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PHENOLOGY, GROWTH AND YIELD ARE STRONGLY INFLUENCED BY HEAT STRESS IN LATE SOWN MUSTARD (*BRASSICA* SPP.) VARIETIES

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Abstract

In rice-based cropping system of northern Bangladesh, mustard planting is delayed due to late harvest of monsoon rice (Transplanted Aman rice; *T. Aman* rice). The late sown mustard is often exposed to high-temperature stress during the reproductive stage, which causes a significant decrease in seed yield. Most of the farmers plant a low yielding local mustard variety 'Tori-7', which is sensitive to high-temperature stress. The Oil Seeds Research Centre of Bangladesh Agricultural Research Institute has recently released short duration and high-yielding mustard varieties for the rice-based cropping system of northern Bangladesh to tackle this issue. However, the performance of these varieties in the target cropping system under late sown conditions (together with exposure to heat stress) has not been evaluated yet. Therefore, this two-year field experiment was conducted to assess the performance of newly released mustard varieties 'BARI Sarisha-14' and 'BARI Sarisha-15' in comparison with the local check variety 'Tori-7' sown at five planting dates (*viz*. October 21, November 1, November 10, November 20, and November 30). The delay in sowing shortened time (days) to flowering and maturity, regardless of the variety. Similarly, plant height, branches/plant and total dry matter accumulation of the tested varieties were also reduced upon delay in planting. The greatest seed yield was observed in varieties 'BARI Sarisha-15' and 'BARI Sarisha-14' when sown on October 21. These two varieties produced fair seed yield when sown at November 20. However, the local variety 'Tori7' yielded the least across all the planting dates. Therefore, the varieties 'BARI Sarisha-14' and 'BARI Sarisha-15' may be planted in the rice-based cropping system of northern Bangladesh after harvest of T. *Aman* rice to get maximum seed yield.

Key words: Sowing date, Phenology, Growth, Mustard, Varieties, High temperature, Late sowing, Seed yield.

Introduction

Mustard (*Brassica* spp.) is one of the important edible oilseed crop across the worldwide including Bangladesh. Other than the use of mustard oil for industrial and edible purposes, its cake is a nutritious feed for cattle because of up to 40% protein (Wanasundara *et al*., 2016; Rahman *et al*., 2018). However, it is production is mostly restricted by drought, which can become critical in climate change (EL Sabagh *et al*., 2019; Islam *et al*., 2019). It is a photo-sensitive crop, sensitive to temperature extremes as well (Ghosh and Chatterjee, 1988). Optimum growth occurs between 12°C and 25°C, preferably at 20°C, and grows poorly at <5°C (Wahhab *et al*., 2002). In Bangladesh, average mustard seed yield ha^{-1} is about 1001 kg (Anon., 2008), which is far lower than the global averages (Ahmed *et al*., 1988). Delay in planting, especially in the rice-wheat cropping system, is one of the major reasons for this low seed yield.

The timely sowing enables the crop plants to complete both vegetative and reproductive growth phases and yield well (Iraddi, 2008; Sharghi *et al*., 2011). Nonetheless, change in planting date, other than flower appearance in photo-sensitive crops (Miralles *et al*., 2001), may expose the crop plants to less than optimum conditions (Martiniello & Teixeira da Silva, 2011), and insect-pests attacked by and disease infestation (Singh *et al*., 2007) resulting in drastic yield reduction (Rahman *et al*., 2004).

In Bangladesh, the time window for mustard planting is very short ranging from 15 October to 15 November (Mondal *et al*., 1992 & 1999; Alam *et al*., 2014). However, due to the delay in harvest of T. Aman rice, mustard planting is delayed in the rice-based cropping system of northern Bangladesh. The late-planted mustard is exposed to high-temperature stress during the reproductive phase, forcing plants to mature quickly as a result of increased senescence, reducing the length of the seed-filling period, lowering seed size and weight, and resulting in substantial reduction in seed yield (Uddin *et al*., 2009; Bala *et al*., 2011; Sharif *et al*., 2017). Most of the Bangladeshi farmers plant a low-yielding local mustard variety 'Tori-7' in the rice-mustard cropping pattern. To meet the oil seed demand of increasing population, Oil Seeds Research Centre of Bangladesh Agricultural Research Institute recently released some short duration and high-yielding mustard varieties for rice-based cropping system of northern Bangladesh.

However, the performance of these varieties in the target cropping system, under late sown conditions (together with exposure to heat stress), has not been reported yet. In the context, this study was conducted to evaluate the performance of newly released mustard varieties (‘BARI Sarisha-14’, ‘BARI Sarisha-15’) in comparison with the local variety ‘Tori-7’ at different planting times (Oct. 21, November (Nov.) 1, Nov. 10, Nov. 20, and Nov. 30) in rice-based cropping system of northern Bangladesh.

Materials and Methods

Site description: The experiment was conducted at the Agricultural Research Station (25.63° N, 88.65º E, 42 m above sea level) of Bangladesh Agricultural Research Institute (BARI), Rajbari-Dinajpur 5200, Bangladesh during two consecutive winter seasons of 2015-16 and 2016-17. The experimental site belongs to the Old Himalayan Piedmont Plain of AEZ-1, where soils are predominant with deeply and rapidly permeable sandy loams and sandy clay loams. The experimental site has a tropical wet and dry climate with a distinct monsoon season (Table 1).

Soil nutrients status in experimental soils: The soil pH was 6.66, where organic matter, N, P, K, S, Zn and B of the experimental soil were 1.71%, 0.085%, 24.19 µg/g soil, 0.21 meq 100g^{-1} soil, 24.04 µg g^{-1} soil, 1.31 µg g^{-1} soil and 0.84 µg g^{-1} soil, respectively.

Meteorological information during the crop growth stage in both-year: During crop growth period, weather data on temperature (maximum, minimum and average), rainfall (mm) and relative humidity (%) were recorded in both the years (Table 2). The annual rainfall was 2536 mm, the most of which was received from July to September. The average maximum and minimum temperature in the crop season (October to February) were 27.95°C and 15.34°C, 28.05°C and 15.54°C during in 2015-16 and in 2016-17, respectively. However, in both the crop season, the maximum monthly mean temperature was recorded in October and January was the coldest month with mean minimum temperature of 10°C during both seasons. The monthly average humidity and rainfall were 79.55% and 0.76 mm in 2015-16 while 79.62% and 1.17 mm in 2016-17, respectively (Table 2).

Treatments and experimental design: Two newly released mustard varieties ‘BARI Sarisha-14’, ‘BARI Sarisha-15’ with a local check variety ‘Tori-7’ were sown at five planting dates (i.e., October 21, November 1, November 10, November 20, and November 30 in both years) within a split-plot arrangement with three replications. Five planting dates were assigned in main plots and three mustard varieties were arranged in sub-plots (net plot size was of 3 m × 3 m).

Experimental procedure: Fertilizers such as Urea-TSP-MP-Gypsum-Zinc sulphate and Boric acid at the rate of 250-170-85-150-5 and 10 kg ha^{-1}, respectively were applied as per the recommendation of Fertilizer Recommendation Guide (FGR) of Bangladesh Agricultural Research Council (BARC) (Anon., 2012). Whole of P, K, Zn and B, and half of N were applied as basal dose; while remaining half of N was top-dressed 22 days after seedling emergence with first irrigation. Seeds were sown in 30 cm spaced rows using seed rate of 7 kg ha^{-1}. Thinning and weeding were performed twice, 12 and 20 days after seedling emergence. The crop was irrigated twice, at 22 and 45 days after seed emergence in each plot according to the sowing date. For controlling aphids, Malathion (57 EC) was applied at 2 ml L^{-1}.

Observations: Data on plant height, branches plant^{-1}, siliquas plant^{-1} and seeds silique^{-1} were recorded from ten randomly harvested plants from each plot. Crops were harvested on different dates depending on maturity. The 1000-grain weight was recorded plot-wise by an electrical balance in g. Six central lines of 2 m length from each plot were harvested and threshed to record seed and stover yields.

Statistical analysis

Data were statistically analyzed using statistical package MSTAT-C (Gomez & Gomez, 1983; Russell, 1986). Treatment means were separated by the least significant difference (LSD) test by using the Statistical Package R at a 5% level of significance (R Core Team, 2013).

Table 1. Initial soil chemical properties in experimental field.

Soil properties	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (meq 100^{-1}g soil)	Available S (ppm)	B (µg/g)	Zn (µg/g)
Initial	6.66	1.71	0.09	24.19	0.21	24.04	1.31	0.84
Status	N	L	VL	H	M	H	VH	L

N= neutral, H= high, VH= very high, VL= very low, L= low and M= medium

Table 2. Meteorological information during crop growing period in both the years (2015-16 & 2016-17).

Month	Temperature (ºC)				Relative humidity (%)		Rainfall (mm)	
	2015-16		2016-17		2015-16	2016-17	2015-16	2016-17
	Max.	Min.	Max.	Min.				
October	32.60	22.99	32.00	23.43	81.34	83.95	3.250	5.590
November	30.22	16.97	29.90	16.56	78.15	77.93	0.000	0.000
December	25.33	12.46	26.23	13.43	82.97	82.48	0.177	0.000
January	23.43	10.29	24.12	10.59	81.61	80.71	0.350	0.248
February	28.19	13.98	27.99	13.69	73.68	73.04	0.000	0.000
Mean	27.95	15.34	28.05	15.54	79.55	79.62	0.760	1.170

Results and Discussion

Phenological variation: Phenologication variation on days to emergence, flowering and physiological maturity of three mustard varieties varied significantly with sowing dates (Fig. 1). All the genotypes took only 4 days for seedling emergence when planted on 21 October and 01 November sowing while when sown on 10 and 20 November, they took 5 days for seedling emergence. Similarly, all the genotypes took 6 days for seedling emergence on 30 November sowing. The days to seedling emergence were increased, due to cool weather for the low temperature at late sown condition (Table 2). However, all the genotypes had less time to flowering and maturity due to high-temperature stress at late sowing. The genotypes 'BARI Sarisha-14', 'BARI Sarisha-15' and 'Tori-7' took 37, 36 and 30 days for flowering on 21 October sowing while seed sowing on 30 November the varieties took 33, 34 and 25 days, respectively. In case of maturity, the genotypes 'BARI Sarisha-14', 'BARI Sarisha-15' and 'Tori-7' took 84, 90 and 81 days for maturity when seed sowing on 21 October, but the number of days for maturity decreased to 80, 85 and 75 days, respectively due to seed sowing on 30 November. The more number of days were taken to emergence of seedlings by crop sown on November 21 and least number of days was taken to emergence of seedlings by crop sown on October 16 when considered irrespective of genotypes as described by Kumar *et al*., (2018). Due to rise of temperature in late sowing, the number of days for flowering and maturity were reduced. Delayed sowing accelerates growth and decreases day number for flowering (Mendham *et al*., 1990). Late sowing forced to decrease the number of days to flowering in canola (Khan *et al*., 1994). Delay in sowing caused a significant reduction in the length of the flowering period also reported by Devi & Sharma (2017). Other workers (Rameeh, 2012; Robertson *et al*., 2004; Asgari & Moradi-Dalyny, 2008) have also reported a noteworthy upshot effect of sowing date on the phenology of mustard particularly length of the flowering and maturity duration that ultimately lead to decrease the final seed yield.

Variation of plant height and branches plant^{-1}: Significant difference in plant height and branches/plant of three mustard varieties were noted due to various sowing dates and varieties (Fig. 2). Among the varieties, the tallest plants were recorded in 'BARI Sarisha-15' and the shortest were in 'Tori-7' regardless of sowing dates. Similarly, early seed sowing recorded the higher plant height compared to the late sown condition irrespective of genotypes. However, the plant height 100.84, 108.44 and 83.01 cm was recorded in 'BARI Sarisha-14', 'BARI Sarisha-15' and 'Tori-7', respectively on 21 October sowing, while the plant height of those genotypes decreased to 85.47, 91.67 and 75.83 cm, respectively on delay (30 November) sowing. The findings of the present study related to variation of plant height under different sowing dates also confirmed by Abdul *et al*., (2013), who reported that plant height in delayed sowings was negatively influenced, while plant height in early planting was increased, may be due to more light, water and mineral absorption by plant canopies thus increasing photosynthetic capacity. The results are in agreement with the earlier findings of Afroz *et al*., (2011); Kumar *et al*., (2018), who noticed that the plant height reduced with delaying the sowing date. Mondal & Islam (1993) also revealed that sowing in the last October gave the tallest plant height than in sowing in early (first October) and late sowing (last week of November). Singh *et al*., (2014) also found that the plant height decreased by 22.8% on 26 November sowing compared to early sowing (26 October sowing).

The maximum branches/plant were recorded when sown on 21 October and gradually decreased with delaying in sowing time. Considering on the varieties, number branches plant^{-1} of 'Sarisha-14', 'BARI Sarisha-15' and 'Tori-7' were 7.8, 8.1 and 11.45 in 'BARI, respectively, when sown on 21 October sowing. While branches of those genotypes were decreased to 6.06, 6.12 and 9.49 of, respectively when sown at late (30 November) (Fig. 2). It is due to late sown crops faced high-temperature stress that ultimately decreased stand established and growth of the plant finally reduced the branches plant^{-1}. The assumption is also confirmed by Alam *et al*., (2015), who reported that the decreased in plant height and branch plant^{-1} in delayed sowing might be due to high-temperature stress at reproductive stages. Bala *et al*., (2011) reported that the highest number of branches was recorded in 8 November sowing and sowing on 13 December produced the lowest branches plant^{-1}, respectively.

Dry matter assimilation: Total dry matter (TDM) accumulation in mustard measured at 25, 50 and 75 days after sowing varied significantly with sowing dates over years are presented in (Fig. 3). Early sowing recorded the higher dry matter accumulation than delay sowing in all the varieties. Varietal variation for TDM, recorded at 25, 50 and 75 days after sowing (DAS), the maximum TDM was recorded when sown at 21 October sowing, followed by sown at 10 November, while the lowest TDM was recorded when sown at late (30 November sowing). Dry matter accumulation reduced gradually with delay the sowing time regardless of variety throughout the season, may be due to high-temperature stress at late sown condition. The findings of present study related to TDM variation regardless of varieties under different sowing dates also confirmed by Kumar *et al*., (2018) who reported that the warmer temperature at 23 September sown crop might have accelerated the plant growth rate which might have resulting into increased plant growth and low temperature at vegetative phase and high temperature at reproductive phase in 21 November sown crop might have resulted into decreased plant growth and development. Keerthi *et al*., (2017) also reported that the total dry matter accumulation decreased significantly with delay in sowing dates at all the growth stages of mustard.

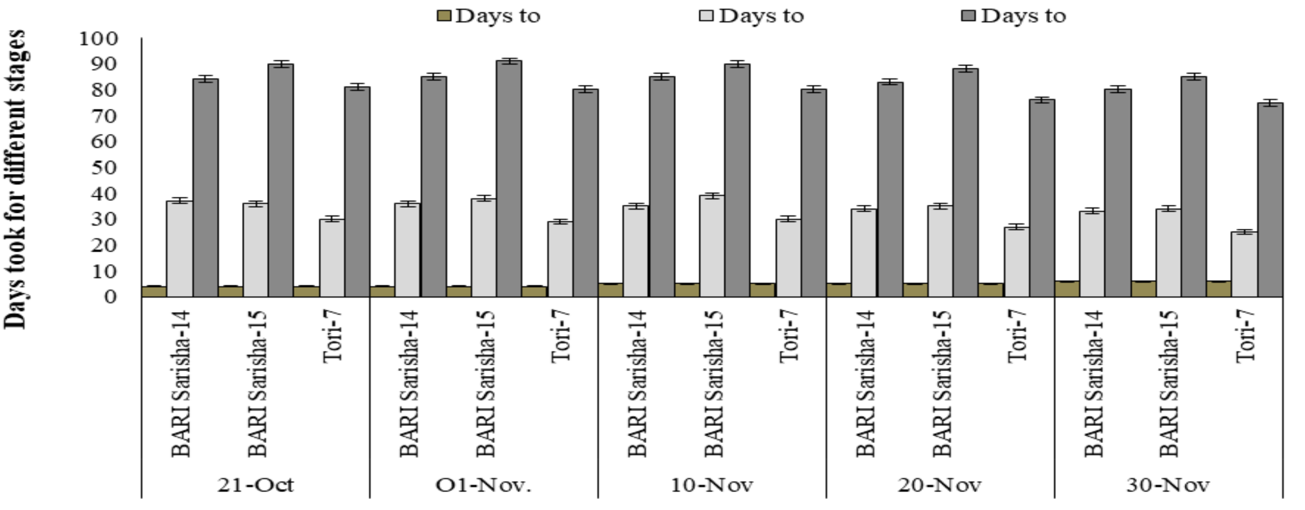

Fig. 1. Phenological variation of three mustard varieties as affected by late sown high-temperature stress (two years mean). Bars for phenological stages of different varieties are significantly different at $p \leq 0.05$ (LSD test). Mean ±SD in each bar was calculated from three replications for each treatment.

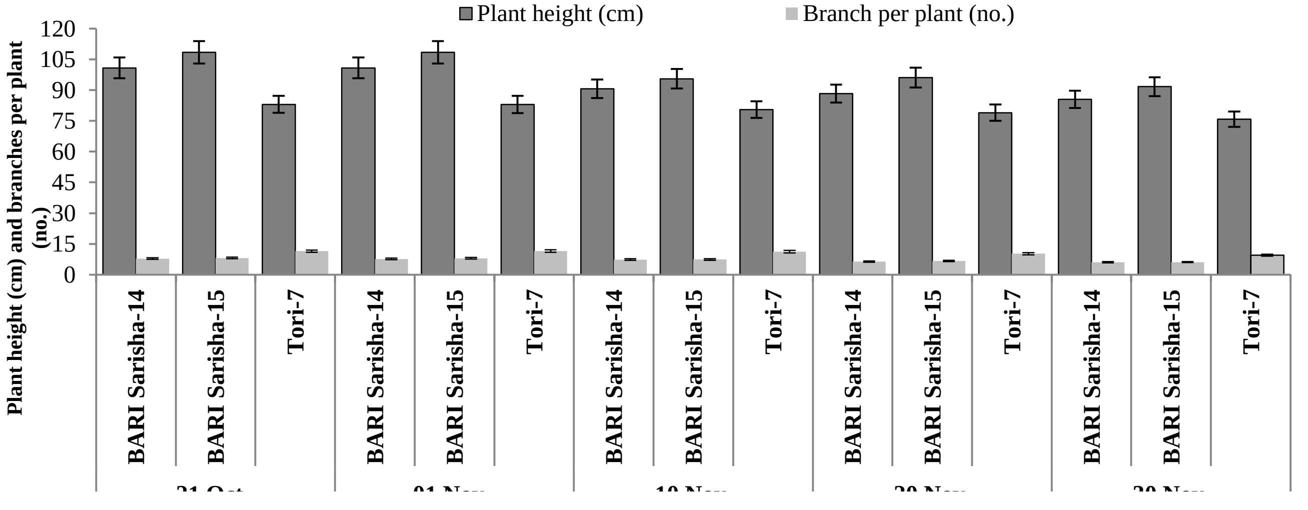

Fig. 2. Plant height (cm) and branch plant^{-1} (no.) of three mustard genotypes as affected by sowing dates (two years mean). Bars for plant height and branches plant^{-1} of different varieties are significantly different at $p \leq 0.05$ (LSD test). Mean ±SD showing in each bar was calculated from three replications for each treatment.

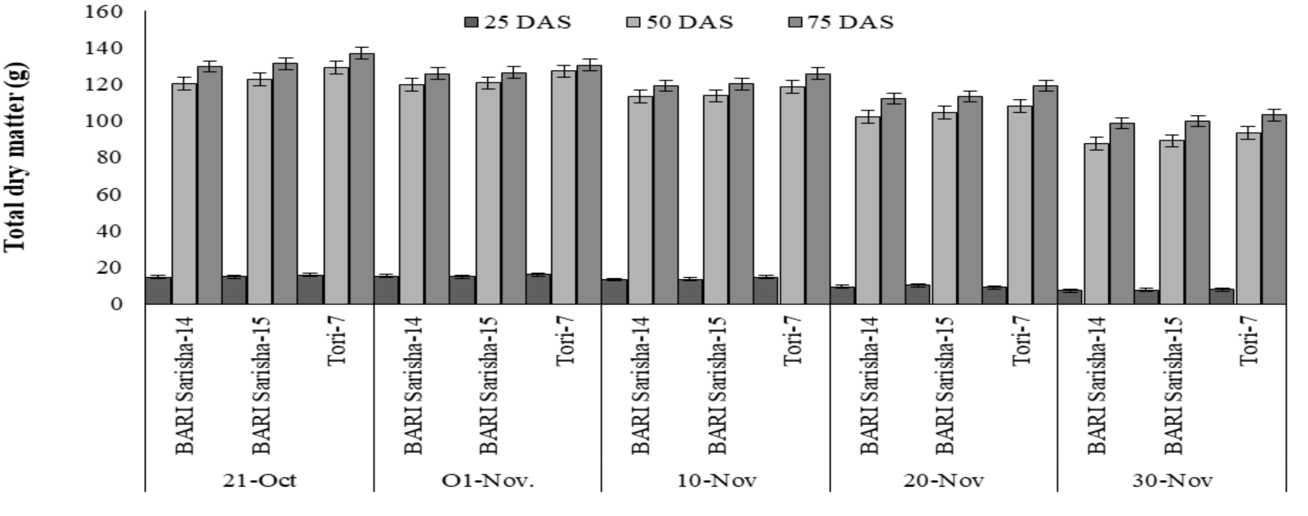

Fig. 3. Total dry matter of mustard varieties as affected by sowing dates (two years mean). Bars for a total dry matter of different varieties at 25, 59 and 75 Das are significantly different at $p \leq 0.05$ (LSD test). Mean ±SD showing in each bar was calculated from three replications for each treatment.

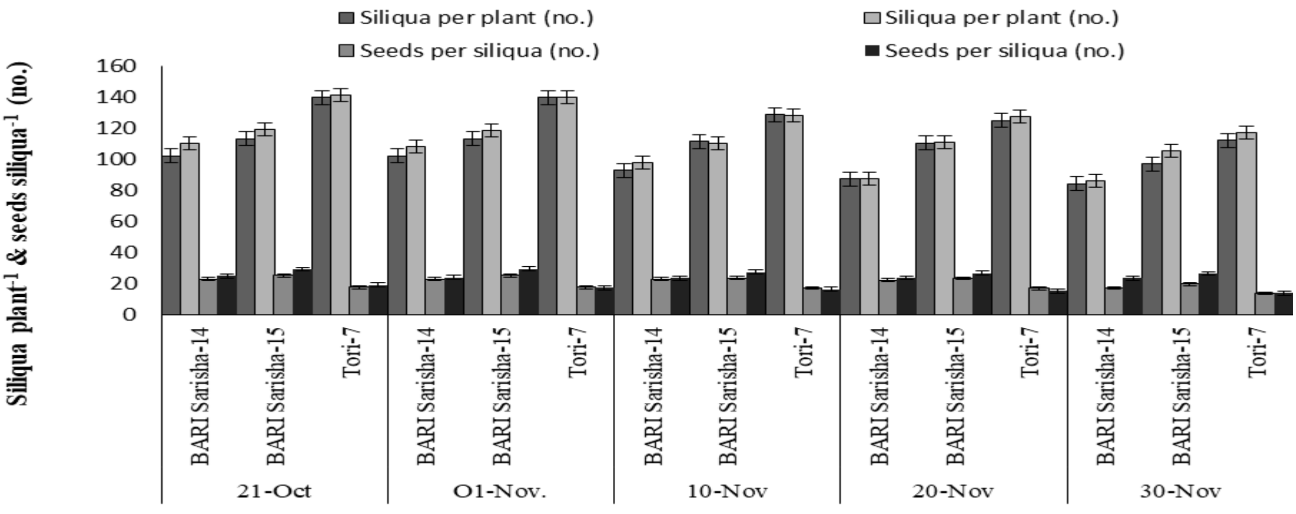

Fig. 4. Siliqua plant^{-1} and seeds siliqua^{-1} of three mustard varieties as affected by late sown heat stress condition in both the years. Bars for siliqua plant^{-1} and seeds siliqua^{-1} of different varieties are significantly different at $p \leq 0.05$ (LSD test). Mean ±SD showing in each bar was calculated from three replications for each treatment.

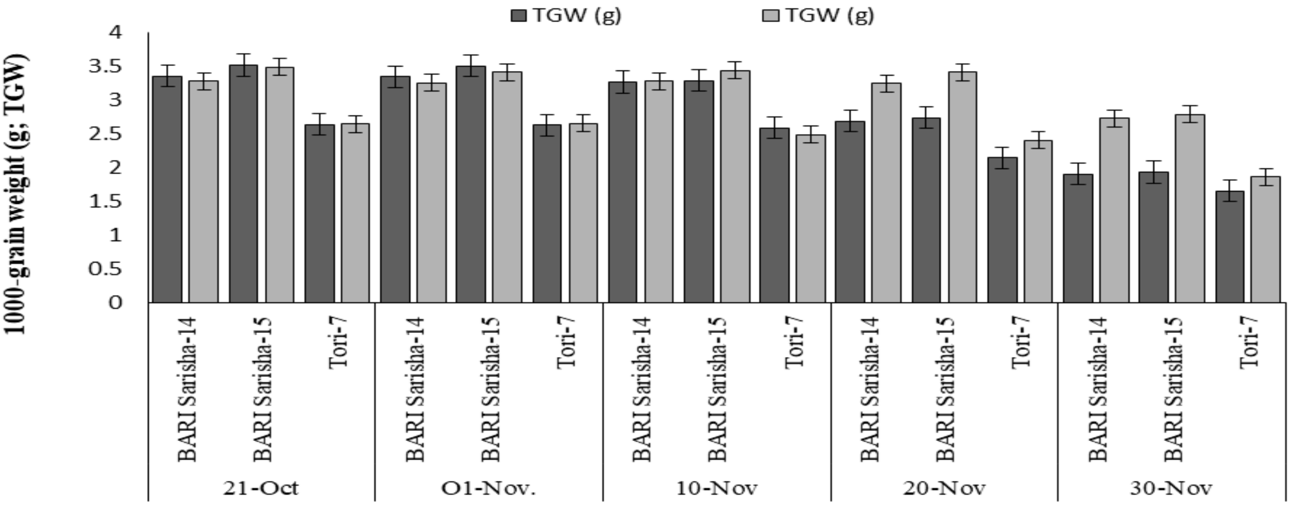

Fig. 5. 1000-grain weight (g; TGW) of three mustard varieties as affected by late sown heat stress condition in both the years. Bars for the 1000-grain weight of different varieties are significantly different at $P \leq 0.05$ (LSD test). Mean ±SD showing in each bar was calculated from three replications for each treatment.

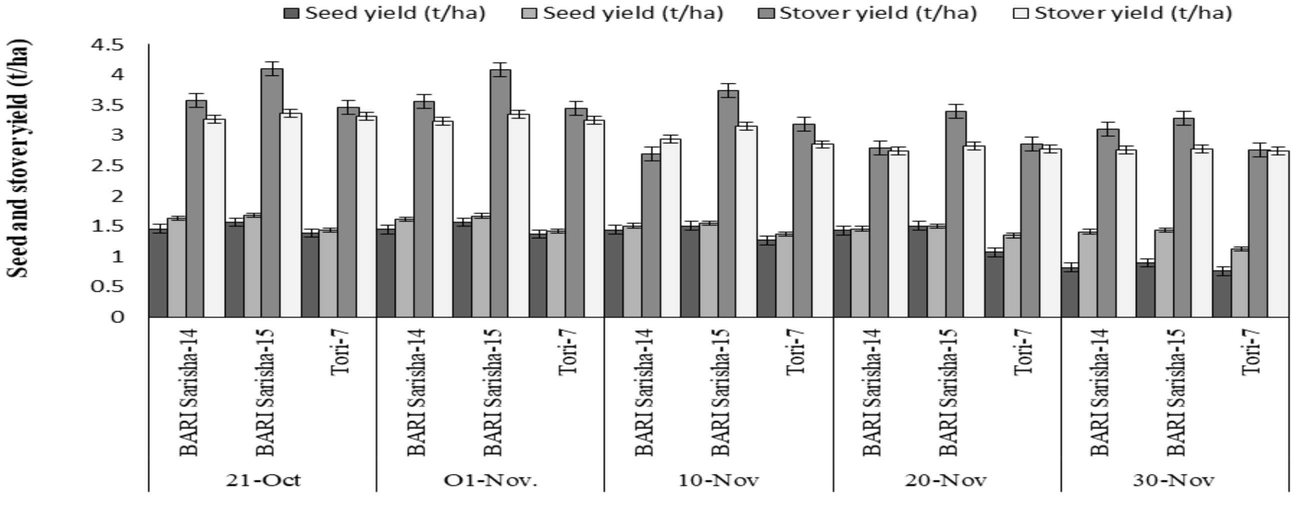

Fig. 6. Seed and stover yield of mustard varieties as affected by sowing time. Bars for seed and stover yield of different varieties are significantly different at $p \leq 0.05$ (LSD test). Mean ±SD showing in each bar was calculated from three replications for each treatment.

Variation of yield attributes: The difference of yield and yield traits due to various varieties under different sowing conditions are presented in Figs. 4-6). However, significant difference on siliqua plant^{-1}, seeds siliqua^{-1} and 1000 seed weight were found due to different dates of sowing and varieties. The maximum siliqua plant^{-1} (140.20 and 141.67) was acquired from 21 October sowing from local variety 'Tori-7' in both years, which differed significantly from that of other sowings. The lowest number of siliqua plant^{-1} was found on late sowing (30 November) regardless of variety. When sown at 21 October, the number of seeds siliqua^{-1} was recorded 25.34 and 29.43 in 'BARI Sarisha-15', 23.02 and 25.10 in 'BARI Sarisha-14' and 17.87 and 19.23 in 'Tori-7'. While sown at late (30 November), the number of seeds siliqua^{-1} decreased gradually irrespective of variety in both the years (Fig. 4). The thousand seed weight was observed higher in timely sowing condition which reduced gradually with delay the sowing time regardless of variety. Among the genotypes 'BARI Sarisha-15' recorded the higher 1000-seed weight followed by 'BARI Sarisha-14' and the lower in 'Tori-7' at all the sowing time. However, 1000-seed weight has obtained the maximum when sown at 21 October and the lowest on late sowing (30 November) irrespective of genotypes (Fig. 5). Delaying sowing resulted in the significant reduction in the seed set, seed set percentage, 1000 seed weight and seeds siliqua^{-1} (Devi & Sharma, 2017). Plant height, branches plant^{-1}, pods plant^{-1} and pod length were decreased significantly when sown at delay Afroz *et al*., (2011).

Seed and stover yield (t ha^{-1}): Regardless of sowing time, seed yield and stover yield were higher in 'BARI Sarisha-15' followed by that of 'BARI Sarisha-14' and the lowest in 'Tori-7' (Fig. 6). The greatest seed yield was noted from 'BARI Sarisha-15' on 21 October sowing which was identical to 'BARI Sarisha-14'. Although the seed yield reduced gradually with delay sowing, both the variety gave statistically identical seed yield up to 20 Nov. sowing. Mustard sowing after 20 November, seed yield decreased drastically irrespective of variety might be due to decrease the crop growth duration, siliqua plant^{-1}, seeds siliqua^{-1} and seed weight. Higher seed yield of 'BARI Sarisha-15' and 'BARI Sarisha-14' than that of 'Tori-7' might be due to higher seeds siliqua^{-1} and seed weight. Stover yield also followed the similar trend of seed yield. The results of the current research related to difference of yield and yield attributes under different sowing condition particularly late sowing also confirmed by Rahman *et al*., (1993), who reported that seed yield of mustard declined gradually by 11.7, 21.5, 43.4 and 62.9%, respectively, for each week delay after optimum sowing (1 November). While, Nandlal Patel *et al*., (2015) conducted a field research in India and found that the crop sown on optimum (October 20), resulted in significantly more number of siliqua plant^{-1}, 1000 seeds weight, seed yield, biological yield and stover yield. Similarly results also confirmed by earlier findings as reported by Khatun *et al*., (2011); Bala *et al*., (2011) and Afroz *et al*., (2011), who revealed that mid-October to the first week of November sowing is the best sowing time to get highest grain yield of mustard.

Conclusion

All of tested varieties produced higher seed yield at early sowing and delay in sowing caused gradual reduction in seed yield. Among the varieties, 'BARI Sarisha-15' and 'BARI Sarisha-14' produced the satisfactory seed yield up to 20 November sowing than that of 'Tori-7'. Therefore, the variety 'BARI Sarisha-14' and 'BARI Sarisha-15' may be planted in the rice-based cropping system of northern Bangladesh after harvesting of T. *Aman* rice to get maximum seed yield.

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