets spike^{-1}	Number of grains spike^{-1}	1000 grains weight (g)
V_1S_1	9.46 d	16.53 c	49.33 b	45.05 b
V_1S_2	9.26 de	16.13 d	38.06 e	43.83 c
V_1S_3	9.20 e	15.53 e	36.80 ef	41.77 de
V_1S_4	8.06 f	15.46 e	34.66 fg	40.64 ef
V_1S_5	8.03 f	14.40 f	34.00 g	39.27 g
V_2S_1	11.46 a	18.46 a	56.46 a	47.35 a
V_2S_2	11.06 b	17.95 b	46.73 c	46.48 a
V_2S_3	10.90 b	17.93 b	45.20 c	42.46 d
V_2S_4	10.60 c	17.66 b	45.40 c	41.25 e
V_2S_5	9.13 e	15.96 d	40.46 d	40.00 fg
$LSD_{0.05}$	0.24	0.35	2.15	1.16
CV%	4.50	5.25	4.96	4.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1: BARI Gom-32 ,V_2: BARI Gom-33, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

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

Effect of variety

Different varieties significantly influenced grain yield of wheat (Fig. 13). Experimental result showed that the highest grain yield (4.73 t ha^{-1}) was observed in V_2 treatment, where as the lowest grain yield (3.96 t ha^{-1}) was observed in V_1 treatment. Different wheat varieties had different genetic makeup which affects the growth and yield among varieties. The result obtained from the present study was similar with the findings of Verma *et al.* (2016) who founded significantly higher grain yield (5320 kg/ha) and straw yield (6171 kg/ha) of wheat genotype DBW 39 over the rest of the three varieties *i.e.* HD 2967, HD 2733 and PBW 502.

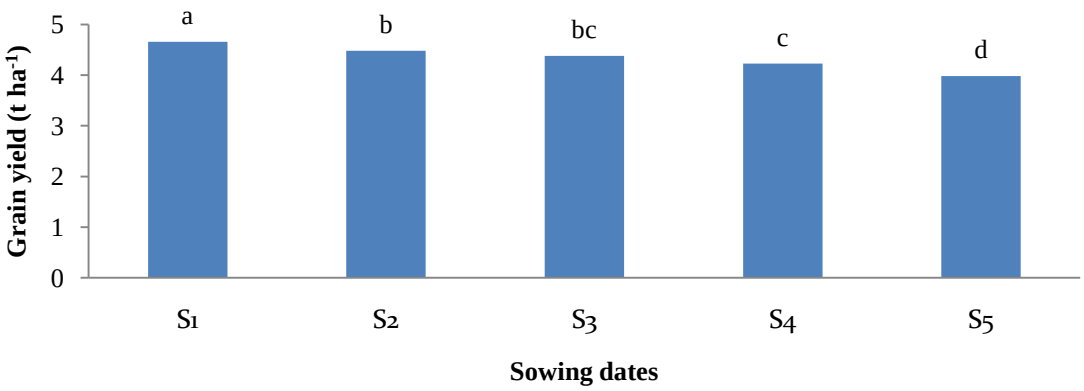


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 13. Effect of variety on grain yield of wheat ($LSD_{(0.05)}$: 0.09)

Effect of sowing date

Different sowing dates had shown significant affect on grain yield of wheat. According to the experimental findings the S_1 treatment recorded the highest grain yield (4.66 t ha^{-1}) of wheat whereas S_5 treatment recorded the lowest grain yield (3.98 t ha^{-1}) of wheat. The result was similar with the finding of Singh (2016) who reported that the grain yield increases under early and timely sown crop, which were due to favourable growing conditions and allocation of long growing period and favourable temperature at reproductive stage of wheat crop as compared to late sown conditions.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 14. Effect of sowing dates on grain yield of wheat ($LSD_{(0.05)}$: 0.15)

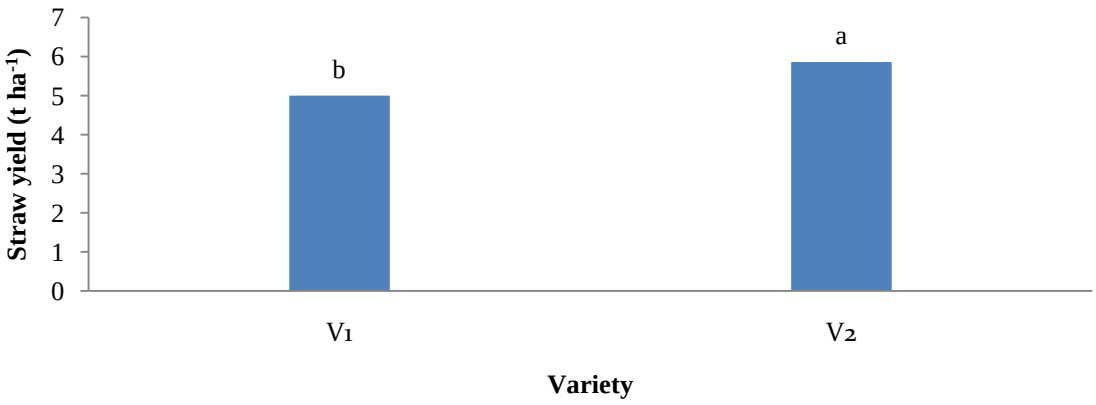
Combined effect of variety and sowing dates

Wheat grain yield was significantly influenced by the combination of variety and sowing dates (Table 4). Wheat grain yield (5.02 t ha^{-1}) was highest in the V_2S_1 combination treatment which was statistically similar to the V_2S_2 combination treatment (4.80 t ha^{-1}). While the lowest wheat grain yield (3.52 t ha^{-1}) was observed in the V_1S_5 combination treatment.

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

Effect of variety

Straw yield was significantly influenced by different wheat varieties (Fig. 15). The highest straw yield (5.86 t ha^{-1}) was observed in the V_2 treatment, while the lowest straw yield (5.00 t ha^{-1}) was observed in the V_1 treatment. Different wheat varieties had different genetic makeup which affects the growth and yield among varieties. The result obtained from the present study was similar with the findings of Mahajan *et al.* (2018) who reported that the highest values of straw yield (61.58 q ha^{-1}) was recorded in variety NIAW-1994 (Phule Samadhan) as compare to NIAW-301 (Trimbak), NIAW917 (Tapovan), NIAW-34 (Niphad -34) varieties of wheat.

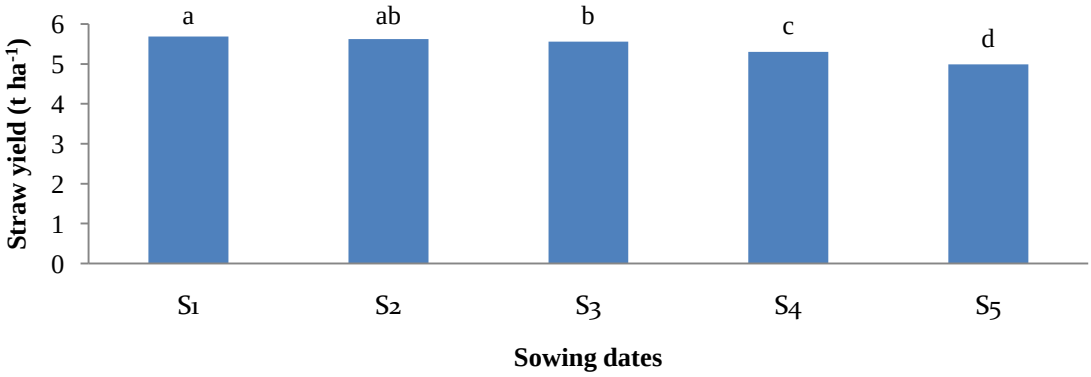


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 15. Effect of variety on straw yield of wheat ($LSD_{(0.05)}$: 0.04)

Effect of sowing date

Wheat straw yield had been significantly impacted by various sowing dates (Fig. 16). According to the results of the experiment, the S_1 treatment had the highest wheat straw yield (5.69 t ha^{-1}), which was statistically similar with S_2 (5.62 t ha^{-1}) treatment, while the S_5 treatment had the lowest straw yield (4.99 t ha^{-1}) of wheat. Higher straw yield with November sown crops could be attributed The higher grain yield in normal sown crop may be attributed to better plant growth leading to significantly more growth and yield attributes, bold grains and better partitioning of photosynthates compared to its delayed sowing. Suleiman *et al.* (2014) concluded that the straw yield decreased with delay in sowing date.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 16. Effect of sowing dates on straw yield of wheat ($LSD_{(0.05)}$: 0.07)

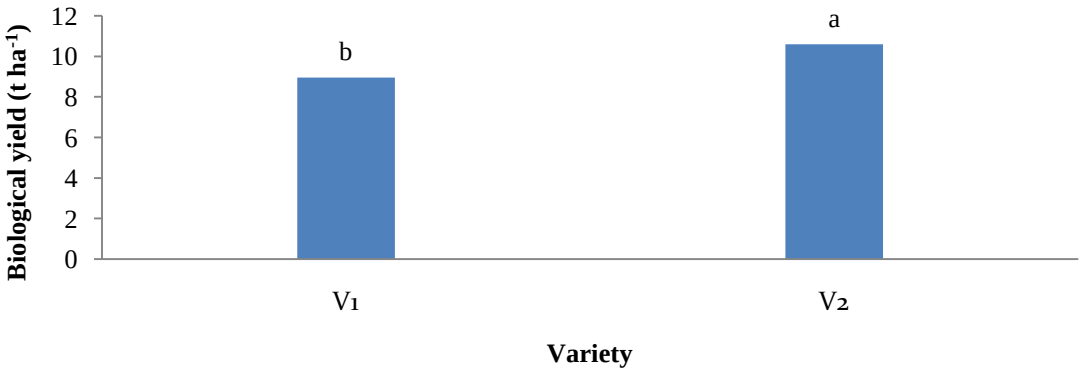
Combined effect of variety and sowing dates

The combination of variety and sowing dates significantly affected wheat straw yield (Table 4). The V_2S_1 combination treatment had the highest grain yield (6.07 t ha^{-1}) of wheat, which was statistically similar with V_2S_2 (6.02 t ha^{-1}) and V_2S_3 (6.02 t ha^{-1}) combination treatment. While the V_1S_5 combination treatment had the lowest wheat straw yield (4.52 t ha^{-1}).

4.9 Biological yield (t ha^{-1})

Effect of variety

Varieties of wheat had a significant impact on biological yield (Fig. 17). According to the experimental findings the highest biological yield (10.59 t ha^{-1}) was observed in the V_2 treatment, while the lowest biological yield (8.96 t ha^{-1}) was observed in the V_1 treatment. Various wheat varieties have varied genetic makeup, which influences growth and productivity of wheat. Kamboj (2018) reported similar results as varieties differed significantly in biological yield of wheat.



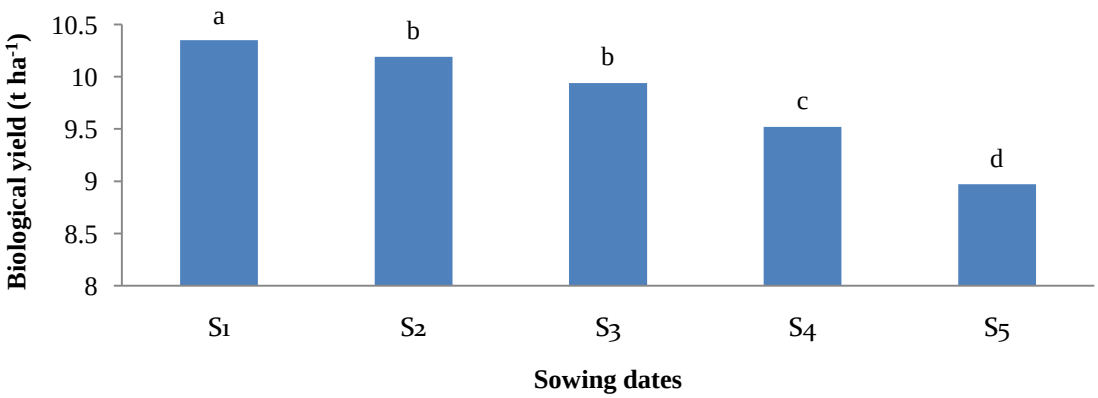
Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 17. Effect of variety on biological yield of wheat ($LSD_{(0.05)}$: 0.10)

Effect of sowing date

Different sowing dates had a significant impact on wheat biological yield (Fig. 18). According to the results of the experiment, the S_1 treatment had the highest biological yield (10.35 t ha^{-1}) of wheat, , while the S_5 treatment had the lowest biological yield (8.97 t ha^{-1}) of wheat. Higher biological yield with November sowings was attributed to availability of optimum temperature during crop growth span which prolonged growing period of the crop and resulted in maximum accumulation of GDD (Growing

degree days) and HTU (heliothermal units) which ultimately resulted in higher growth and yield attributing parameters *viz*. plant height, number of tillers, leaf area index, dry matter production, effective tillers, spike length, number of grains per spike and test weight. The finding is similar to that of Gupta *et al.* (2017) who reported lesser biological yield with late sown crop.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

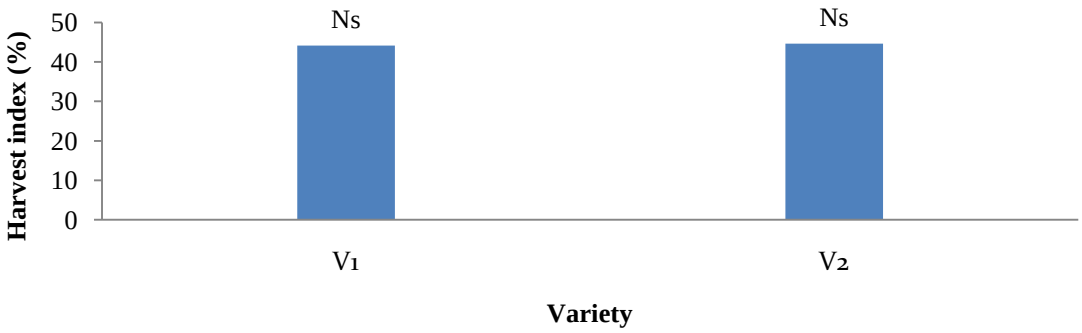
Fig. 18. Effect of sowing dates on biological yield of wheat ($LSD_{(0.05)}$: 0.16)

Combined effect of variety and sowing dates

The combination of variety and sowing dates significantly affected wheat biological yield (Table 4). The highest wheat biological yield (11.09 t ha^{-1}) was observed by the V_2S_1 combination treatment. While the lowest biological yield of wheat (8.04 t ha^{-1}) was observed by the V_1S_5 combination treatment.

4.10 Harvest index (%)

Wheat varieties had shown non significant effect on harvest index (Fig. 19). According to the experimental findings the highest harvest index (44.66 %) was observed in V_2 treatment while the lowest harvest index (44.66 %) was observed in V_1 treatment.

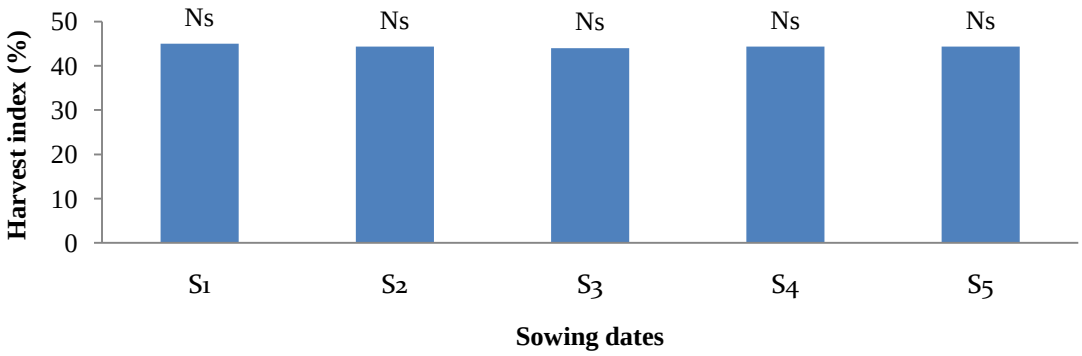


Here, V_1: BARI Gom-32 and V_2: BARI Gom-33.

Fig. 19. Effect of variety on harvest index of wheat ($LSD_{(0.05)}$: Ns)

Effect of sowing date

Harvest index of wheat had shown non significant effect due to different sowing dates. Experimental result showed that the highest harvest index (45.01%) was observed in S_1 treatment while the lowest harvest index (44.03 %) was observed in S_3 treatment.



Here, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

Fig. 20. Effect of sowing dates on harvest index of wheat ($LSD_{(0.05)}$: Ns)

Combined effect of variety and sowing dates

The combination of variety and sowing dates had shown non significant affected on harvest index of wheat (Table 4). The highest harvest index of wheat (45.27 %) was observed by the V_2S_1 combination treatment. While the lowest harvest index of wheat (43.78 %) was observed by the V_1S_5 combination treatment.

Table 4. Combined effect of variety and sowing dates on grain yield, straw yield, biological yield and harvest index of wheat

Treatments combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_1	4.30 de	5.31 d	9.61 e	44.75
V_1S_2	4.15 ef	5.22 d	9.37 f	44.29
V_1S_3	4.00 fg	5.10 e	9.10 g	43.96
V_1S_4	3.81 g	4.86 f	8.67 h	43.94
V_1S_5	3.52 h	4.52 g	8.04 i	43.78
V_2S_1	5.02 a	6.07 a	11.09 a	45.27
V_2S_2	4.80 ab	6.02 a	10.82 b	44.36
V_2S_3	4.75 b	6.02 a	10.77 b	44.10
V_2S_4	4.64 bc	5.73 b	10.37 c	44.74
V_2S_5	4.44 cd	5.46 c	9.90 d	44.85
$LSD_{0.05}$	0.22	0.10	0.22	Ns
CV%	3.00	5.16	4.37	4.59

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1: BARI Gom-32 ,V_2: BARI Gom-33, S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summery

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2021 to March 2022 in Rabi season, to study on grain yield and yield components of wheat when sown late. The experiment consisted of two factors, and followed Randomized block design with three replications. Factor A. Wheat varieties (2) *viz;* V_1: BARI Gom-32 and V_2: BARI Gom-33 and Factor B. Different sowing date (5) *viz;* S_1: 1st sowing date : 28th November, 2021, S_2: 2nd sowing date : 5th December, 2021, S_3: 3rd sowing date : 15th December, 2021, S_4: 4th sowing date : 21th December, 2021 and S_5: 5th sowing date : 28th December, 2021. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated. The analysis of various parameter data revealed significant and non-significant differences in growth, yield, of wheat as a result of varieties, sowing dates and their combination treatments.

In case of different varieties of wheat the highest growth parameters *i.e.* plant height and number of tiller plant^{-1} were observed by V_2 (BARI Gom-33) treatment at different days after sowing. However this treatment also recorded the highest spike length (10.63 cm), spikelets spike^{-1} (17.59), grains spike^{-1} (46.85), 1000 grains weight (43.51 g), grain yield (4.73 t ha^{-1}), straw yield (5.86 t ha^{-1}), biological yield (10.59 t ha^{-1}) and harvest index (44.66 %). Whereas the lowest spike length (8.80 cm), spikelets spike^{-1} (15.61), grains spike^{-1} (38.57), 1000 grains weight (42.11 g), grain yield (3.96 t ha^{-1}), straw yield (5.00 t ha^{-1}), biological yield (8.96 t ha^{-1}) and harvest index (44.66 %) were observed in V_1 (BARI Gom-32) treatment.

However in terms of different sowing dates 28th November (S_1 treatment) sown crop recorded the highest growth parameters *i.e.* plant height and number of tiller plant^{-1}. In contrast to other treatments, this (S_1) treatment recorded the highest spike length (10.46 cm), spikelets spike^{-1} (17.49), grains spike^{-1} (52.89), 1000 grains weight (46.20 g), grain yield (4.66 t ha^{-1}), straw yield (5.69 t ha^{-1}), biological yield (10.35 t ha^{-1}) and harvest index (45.01%). Whereas the crop sown on 28th December (S_5 treatment) recorded the lowest spike length (10.46 cm), spikelets spike^{-1} (15.18), grains spike^{-1}

(37.23), 1000 grain weight (39.64 g), grain yield (3.98 t ha^{-1}), straw yield (4.99 t ha^{-1})and biological yield (8.97 t ha^{-1}) of wheat.

In case of combination, the V_2S_1 treatment combination demonstrated the best growth traits in terms of plant height and number of tiller $plant^{-1}$. This treatment combination, however, also recorded the highest spike length (11.46 cm), spikelets $spike^{-1}$ (18.46), grains $spike^{-1}$ (56.46), 1000 grains weight (47.35 g), grain yield (5.02 t ha^{-1}), grain yield (6.07 t ha^{-1}), biological yield (11.09 t ha^{-1}) harvest index (45.27 %) comparable to other treatment combination. While the lowest spike length of wheat (8.03cm), spikelets $spike^{-1}$ (14.40), grains $spike^{-1}$ (34.00), 1000 grains weight (39.27 g), grain yield (3.52 t ha^{-1}), straw yield (4.52 t ha^{-1}), biological yield (8.04 t ha^{-1}) and harvest index of wheat (43.78 %) were observed by the V_1S_5 combination treatment.

5.2 Conclusion

Based on the above findings experimental results revealed that different varieties and sowing dates significantly influenced the growth and grains yield of wheat

i. In case of different wheat varieties the lowest grain yield (3.96 t ha^{-1}) was observed in V_1 (BARI Gom-32) treatment. Whereas cultivating BARI Gom-33 (V_2) variety gave the highest spike length (10.63 cm), spikelets $spike^{-1}$ (17.59), grains $spike^{-1}$ (46.85), 1000 grains weight (43.51 g), grain yield (4.73 t ha^{-1}), straw yield (5.86 t ha^{-1}), biological yield (10.59 t ha^{-1}) and harvest index (44.66 %).
ii. Among different sowing dates, crop sown on 28th November (S_1 treatment) recorded the highest spike length (10.46 cm), spikelets $spike^{-1}$ (17.49), grains $spike^{-1}$ (52.89), 1000 grains weight (46.20 g), grain yield (4.66 t ha^{-1}), straw yield (5.69 t ha^{-1}), biological yield (10.35 t ha^{-1}) and harvest index (45.01%).
iii. In case of combination treatment the V_2S_1 combination treatment gave the highest highest spike length (11.46 cm), spikelets $spike^{-1}$ (18.46), grains $spike^{-1}$ (56.46), 1000 grains weight (47.35 g), grain yield (5.02 t ha^{-1}), grain yield (6.07 t ha^{-1}), biological yield (11.09 t ha^{-1}) harvest index (45.27 %) comparable to other combination treatments.

Therefore considering above all facts, it may be concluded that BARI Gom-33 variety seed sown on 28th November (V_2S_1) seems promising for increasing growth and yield

of wheat than compared to other combination treatment and planting wheat seeds later than 28th November should be discouraged as it reduces wheat yield in both varieties.

5.3 Recommendations

Considering the results of the experiment, further studies in the following areas are suggested:

- ✓ More varieties and others sowing dates may be taken for further experiments to get more accurate result.
- ✓ Studies of similar nature could be carried out in different agro-ecological zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

REFERENCES

Ahmed, M. (2015). Response of spring wheat (*Triticum aestivum L*.) quality traits and yield to sowing date. *Plos one*. **10**(4): e0126097.

Ahmed, M.I.M., Hassan, A.F., El-Bialy, M.A. and. El-Mansoury, M.A.M. (2020). Effect of planting dates and planting methods on water relations of wheat. *Intl. J. Agron.* 1: 11.

Alam, M.P., Kumar, S., Ali, N., Manjhi, R.P., Kumari, N., Lakra, R.K. and Izhar, T. (2013). Performance of wheat varieties under different sowing dates in Jharkhand. *J. Wheat Res.* **5**(2): 61-64.

Alam, M.S. (2013). Growth and yield potentials of wheat as affected by management practices. *African J. Agric. Res.* **8**(47): 6068-6072.

Alam, M.S., Kumar, R. and Patel, J.N. (2022). Effect of sowing dates and varieties on the nutrient uptake and economics of Wheat crop (*Triticum aestivum* L.) under changing climate. *The Pharma Inn. J.* **11**(2): 533-538.

Ali, A., Ullah, Z., Ali, N. and Anjum, M.M. (2017). Evaluation of wheat advanced lines for agronomic traits under vary sowing dates. *Agril. Res. Tech.* **7**(1): 01-011.

Ali, M.A., Ali, M., Sattar, M. and Ali, L. (2010). Sowing date effect on yield of different wheat varieties. *J. Agric. Res.* **48**(2): 157-162.

Al-Musa, M.A.A., Ullah, M.A., Moniruzzaman, M., Islam, M.S. and Mukherjee, A. (2012). Effect of BARI wheat varieties on seed germination, growth and yield under Patuakhali District. *J. Environ. Sci. Nat. Res.* **5**(2): 209-212.

Amrawat, T., Solanki, N.S., Sharma, S.K., Jajoria, D.K. and Dotaniya, M.L. (2013). Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates. *African J. Agril. Res.* **8**(49): 6366-6374.

Aryal, A., Balchhaudi, A., Khadka, R., Sah, S.K., Santosh, M. and Parajuli, T. (2022). Response of sowing dates, crop establishment methods and mulching on growth, productivity and profitability of spring wheat at Rampur, Chitwan, Nepal. *Int. J. Appl. Sci. Biotechnol*. **10**(4): 237-244.

Aslani, F. and Mehrvar, M.R. (2012). Responses of wheat genotypes as affected by different sowing dates. *Asian J. Agric. Sci.* **4**(1): 72-74.

Bachhao, K.S., Kolekar, P.T., Nawale, S.S. and Kadlag, A.D. (2018) Response of different wheat varieties to different sowing dates. *J. Pharma. Phytochem.* **7**(1): 2178-2180.

Baloch, M.S., Shah, I.T.H., Nadim, M.A., Khan, M.I. and Khakwani, A.A. (2010). Effect of seeding density and planting time on growth and yield attributes of wheat. *The J. Animal Pl. Sci.* **20**(4): 239-240.

Basu, S., Parya, M., Dutta, S.K., Jena, S., Maji, S., Nath, R. and Chakraborty, P.K. (2012). Effect of growing degree day on different growth processes of wheat (*Triticum aestivum* L.). *J. Crop Weed*. **8**: 18-22.

BBS (2022). Statistical year book of Bangladesh. Statistics Division, ministry of planning, government of the people republic of Bangladesh, Dhaka. pp. 1-8.

Bhardwaj, V., Yadav, V. and Chauhan, B.S. (2010). Effect of nitrogen application timings and varieties on growth and yield of wheat grown on raised beds. *Arc. Agron. Soil Sci.* **56(**2): 211-222.

Chakrabarti, B., Singh, S.D., Nagarajan, S. and Aggarwal, P.K. (2011). Impact of temperature on phenology and pollen sterility of wheat varieties. *Australian J. Crop Sci.* **5**: 1039-1043.

Chourasiya, A., Tomar, S.S., Tomar, S.P.S., Tomar, S.S. and Srivastava, S.C. (2013). Response of wheat (*Triticum aestivum* L.) varieties to sowing dates in Grid region of Madhya Pradesh. *Cur. Adv. Agric. Sci.* **5**(1): 129-131.

Coventry, D.R., Gupta, R.K., Poswal, R.S., Chhokar, R.S., Sharma, R. K., Yadav, V.K., Gill, S.C., Mehta, A., Kleemann, S.G.L., Bonamano, A. and Cummins, J.A. (2011). Wheat quality and productivity as affected by varieties and sowing time in Haryana, India. *Field Crops Res*. **123(**3): 214-225.

Dar, S.B., Kanth, R.H., Raja, W., Bangroo, S.A. and Mir, S.A. (2018). Performance of wheat in relation to sowing dates and nitrogen levels under rainfed conditions of kashmir. *Int. J. Curr. Microbiol. App. Sci*. **7**(4): 2600-2608.

Deva, C.R., Urban, M.O., Challinor, A.J., Falloon, P. and Svitákova, L. (2020). Enhanced leaf cooling is a pathway to heat tolerance in common bean. *Front. Plant Sci*. **11**: 19.

Dogiwal, G., Pannu, R. and Tyagi, P.K. (2013). Effect of sowing time on biomass portioning in different plant parts of wheat varieties. *Haryana J. Agron.* **19**(2): 158-160.

Edris, K.M., Islam, A.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, BAU and Govt. Peoples Republic of Bangladesh. p 118.

Fazily, T. (2021). Effect of sowing dates and seed rates on growth and yield of different wheat varieties: *A Rev. Int. J. Agril. Sci. Tech*. **8**: 10-26.

Galdi, M.B., Abbas, B., Hossein, S. and Hossein, A.F. (2021) Effect of Sowing Date on Grain Yield and Yield Components of Wheat Cultivars under Dryland Condition. *Intl. J. Food Sci. Agric.* 5(4): 574-583.

Gill, K.K., Babuta, R., Kaur, N., Kaur, P. and Sandhu, S.S. (2014). Thermal requirement of wheat crop in different agroclimatic regions of Punjab under climate change scenarios. *MAUSAM*. **65**(3): 417-424.

Gomez, M. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. pp. 97-129, 207-215.

Grote, U., Fasse, A., Nguyen, T.T. and Erenstein, O. (2021). Food Security and the dynamics of wheat and maize value chains in Africa and Asia. *Front. Sustain. Food Syst*. **4**: 617009.

Gupta S. (2017). effect of different sowing dates on growth and yield attributes of wheat in udham singh nagar district of Uttarakhand, India. *Plant Arch.* **17**(1):232-236.

Gupta V, Gupta M, Bharat R, Singh M and Sharma B.C. (2020). Performance of wheat (*Triticum aestivum*) varieties under different thermal regimes and N-levels under lower Shivalik foothills. *Indian J. Agric. Sci.* **90**(4): 775-779.

Gupta, A., Singh, C., Kumar, V., Kundu, S., Tiwari, V. and Singh, G.P. (2017). Indian wheat varieties at a glance Volume II. ICAR-Indian Institute of wheat and barley research. pp. 2-8.

Gupta, V. and Gupta, M. (2022). Adaptation strategies for optimum sowing of wheat varieties and validation through ceres-wheat model in changing climatic conditions under shivalik range of new himalayas. *Bangladesh J. Bot.* **51**(4): 759-765.

Halecki, W. and Bedla, D. (2022). Global wheat production and threats to supply chains in a volatile climate change and energy crisis. *Res.* **11**: 118.

Hossain A, Sarker, M.A.Z.,Hakim, M.A., Lozovskaya, M.V. and Zvolinsky, V.P. (2011). Effect of temperature on yield and some agronomic characters of spring wheat *(Triticum aestivum L*.) *varieties. Intl. J. Agril. Res. Innov. Tech.* **1**: 44-54.

Hussain, J., Khaliq, T., Rahman, M.H.U., Ullah, A., Ahmed, I., Srivastava, A.K., Gaiser, T. and Ahmad, A. (2021). Effect of temperature on sowing dates of wheat under arid and semi-arid climatic regions and impact quantification of climate change through mechanistic modeling with evidence from field. *Atmos*. *12*: 927.

Jat, L.K., Singh, S.K., Latare, A.M., Singh, R.S. and Patel, C.B. (2013). Effect of dates of sowing and fertilizer on growth and yield of wheat (*Triticum aestivum* L.) in an Inceptisol of Varanasi. *Indian J. Agron.* **58**(4): 168-171.

Javid, I.M., Shams, N. and Fatima, K. (2022). Nutritional quality of wheat. *J. Wheat*. **1**: 2-12.

Kamboj, E. (2018). Performance of wheat varieties under different sowing times. Thesis, M.Sc. (Agronomy) CCS, HAU, Hisar. pp. 1-27.

Kamboj, N.K., Hooda, V.S., Gupta, G., Devi, S. and Jinger, D. (2017). Performance of wheat under different planting methods and weed management practices. *Ann. Agric. Res.* **38**(1): 31 -37.

Kaur, K. and Kaur, P. (2017). Effect of different sowing dates on phonological development and heat unit requirements of wheat cultivars. School of climate change and agricultural meteorology Punjab agricultural university Ludhiana-141004. *Agric. Res. J. Punjab*. **54**(4): 510- 517.

Kaur, P., Singh, H., Rao, V.U.M., Hundal, S.S., Andhu, S.S., Nayyar, S., Rao, B.B. and Kaur, A. (2015). Agrometeorology of wheat in Punjab state of India. Punjab Agricultural University, Ludhiana.. pp. 85.

Kumar, S. (2013). Performance of new wheat varieties under timely and late sown condition. Thesis M.Sc. (Agronomy), Birsa Agricultural University, Kanke, Ranchi. pp. 2-8.

Madhu, U., Begum, M., Salam, A. and Sarkar, S.K. (2018).Influence of sowing date on the growth and yield performance of wheat (*Triticum aestivum* L.) varieties. *Arch. Agr. Environ. Sci*, **3**(1): 89-94.

Mahajan, A.Y., Mohite, A.B., Jadhav, Y.R. and Patil, J.B. (2018). Effect of varieties (*Triticum aestivum* L.) under extended sowing times on yield, protein content, nutrients uptake and soil properties of wheat. *Intl. J. Chem. Stud*. **6**(6): 55-58.

Mukherjee, D. (2012). Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) cultivars under mid hill situation of West Bengal. *Indian J. Agron.* **57**(2): 152-156.

Mukherjee, D. (2012). Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) cultivars under mid hill situation of West Bengal. *Indian J. Agron.* **57**(2): 152-156.

Mumtaz, M.Z., Aslam, M., Nasrullah, H.F., Akhtar, M. and Ali, B. (2015). Effect of various sowing dates on growth, yield and yield components of different wheat genotypes. *American-Eurasian J. Agric. Environ. Sci.* **15**(11): 2230-2234.

Nahar, K., Ahmad, K. and Fujita, M. (2010). Phenological variation and its relation with yield in several wheat (*Triticum aestivum L*.) cultivars under normal and late sowing mediated heat stress condition. *Not. Sci. Biol.* **2**: 51-56.

Poudel, P., Jaishi, U., Poudel, L. and Poudel, M. (2020). Evaluation of wheat genotypes under timely and late sowing conditions. *Intl. J. App. Sci. Biotech.* **8**: 161-169.

Rahman, D.M.M and Miah, M.G. (2017). Wheat production in north west region of Bangladesh. *Bangladesh J. Admin. Manage*. **15**: 1-19.

Ram, H., Singh, G., Mavi, G.S. and Sohu, V.S. (2012). Accumulated heat unit requirement and yield of irrigated wheat (*Triticum aestivum L*.) varieties under different crop growing environment in central Punjab. *J. Agro-met.* **14**(2): 147-153.

Sah, M.K., Shrestha, A., Shah, P., Yadav, R.P. and Mishra, A. (2022). Impact of sowing dates on wheat varieties in central Terai region of Nepal. *Agron. J. Nepal.* **6**(1):162-169.

Saikia, T.P., Bordoloi, P.K. and Kalita, B. (2021). Evaluation of new wheat genotypes at different dates of sowing under irrigated conditions of central brahmaputra valley zone of Assam. *Int. J. Curr. Microbiol. App. Sci*. **10**(02): 1753-1760.

Sandhu, S., Balkaran. and Dhaliwal, S., Nirmaljit, S.D. (2017). Comparative performance of wheat cultivars in Muktsar district of Punjab. *Adv. Res. J. Crop Imp.* **8**(2):186-190.

Shah, F., Coulter, J.A., Ye, C., Wu, W. (2020). Yield penalty due to delayed sowing of winter wheat and the mitigatory role of increased seeding rate. *European J. Agron.* **119**: 1-7.

Shibeshi, S. and Kassa, D. (2021). Evaluation of durum wheat varieties for yield and yield related traits in highland areas of southern Ethiopia. *Int. J. Agril. Res. Innov. Tech.* **11**(1): 26-28.

Shirinzadeh, A., Abad, H.H.S., Nourmohammadi, G., Haravan, E.M. and Madani, H. (2017). Effect of planting date on growth periods, yield and yield components of some bread wheat cultivars in Parsabad Moghan. *Intl. J. Farm. Alli. Sci.* **6**(4): 109-119.

Shorti, S.K. and Chauhan, S.K. (2015). Performance of wheat genotypes at different dates of sowing under Irrigated conditions. *Ann. Agric. Res.* **36**(4): 390-393.

Singh, B. (2016). Response of wheat *(Triticum aestivum L.)* varieties to different sowing dates and growth regulator (Doctoral dissertation, Punjab Agricultural University, Ludhiana). pp. 7-9.

Singh, B., Kumar, M. and Dhaka, A.K. (2018). Relationship of temperature based meteorological indices with phenology and yield performance of wheat as influenced by sowing times. *Intl. J. Cur. Microb. App. Sci.* **7**(3): 230-24.

Singh, D., Shamim, M., Pandey, R. and Kumar, V. (2012). Growth and yield of wheat genotypes in relation to environmental constraints under timely sown irrigated condition. *Indian J. Plant Phy.* **17**(2): 113-120.

Singh, D.P., Chandra, V. and Tiwari, T. (2022). Effect of sowing dates on yield and yield components of wheat in Maharajganj district Eastern U.P. The Pharma Inn. J. **11**(1): 228-231.

Singh, P. and Uma. (2015). Effect of sowing dates on yield contributing characters and yield of some new wheat genotypes under irrigated conditions. *J. Multi. Adv. Res.* **4**(1): 32-35.

Statista (2022). https://www. statista.com/statistics/237912/global-top-wheat - producing-coun tries. pp. 1-3.

Suleiman, A.A., Nganya, J.F. and Ashraf, M.A. (2014). Effect of variety and sowing date on growth and yield of wheat (*Triticum aestivum* L.) in Khartoum, Sudan. *J. Forest Prod. Ind.* **3**: 198-203.

USDA (2022). United state department of agriculture. Foreign and agricultural service . An report on grain and feed update in Bangladesh. pp: 5.

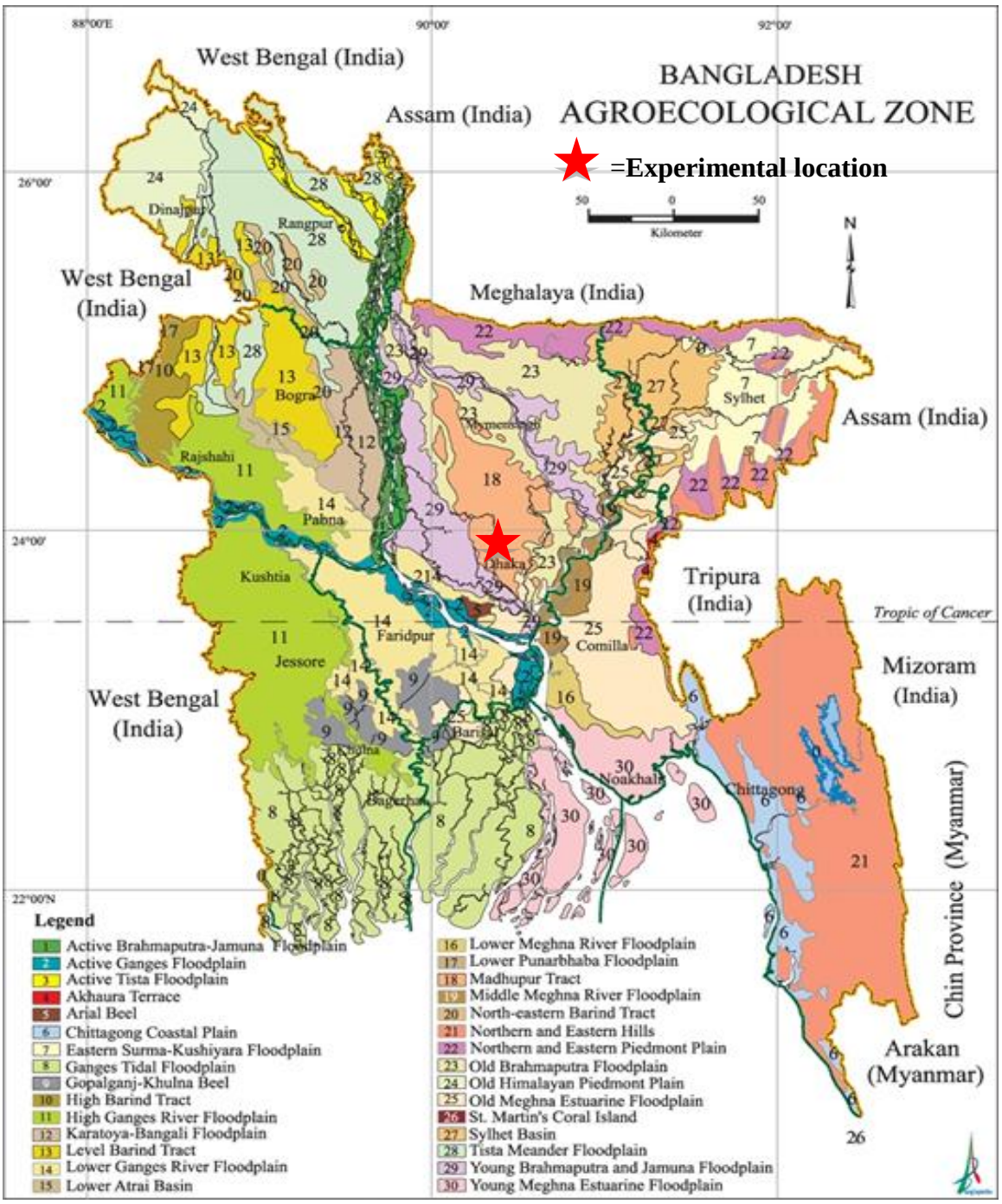
Verma, D.K., Verma, S., Giri, S.P., Pandey, M.K. and Pandey, A. (2016). Response of newly released wheat (*Triticum aestivum* L.) varieties to different sowing dates under changing climate condition in eastern Uttar Pradesh. *Intl. J. Agric. Sci.* **12**(2): 199-202.

Yadav, V., Mishra, D.N., Chauhan, R.S., Tomar, P and Singh, R. (2017). Performance of newly released wheat (*Triticum aestivum* L.) varieties on different sowing dates under NWPZ of U.P. *J. Pharma. Phytochem.* **1**: 720-722.

Yusuf, M., Kumar, S., Dhaka, A.K., Singh, B. and Bhukar, A. (2019). Performance of wheat (*Triticum aestivum* L.) varieties to different sowing dates. *Agric. Sci. Digest.* **39**(4): 308-310.

APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

Appendix III. Monthly meteorological information during the period from October 2021 to March, 2022.

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m
	March	31.9	20.1	38	71 mm

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on plant height of wheat at different days after sowing

Source	Df	Plant height (cm) at different days after sowing				
		30	45	60	75	At harvest
Variety (V)	1	323.540*	273.975*	250.043*	484.089**	336.072**
Sowing (S)	4	24.902*	27.432*	27.268*	44.324**	31.646**
V×S	4	1.213*	0.518*	1.845*	0.759*	0.390*
Error	20	3.639	4.440	8.442	1.825	2.599

Ns: Non significant
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on number of tiller plant^{-1} of wheat at different days after sowing

Source	Df	Number of tiller plant^{-1} at different days after sowing				
		30	45	60	75	At harvest
Variety (V)	1	0.16875**	1.99692**	1.89003**	5.83443**	6.74028**
Sowing (S)	4	0.43263**	0.43553**	0.56441**	1.03895**	1.72820
V×S	4	0.02115*	0.01414*	0.03131*	0.02650*	0.03790*
Error	20	0.01400	0.01800	0.00596	0.02400	0.01200

Ns: Non significant
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on spike length, number of spikelets spike^{-1}, number of grains spike^{-1} and 1000 grains weight of wheat

Source	Df	Spike length	Number of spikelets spike^{-1}	Number of grains spike^{-1}	1000 grains weight
Variety (V)	1	25.0802**	29.4823**	514.188**	14.6161**
Sowing (S)	4	3.4139**	4.5465**	215.956**	46.5547**
V×S	4	0.4376*	0.1606*	4.070*	1.4802*
Error	20	0.0213	0.0433	1.600	0.4667

Ns: Non significant
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on grain yield, straw yield, biological yield and harvest index of wheat

Source	Df	Grain yield	Straw yield	Biological yield	Harvest index
Variety (V)	1	4.49307**	5.52123**	19.9757**	2.02800^{Ns}
Sowing (S)	4	0.39694**	0.49863**	1.7575**	0.78805^{Ns}
V×S	4	0.01625*	0.00888*	0.0429*	0.27293^{Ns}
Error	20	0.01700	0.00400	0.0180	0.50000

Ns: Non significant

** : Significant at 0.05 level of probability

*: Significant at 0.01 level of probability

PLATES

Plate 1. Experimental signboard

Plate 2. Data collection