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Comparative performance of three wheat (*Triticum aestivum L.*) varieties under heat stress

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ABSTRACT

The present investigation was conducted during *rabi* season of 2016-17 in the research farm of Wheat Research Centre (WRC), Dinajpur, Bangladesh to evaluate the performance of three wheat varities which are recently released by BARI (Bangladesh Agricultural Research Institute). Treatments were three sowing dates *viz.*, early sowing (1^{st} November), optimum sowing (15^{th} November) and late sowing (30^{th} December), and three recently released wheat varieties namely 'Shatabdi', 'BARI Gom 27' and 'BARI Gom 28'. The experiment was laid out in split-plot design with three replications. Three sowing dates were arranged in main plots and three wheat varieties were in sub-plots. Phenology data on days to emergence, days to booting, days to heading and days to physiological maturity; growth data on plants m^{-2}, tillers m^{-2}, and yield and yield components' data on spikes m^{-2}, plant height at harvest, spike length, spikelets $spike^{-1}$, grains $spike^{-1}$, 1000-grain weight, harvest index, biomass yield at harvest and grain yield were recorded for drawing valid conclusions. Except few, most of the parameters were significantly influenced by sowing dates and varieties. Among the three sowing dates, the highest grain yield was obtained from optimum sowing (15^{th} November) sowing and the lowest was from late sowing (December 30^{th}). Among the varieties, 'BARI Gom 28' was found significantly superior to all other varieties with respect to spikelets $spike^{-1}$, grains $spike^{-1}$, 1000-grain weight, harvest index, biomass and grain yield. Considering on grain yield, the maximum grain yield was obtained from 'BARI Gom 28' and the lowest was in 'BARI Gom 27'. The combine effect between sowing dates and variety were influenced significantly in respect of yield and yield attributes except spike length. Among three varieties 'BARI Gom 28' produced significantly the highest grain yield in 15^{th} November followed by 'Shatabdi' at the same sowing date and the lowest grain yield was recorded from 'BARI Gom 27'on 30^{th} December sowing. Therefore, it can be concluded that 'BARI Gom 28' is the best variety, followed by 'Shatabdi' and 'BARI Gom 27' for producing higher grain yield and November 15^{th} is the best time for sowing wheat, whereas December 30^{th} is the worst sowing condition that negatively effect on grain yield of wheat.

INTRODUCTION

Wheat is an especially critical "staff of life" for many people of the world. As there is little scope to increase agricultural lands suitable for cultivation globally, wheat production could be increased by increasing yield or by adopting improved agronomic management practices (Long and Ort, 2010; Chand, 2009; Reynolds et al., 2009). Therefore, in order to increase wheat yield, greater efforts are needed to develop new wheat varieties with higher grain yield (GY) potential and to develop and adopt improved crop management practices (Li et al., 2016).

In Bangladesh, wheat is ranked as the second most important cereal after rice and plays an important role in meeting the country's target of achieving food security for an ever-increasing population (Timsina et al., 2016). It is grown in large areas of 130,768 ha in 2015-16 in the North-Western part of Bangladesh (BBS, 2016). According to the report of BBS (2016), 1.35 million tons of wheat was harvested from 0.44 million ha in 2015-16, of which 30.65% was in Northern Bangladesh (or

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Old Himalayan Piedmont Plain only). However, average yield of wheat was only 3.03 t h^{-1} in 2015-16 (BBS, 2016), compared to the global average wheat yield (3.07 t ha^{-1}) for the same year (Statista, 2016).

Optimum seeding time is considered to be an important management strategy for improving wheat grain yield (Hossain and Teixeira da Silva, 2012). This is particularly important because it is under the control of farmers (Slafer and Satorre, 1991; Laghari et al., 2011). Optimum time for sowing of wheat in Bangladesh is between mid-November and first week of December (Hossain and Teixeira da Silva, 2012), due to its own definite requirements for temperature and light for emergence, growth and flowering (Hossain et al., 2013). But, about 85% of the total wheat area follows previous rice crop (Saunders, 1991) and over 60% of the total wheat crop is cultivated at late sowing conditions (Badruddin et al., 1994). In the north-western part of the country, where high lands generally remain fallow after aus rice or jute cultivation, seeding of wheat can be done in early November (heat stress condition). In some areas where wheat is followed by transplant aman rice or soil remains wet due to excessive rainfall, seeding is continued up to January (heat stress condition) (BARI, 2013).

Too early sowing produces weak plants with poor root systems. Temperature above optimum leads to irregular germination and the embryo frequently dies and the endosperm may undergo decomposition due to activities of bacteria or fungi. In late planting, the wheat variety should be short duration that may escape from high temperature at the grain filling stage (Phadnawis and Saini, 1992). Ansary et al. (1989) reported that delay sowing suppressed the yield, caused by reduction in the yield contributing traits like number of tillers, number of grains $spike^{-1}$ and grain yield. Rajput and Verma, (1994) observed that normal sowing gave higher grain yield than late sowing. Early sowing always produces higher yield than late sowing. Each day delay in sowing from 20th November decreases grain yield @ 39 kg ha^{-1} per day (Singh and Uttam, 1999). Ahmed (1986) also reported that about 1.3% reductions in day of December. The adverse effect of temperature could be minimized by adjusting sowing time to an optimum date and to find out heat tolerant genotypes, which are suitable for late and very early sown conditions to ensure high grain yield.

Recently, some advanced wheat genotypes were released as varieties by Wheat Research Center of Bangladesh Agricultural Research Institute. These varieties were developed for optimum as well as late sown condition i.e., these genotypes have some heat tolerant characteristics (WRC, 2016). The newly developed varieties need to be evaluated for their agronomic performance under different environmental conditions. Therefore, the present study was undertaken to evaluate the performance of newly released varieties under different high temperature stress in early and late sown conditions, to find out the suitable variety for optimum and late sown condition, to find out heat tolerant and heat sensitive variety and to find out the optimum sowing time for a specific variety.

MATERIALS AND METHODS

Experimental field

The experiment was conducted in the research farm of Wheat Research Center (WRC), BARI, Dinajpur during wheat season (Nov. to April) 2016-17. The geographical position of the area is between 25º44.574" N and 88º40.344" E, and 40 m above sea level. The Agro Ecological Zone (AEZ) of the area is the Old Himalayan Piedmont Plain (AEZ-1). This zone has largest wheat area and also produces largest amount of wheat in the country.

Climatic conditions

Weather data on weekly average temperature, humidity and rainfall during experimental period, were recorded regularly at the meteorological station of Wheat Research Center (WRC), BARI, Dinajpur. Data are presented in Figure 1.

Characteristics of the experimental soil

Soils of the experimental sites were analyzed before sowing wheat. The pre-seeding total soil N was 0.08%, indicating a deficiency in soil N. Soil available K was 0.19 meq $100g^{-1}$ soil, and available P, S, Zn and B were 17.5, 6.5, 0.78 and 0.16 µg g^{-1} soil, respectively. Based on the critical level of these plant nutrients, K, S, Zn and B were low, but P was high. Soil pH was 5.4 and organic matter was 1.2%.

Experimental design

The experiment was conducted in a split-plot design with three replications. Treatments were three sowing dates (Early sowing - 01 November, Optimum sowing - 15 November and Late sowing - 30 December) and three elite existing wheat varieties (‘Shatabdi’, ‘BARI, Gom 27’ and ‘BARI Gom 28’). Three sowing dates were arranged in main plots and three varieties were in sub-plots.The unit plot size (3 m × 2 m) consisted of 10 rows, each 3 m long, and a row-to-row distance of 20 cm and a block-to-block distance of 1.5 m.

Variety, seeding rate, sowing time, seed treatment and insecticide

The characteristics of the three wheat varieties used in this research are presented in Table 1. During experimentation, all varieties were sown as per treatments. Seeding rate was 120 kg ha^{-1} for each treatment. Before sowing, seeds of all varieties were treated with a popular fungicide, Provax-200 WP, which contains carboxin and thiram (marketed by Hossain Enterprise CC Bangladesh Ltd., in association with Chemtura Corp., USA). Furadan 5G (containing Carbofuran, marketed by FMC International S.A. Bangladesh Ltd.) was broadcasted at 10 kg ha^{-1} for controlling soil-borne insects.

Table 1
Characteristics of the three wheat varieties used in this research.

Variety	Stress tolerance capacity	Life span (days)	Yield (kg ha^{-1})	Suitable for cultivation	Year of release	Sowing time	Major diseases and pests resistance
‘Shatabdi’	Good level of tolerance to terminal heat	105-110	3600-5000	All over the country except saline areas	2000	Nov.15-30	Highly tolerant to *Bipolaris* leaf blight and resistant to leaf rust
BARI Gom 27	Moderate level of tolerance to heat stress	105-110	3800-5400	All over the country except saline areas	2012	Nov.15-30	It is resistant to leaf rust and tolerant to *Bipolaris* leaf blight and possesses good level of APR to the Ug99 race of stem rust and its variants
‘BARI Gom 28’	Tolerant to terminal heat stress in late seeding	100-105	4000-5500	All over the country except saline areas	2012	Nov.15-30	It is resistant to leaf rust and tolerant to *Bipolaris* leaf blight

Fertilizer, irrigation, mulching and weeding

Fertilizer N, P, K, S and B was applied at the rate of 100, 27, 40, 20, 1 $kgha^{-1}$ as per recommendation of WRC. During final land preparation, two-thirds of N and a full amount of the other fertilizers were applied as basal. The remaining N fertilizer was applied immediately after the first irrigation at 18 days after sowing (DAS) while the second, third and fourth irrigations were applied at 50, 73 and 88 DAS. Mulching was done at 28 DAS and hand weeding at 45 DAS.

Data collection

Phenological data on days to emergence, days to booting, days to heading and days to physiological maturity were recorded as per sowing dates and varieties. Initial plants m^{-2} was recorded at 12 DAS. The crop was harvested on 30 March 2017 (for the 2016-17 season). Grain yield and yield-related attributes were recorded from a 2 m × 1 m area from the center of each plot. The samples from the harvested area from each plot was bundled separately, tagged and manually threshed on a threshing floor. The bundles were thoroughly dried in bright sunshine before their weights were recorded. Data on plant height (cm), spikes m^{-2}, spike length (cm), number of spikelets $spike^{-1}$, 1000-grain weight (g; TGW), Harvest index (%) and grain yield (kg ha^{-1}) were recorded. Grain yield and TGW were recorded at 12% moisture content as described by Hellevang (1995.

$$Y(M_2) = \frac{100 - M_1}{100 - M_2} \times Y(M_1)$$

Where, $Y(M_2)$ = grain weight at 12% moisture; $Y(M_1)$ = grain weight at actual moisture %; M_1 = actual moisture %; M_2 = expected moisture %.

Harvest index was calculated according to the following equations (Donald, 1962):

$$HI\ (\%) = \frac{\text{Grain yield}}{\text{Grain yield + straw yield}} \times 100$$

Data analysis

Data collected during this study were statistically analyzed using MSTAT statistical package of Michigan State University, USA (Russell, 1986). Duncan's new multiple range test (DNMRT) at a 5% probability level was used to test differences among mean values (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Weather conditions

The data obtained in this study showed that crop sown on November 01, the maximum temperature in vegetative stage was near at ≥30°C and the minimum was ≤15°C, but at grain filling stage maximum was ≥25°C and minimum was 10 to 12°C (Figure 1). The temperature of vegetative stage in November 01 sowings are not suitable for good yield, because at vegetative stage maximum temperature was above 30°C, which affected on stand establishment of crop and tillers production, ultimately poor yield. The result is in accordance with Kumer et al. (1994) and Fischer (1990), who mentioned that in early sown crop got unfavorable environment (high temperature) at vegetative stage as a result crop become thinned and produced less tillers, despite of the heading and grain formation stages is favorable, but the crop did not recover the stress which was got at vegetative stage. On the other hand, wheat sown on November 15, average maximum temperature in vegetative stage, was near at 25°C and minimum was near at 15°C, but at grain-filling stage average maximum temperature was also near at 25°C and minimum was near at 10 to 15°C, which is suitable for good yield in crop (Fig. 1). On the other hand in extremely late sowing (December 30) condition, during germination, minimum temperature was very low ≤10°C and at vegetative stage temperature was maximum ≥25°C and minimum ≤10°C, but at grain filling stage maximum was ≥30°C and minimum was ≤ 18 to 20°C (February-March), which was also not suitable for proper growth and good yield (Figure 1).

Several studies reported that moderately high temperatures (25-32°C) and short periods of very high temperatures (33-40°C and above) during grain filling severely affect the yield, yield components of wheat and barley (Chowdhry and Wardlaw, 1978) and Stone and Nicolas, 1994). The late crop which was sown on extremely late (last week of December) suffered severely from heat stress during grain formation in March leading to abnormal development and poor production, due to shorten of life span (Hossain et al. (2012, 2013), Hossain and Teixeira da Silva (2013, 2012).

Days to emergence

In this study, significant differences in days to germination were found among the three sowing time. Late sowing took more time to germinate where early and optimum sowing took significantly similar time to germinate. On the other hand no significant among three varieties to germinate (Figure 2). At the time of our present research, the maximum temperature during the germination period was >26 to 28°C, sometimes nearing 30°C, while the minimum temperature was between 12 and 13°C, in Optimum sowing (15 November). However, at late sown condition (30 December), the average maximum and minimum temperatures were near 23 and 10°C, and sometimes minimum and maximum temperature ranged between 8-9°C and 20-19°C, respectively (Figure 2). In a field experiment in Bangladesh it reported that low temperature (<10°C) at the germination stage delayed the time taken for grain to germinate (Hossain et al. (2011, 2012c).

Days to booting

In the present study the days to booting of the three sowing time were significant (p≤ 0.01). Optimum sowing took more time to boot and secondly late sowing took time to boot, whereas early sowing took least time for booting (Figure 3). Among the varieties, 'BARI Gom 27' took the more time for booting followed by 'Shatabdi' (took second more time; 59 days) and 'BARI Gom 28' (took the least time; 52 days) for booting under early, optimum and late sown condition (Figure 3). The present findings are in accordance with the earlier studies (Hakim et al., 2012; Hossain et al., 2009, 2011; Nahar et al., 2010) where it was reported that under high temperature, the crop completes its life cycle much faster than under normal temperature and delayed planting reduced plant height, days to heading, days to maturity and the duration of grain filling and ultimately reduced yield and yield components (Din and Singh, 2005; Mahboob et al., 2005).

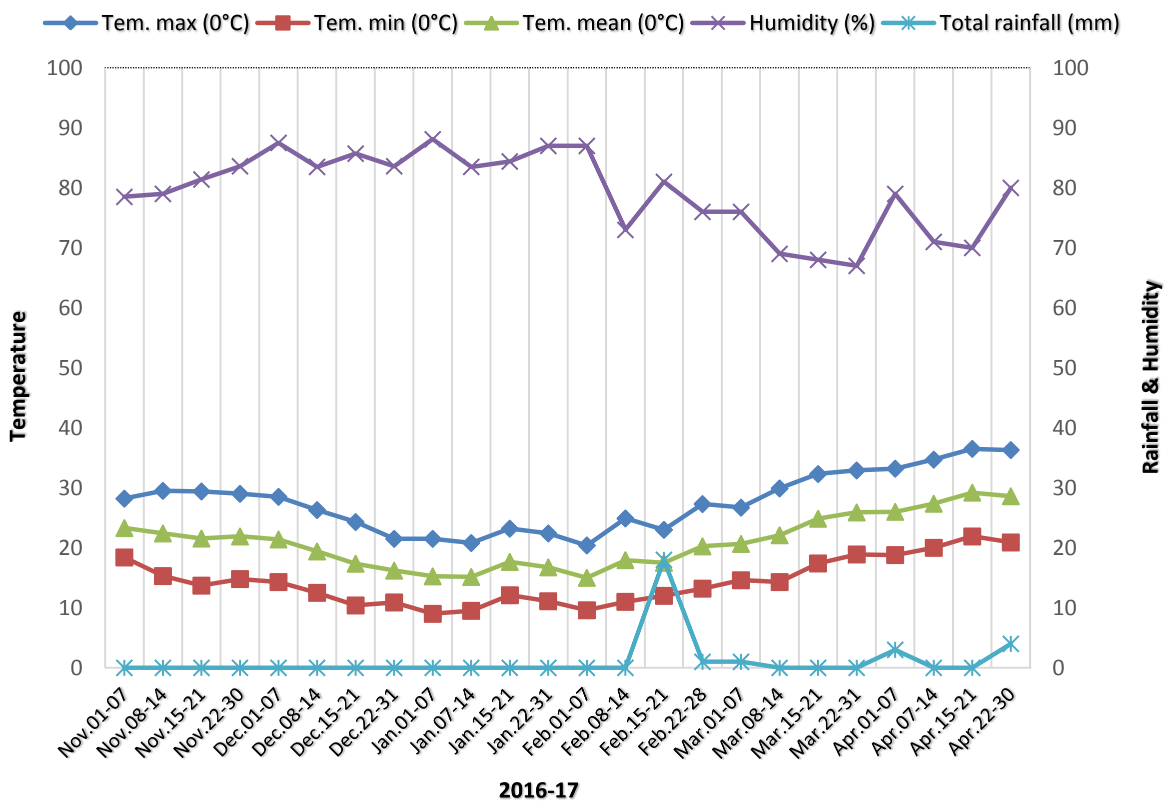

Figure 1
Weekly average temperature, rainfall and humidity during crop growth period (November 2016 to April 2017).

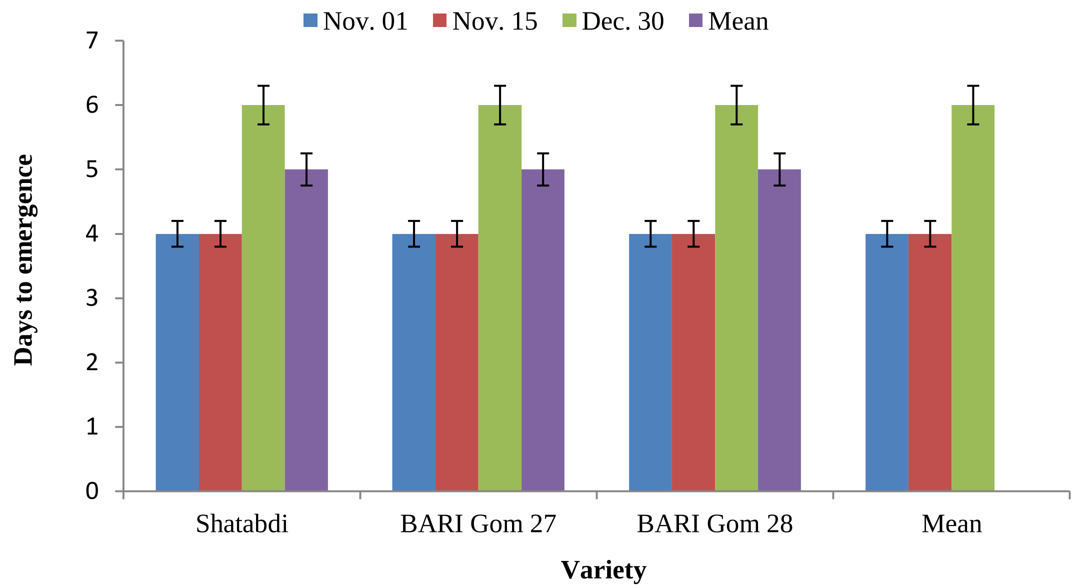

Figure 2
Effect of different sowing dates on days to emergence of three wheat varieties. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

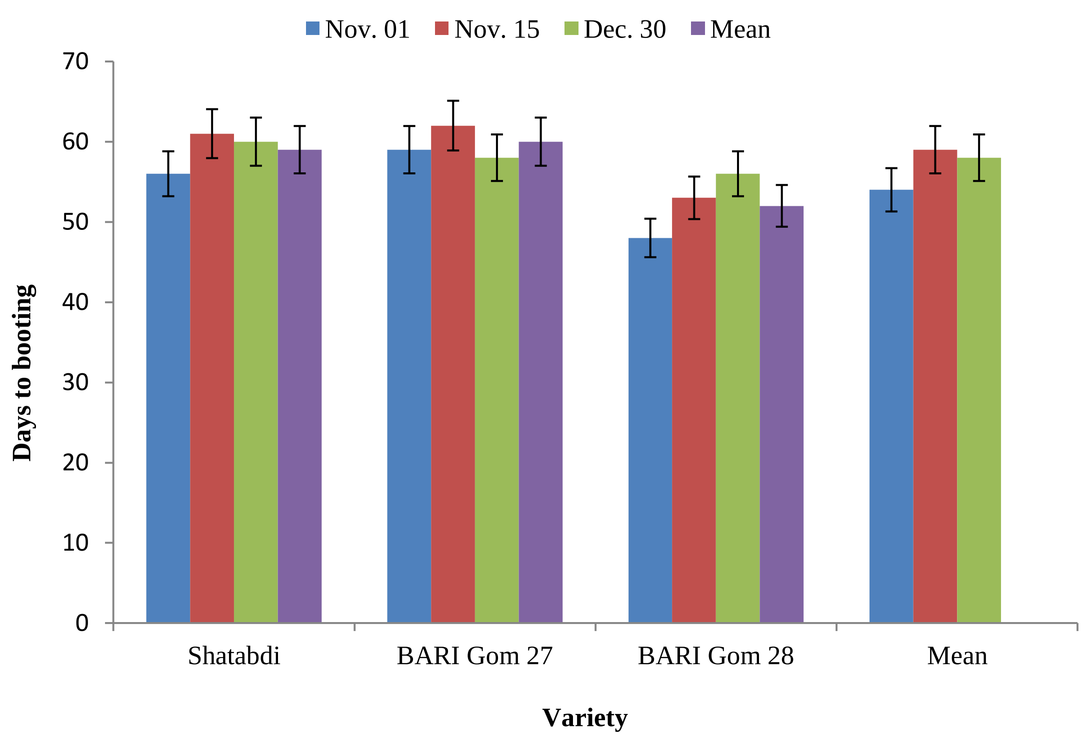

Figure 3
Effect of different sowing dates on days to booting of three wheat varieties. Mean (±SE was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).)

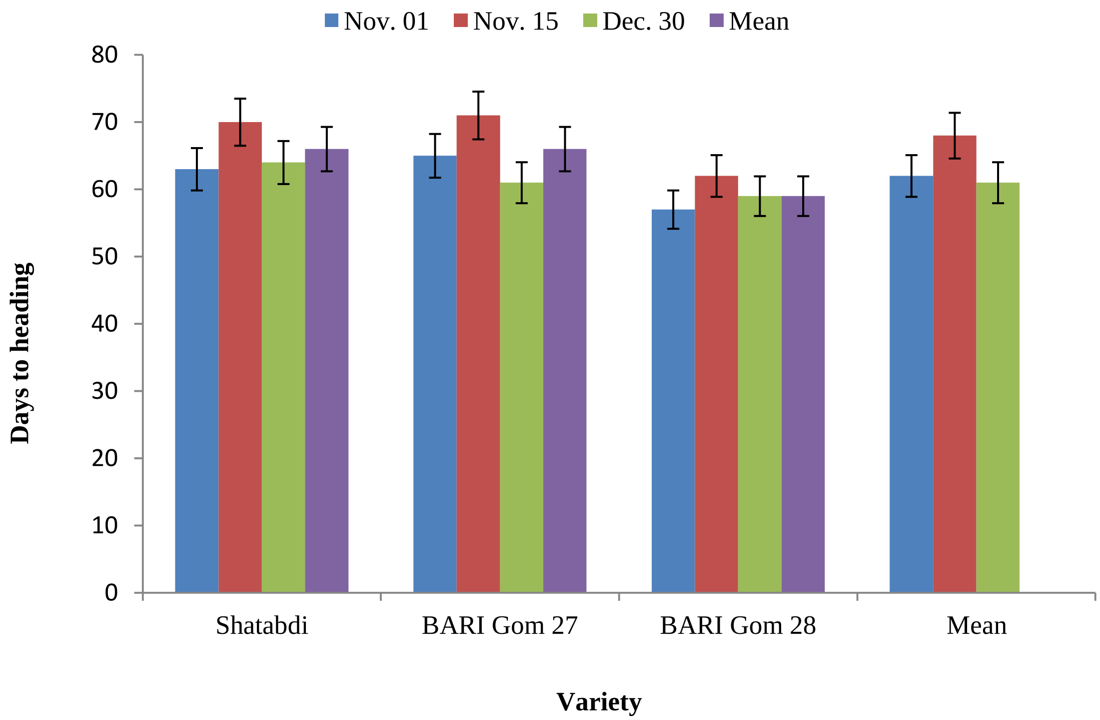

Figure 4
Effect of different sowing dates on days to heading of three wheat varieties. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

Days to heading

In the present study, significant difference was found among three sowing time (Figure 4). Optimum sowing took more time for heading, whereas early sowing and late sown took statistically similar times for heading. Among the three varieties, 'BARI Gom 27'and 'Shatabdi' took more and same time in early, optimum and late sown conditions for heading whereas, 'BARI Gom 28' took least time for heading in all sowing condition. However, in both early and optimum sowing variety 'BARI Gom 27' took more time to spiking than other two varieties but it was late in 'Shatabdi' variety and least in 'BARI Gom 28' (Figure 4). Differences in heading was observed in wheat due to delayed sowing and raising temperature (Hossain et al. (2011; Nahar et al., 2010 and Rahman et al. 2009)

Days to physiological maturity

It was observed that days to physiological maturity decreased from early sowing to optimum and late sowing.. Among the varieties 'Shatabdi' took more time, followed by 'BARI Gom 27' to reach physiological maturity and 'BARI Gom 28' took least time (Figure 5). However, 'Shatabdi' took more time to reach physiological maturity in all sowing conditions (early, optimum and late sown conditions), followed by 'BARI Gom 27' and 'BARI Gom 28' took least time to reach physiological maturity (Figure 5). Similar observation was reported by Hakim et al. (2012); Hossain et al. (2011, 2012b, c) and Rahman et al. (2009).

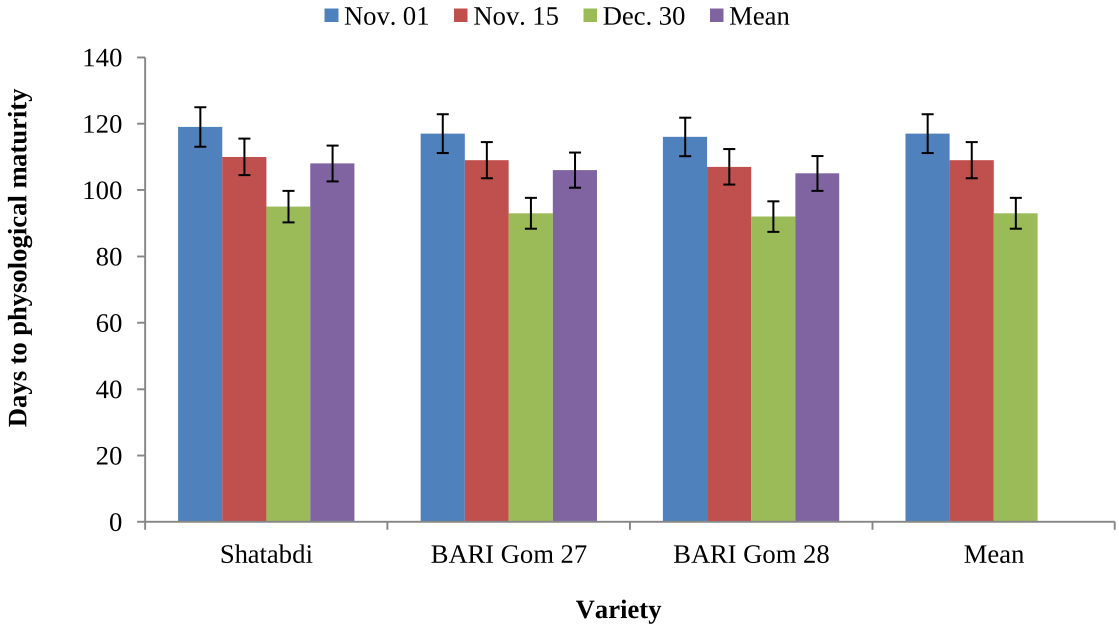

Figure 5
Effect of different sowing dates on days to physiological maturity of three wheat varieties. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

Plant population

In the present study plant population m^{-2} of wheat varieties varied significantly by sowing dates. The highest plant population m^{-2} was recorded in optimum sowing condition), followed by early sowing and the worst were in late sown condition. Considering on genotypes the maximum plant population $m^{-2}$was in 'BARI Gom 27', followed by 'Shatabdi' and the worst in 'BARI Gom 28'. Combined effect of high air temperature (27-33°C) and water stress (-3 to -0.9 MPa) reduces seed germination, causes unequal seedling emergence, and results in variation in the number of plants/unit area, ultimately decreasing seed yield and quality (Hampson and Simpson, 1990).

Yield and yield attributes

Plant height at harvest

Plant height at harvest of wheat varieties was influenced by sowing dates. The tallest plant (97.18 cm) at harvest was recorded from 15th November sowing which was significantly higher than crop sown on 1stNovember and 30th December (Table 2). The shortest plant height was recorded at harvest from 30th December sowing. Varieties also shown significant variation with each other, it is due to genetically variation among the varieties and environmental effect. The results are similar to the findings of Shivani et al. (2003) and Pandey et al. (2010). The tallest plant was obtained from variety 'Shatabdi' followed by 'BARI Gom 27', whereas 'BARI Gom 28' produced the shortest plant at harvest (Table 2). In 15th November sowing, wheat genotypes 'Shatabdi' and 'BARI Gom 27' recorded comparable plant height at harvest and were significantly superior over 'BARI Gom 28'. Under delayed sowing (30th December) 'Shatabdi' and 'BARI Gom 28' were comparable plant height were significantly higher than 'BARI Gom 27' (Table 2).

Productive tillers m^{-2}

Productive number tillers m^{-2} varied significantly by different wheat varieties. Among the three varieties, 'BARI Gom 27' produced significantly higher number of productive tillers m^{-2} followed by 'Shatabdi' whereas 'BARI Gom 28' produced the lowest number of productive tiller m^{-2}. In 15th November sowing, wheat varieties 'BARI Gom 27' and 'Shatabdi' produced the comparable greater numbers of productive tiller and were significantly superior over 'BARI Gom 28'. Under delayed sowing (30thDecember) variety 'BARI Gom 27' and 'Shatabdi' were comparable in productive tiller, which were significantly higher than 'BARI Gom 28'. Among the varieties, 'BARI Gom 27' produced more number of productive tiller than 'Shatabdi' and 'BARI Gom 28' in all sowing dates, whereas 'BARI Gom 28' produced the lowest number of productive tiller m^{-2} (Table 2). Maximum tiller production in 15 November sowings was due to extended vegetative phase weather during this period. While higher mean temperature at vegetative phase of 1st November sowing resulted in reduction of total tillers. Similar results were also reported by Samre et al. (1989), Patil et al. (2001) and Singh and Pal (2003). Similarly, 15th November crop sown recorded highest average tiller numbers (Patil et al., 2001).

Spike length

In the present study, wheat sown on 15th November recorded significantly higher spike length when compared to early sowing and late sowing (Figure 6 & 7). The reduction in ear length under delayed sowing during December 30th could be explained in terms of altered phenology resulting in early heading. Similar results were also reported by Mishra et al. (2003), Shah et al. (2006) and Kaur et al. (2010).The variety 'Shatabdi' and 'BARI Gom 27' recorded significantly more ear length over 'BARI Gom 28' (Figure 6 & 7). The variation in ear length among the genotypes may be due to genetic variation. Similar variation in spike length among genotypes was also reported by Pandey et al. (2007) and Pandey et al. (2010). However, the interaction between variety and date of sowing had no significant effect on spike length (Table 2). Numerically higher ear length was recorded from 'Shatabdi', when sown on 15th November compared to 1st November and 30th December sowings. Similarly, these results were found to be in accordance with study of Singh and Pal (2003) and Mishra et al. (2003).

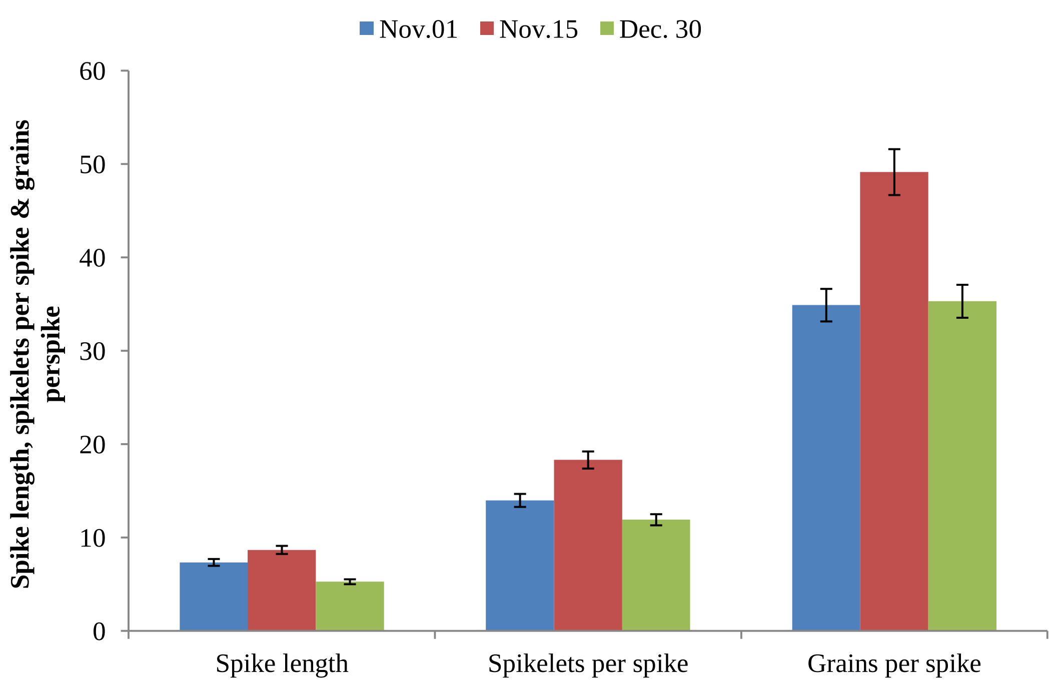

Figure 6
Effect of sowing dates on spike length, spikelets per spike and grains per spike. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

Spikelet spike^{-1}

In the present study, spikelet spike^{-1}was significantly influenced by sowing dates. Crop sown on 15th November significantly higher Spikelets spike^{-1} than crop sown 1st November and 30th December sowing (Figure 6 & 7). Significantly lower spikelet spike^{-}was obtained in 30th December sowing crop. Spikelet spike^{-1} also varied significant among three varieties. Significantly higher Spikelets spike^{-1} was obtained from 'BARI Gom 28' followed by 'Shatabdi', whereas, 'BARI Gom 27' produced the lowest Spikelets spike^{-1} (Figure. 6 & 7). The interaction between variety and date of sowing had significant effect on Spikelets spike^{-1}. The highest Spikelets spike^{-1} was found from 'BARI Gom 28' sown on 15th November and the lowest was observed in 'BARI Gom 27' sown on 30th December. Similarly, Hossain et al. (2012d) reported that all varieties showed more spikelets spike^{-1} in optimum sowing, due to more favourable environment than early and late sowing.

Grains spike^{-1}

The number of grains ear^{-1} in wheat as influenced by sowing dates and genotypes. As sowing was delayed grain number increased up to the 15th November and decreased significantly with 30th December (Figure 6 &7). Wheat sown the 15th November produced significantly higher number of grains spike^{-1} over late sowing on the 30th December sowing. In late sown condition, altered phenology forced to early heading and maturity due to heat stress and get less time for grain formation resulted in reduction of number of grains spike^{-1} reported by Rane *et al.* (2003), Kumar *et al.* (2008), Kaur *et al*. (2010) and Pandey *et al*.(2010). Considering on variety 'BARI Gom 28' produced significantly higher number of grains over 'Shatabdi' and 'BARI Gom 27' produced less number of grain spike^{-1} in early, optimum and late sown condition. It may be due to the variety 'BARI Gom 28' with its longer ear also produced more number of grains ear^{-1} than Shatabdi' and 'BARI Gom 27'. The interaction between variety and date of sowing had significant effect on grain spike^{-1}. The highest grain spike^{-1} was found from 'BARI Gom 28' sown on 15th November and the lowest one observed 'BARI Gom 27'sown on 30th December.

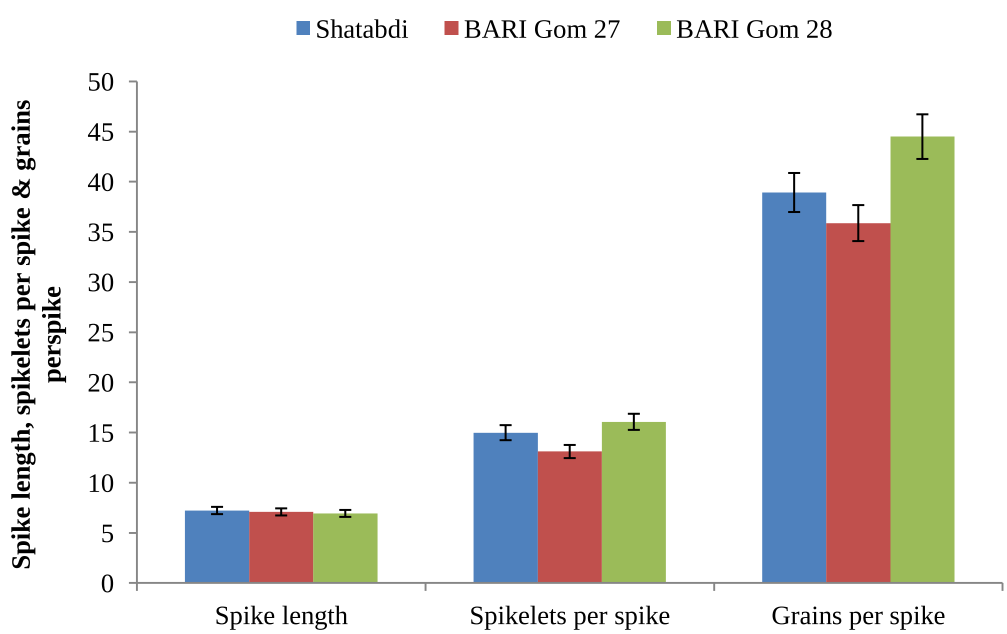

Figure 7
Effect of wheat varieties on spike length, spikelets per spike and grains per spike. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test)

1000-grain weight

Wheat sown 15th November produced significantly highest 1000-grain weight followed by 1st November sowing and the least 1000-grain weight was obtained from 30thDecember sowing (Table 3). This may be due to early heading and forced maturity due to heat stress and also less time available for grain filling and grain maturity due to reduction in days taken to maturity. Similar views are also expressed by Jadav and Karanjikar (2001) Shirpurkar et al. (2007).The reduction in the 1000-grain weight as the sowing was delayed also could be attributed to more number of shriveled grains formed due to prevailing high temperature at the time of grain filling. The results are in conformity with the results of Asana and Saini (1962) who stated that relatively high temperature during early grain development increased the initial rate of grain filling enhanced the yellowing and loss of stem sugars and hence reduced final grain weight. Similar observation of reduction in 1000-grainweight with delay in sowing was also made by Shirpurkar et al. (2007). Kumar et al. (2008) Pandey et al. (2010). Considering on variety, 'BARI Gom 28' produced significantly highest 1000-grain weight over 'Shatabdi' and 'BARI Gom 27'. Interaction effect between sowing dates and varieties on 1000-grain weight was influenced significantly (Table 3).

Table 2
Effect of sowing dates on plants m^{-2}, plant height at harvest, productive tillers m^{-2} and spike length of wheat varieties.

Sowing date	Variety		
	'Shatabdi'	BARI Gom 27	'BARI Gom 28'
	Plant population m^{-2}		
Nov. 01	228.67 b	238.00 b	233.33 b
Nov. 15	311.33 a	342.00 a	293.33 a
Dec. 30	225.67 b	248.67 b	226.00 b
F-test	**	CV (%) 3.35	
	Plant height at harvest		
Nov. 01	96.57 ab	92.62 a	84.74 b
Nov. 15	100.94 a	98.68 a	91.93 a
Dec. 30	93.71b	81.72 b	89.90 ab
F-test	**	CV (%) 4.03	
	Productive tillers m^{-2}		
Nov. 01	234.67 b	230.00 b	238.00 b
Nov. 15	333.67 a	347.33 a	325.00 a
Dec. 30	222.33 c	225.67 b	215.00 c
F-test	**	CV (%) 1.14	
	Spike length		
Nov. 01	7.51	7.35	7.13
Nov. 15	8.79	8.69	8.54
Dec. 30	5.40	5.22	5.15
F-test	NS	CV (%) 1.29	

* Significance at 5% and ** significance at 1%; NS, non-significant; Mean followed by the same letter(s) within a parameter do not differ significantly at 5% level of DMRT.

Table 3
Effect of sowing dates on spikelet spike^{-1}, grains spike^{-1}, 1000-grain weight and harvest index of three wheat varieties.

Sowing date	Variety		
	'Shatabdi'	BARI Gom 27	BARI Gom28
	Spikelets spike^{-1}		
Nov. 01	14.27 b	12.83 b	14.80 b
Nov. 15	18.83 a	15.90 a	20.17 a
Dec. 30	11.88 c	10.60 c	13.23 bc
F-test	*		
CV (%)	5.08		
	Grains spike^{-1}		
Nov. 01	34.40 b	30.40 bc	39.83 b
Nov. 15	49.50 a	45.10 a	52.80 a
Dec. 30	32.90 b	32.13 b	40.87 b
F-test	*		
CV (%)	4.70		
	1000-grain weight		
Nov. 01	44.62 a	35.10 b	45.08 a
Nov. 15	45.59 a	38.16 a	45.84 a
Dec. 30	22.51 b	19.04 c	22.22 b
F-test	**		
CV (%)	1.17		
	Harvest index		
Nov. 01	27.29 b	27.16 b	27.81c
Nov. 15	34.61 a	33.07 a	34.76 a
Dec. 30	28.30 b	28.11 b	28.61b
F-test	*		
CV (%)	1.66		
	Biomass at harvest (kg ha^{-1})		
Nov. 01	8151.19b	7379.76b	8258.33b
Nov. 15	9086.90a	8584.53a	9282.14a
Dec. 30	6233.00c	5572.62c	6404.76c
F-test	**		
CV (%)	1.74		
	Grains Yield (kg ha^{-1})		
Nov. 01	3059.89b	2751.45b	3182.52b
Nov. 15	4809.73a	4245.02a	4946.11a
Dec. 30	2460.01c	2182.97c	2566.84c
F-test	**		
CV (%)	2.79		

* Significance at 5% and ** significance at 1%; Mean followed by the same letter(s) within a parameter do not differ significantly at 5% level of DMRT.

Harvest index

In the present study, harvest index was significantly influenced by sowing dates. Crop sown on 15thNovember significantly higher harvest index than crop sown 1st November and 30th December sowing. Significantly lower harvest index were obtained in 30th December sowing crop (Table 3). Significantly higher harvest index was obtained from 'BARI Gom 28' followed by 'Shatabdi', whereas 'BARI Gom 28' produced the lowest harvest index. The interaction between variety and date of sowing had significant effect on harvest index .The highest harvest index was found from 'BARI Gom 28' sown on 15th November and the lowest one observed 'BARI

Gom 27'sown on 30th December (Table 3). Sowing on 15th November resulted in the greatest mean harvest index reported by (Shah et al., 2006). Natu et al. (2006) reported that the decrease in harvest index by late sowing (28th December) as compared to normal sowing (27thNovember). In case of variety, harvest index was significant among three varieties.

Biomass yield

In our study, biomass production was also varied significantly among three varieties (Figure. 8 & 9). Significantly the highest biomass was obtained from 'BARI Gom 28' followed by 'Shatabdi' whereas 'BARI Gom 28' produced the lowest biomass which can be attributed to the genetic variation among genotypes. These results are in conformity with the findings of Dhaka et al. (2006), Prabhakar et al. (2007) and Pandey et al. (2010). The combine effect of sowing dates and variety on biomass yield was also significant. The highest biomass was found from 'BARI Gom 28' sown on 15th November and the lowest one was observed in 'BARI Gom 27'sown on 30th December (Table 3).

Grain Yield

As shown in Figure 7 grain yield of wheat was significantly influenced by sowing dates and genotypes. Wheat sown on 15th November resulted in significantly higher yields over 1stNovember and 30th December sowings and was on par with 1st November sowing. On the other hand yields 1stNovember and 30th December sowing were significantly lower and were comparable with each other, respectively. This is due to in late sown condition, climate and soil moisture were unfavourable (high temperature, low relative humidity in the air and low soil moisture) for crop production, which ultimately affected crop growth and yield (Hossain et al., 2012d). The poor yields of wheat sown on 1st November and 30thDecember may be attributed to reduction in number of productive tillers and grain $sear^{-1}$ in 1stNovember sowing and also test weight in December 30thsowing (Figure 8 & 9).

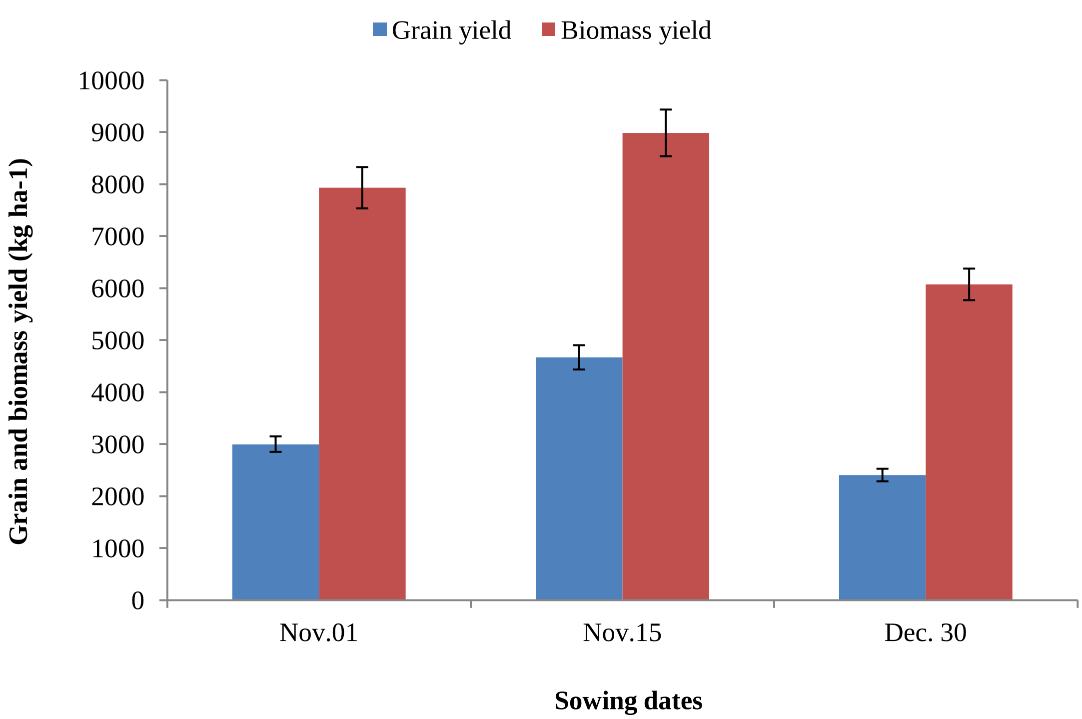

Figure 8
Effect of sowing dates on grain and biomass yield of three wheat varieties. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

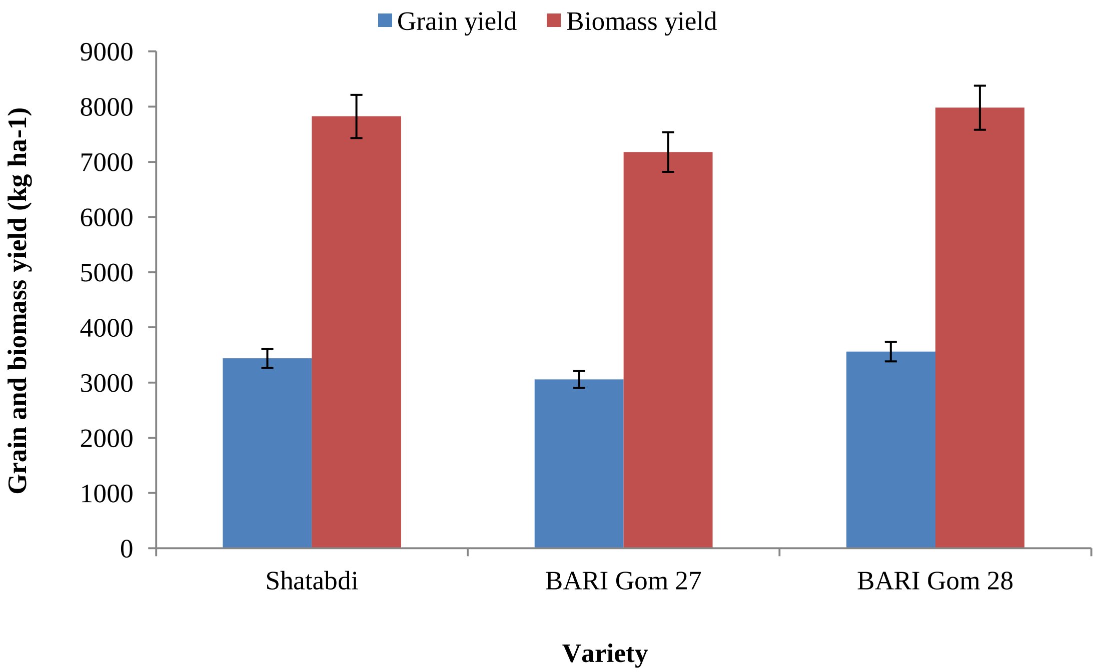

Figure 9
Effect of variety on grain and biomass yield of three wheat varieties. Mean (±SE) was calculated from three replicates for each treatment. Error bars represent significant difference at p≤ 0.01 (LSD test).

Considering on variety, 'BARI Gom 28' produced significantly higher yield over 'Shatabdi' and 'BARI Gom 27' and the lowest yield was recorded from 'BARI Gom 27'. This can be attributed to the genetically potential of the genotypes. These results were in conformity with the findings of Samre et al. (1989), Shirpurkar et al. (2007), Kumar and Pandey (2008) and Pardeshi et al. (2009).

Interaction of sowing dates and genotypes also significantly influenced grain yield as given in Table 3. Significantly more grain yield was obtained from were produce 'BARI Gom 28' when sown on 15th November and 1st November, 'BARI Gom 27' sown on 15th November and 'Shatabdi' sown on 15th November. Among them 'BARI Gom 28' produced highest grain yield in all sowing dates followed by 'Shatabdi' and the lowest yield was obtained from 'BARI Gom 27' (Table 3).

From the present study, it can be concluded that variety 'BARI Gom 28' was the best performing variety under all sowing conditions, followed by 'Shatabdi' and the variety 'BARI Gom 27' was the least performing under all sowing conditions.

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