Journal of Experimental Biology and Agricultural Sciences, April - 2023; Volume – 11(2) page 325 – 338

Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

Growth and development patterns in Mustard (*Brassica* spp.) as influenced by sowing time

Sushan Chowhan[1+*], Majharul Islam[2], Md. Shohel Rana[3], Nazmul Alam Khan[4], Md. Khan Jahan Ali[5], Nasir Uddin Ahmed[6], Md. Moshiur Rahman[7]

[1]Adaptive Research and Extension Division, Bangladesh Institute of Nuclear Agriculture (BINA), Sub-station, Ishurdi, Pabna-6620, Bangladesh
[2]Soil Science Division, BINA, BAU campus, Mymensingh-2202, Bangladesh
[3]Plant Breeding Division, BINA, BAU campus, Mymensingh-2202, Bangladesh
[4]Biotechnology Division, BINA, BAU campus, Mymensingh-2202, Bangladesh
[5]Plant Breeding Division, BINA Sub-station, Ishurdi, Pabna-6620, Bangladesh
[6]Advanta Seeds International, Dhaka, Bangladesh
[7]Plant Breeding Division, BINA Sub-station, Satkhira-9400, Bangladesh
[+]Graduate School of Science and Engineering, Saitama University, Saitama, Japan

Received – February 20, 2023; Revision – April 07, 2023; Accepted – April 28, 2023
Available Online – April 30, 2023

DOI: http://dx.doi.org/10.18006/2023.11(2).325.338

KEYWORDS

Planting date

Binasarisha

BARI Sarisha

Magura

Growth rate

ABSTRACT

Mustard is Bangladesh's leading oil crop, produced only during the winter (*rabi*) season. The sowing date is a key factor determining mustard's optimum growth and development. Because of global warming, gradual changes in season and weather parameters over time is creating a challenge in mustard cultivation. Thus, the present investigation assessed the role of different planting dates on several modern mustard varieties to disclose the optimum growth indicators necessary for elevated biological yield (BY) and harvest index (HI). Three planting times, *viz*. 31st October (D_1), 10th November (D_2), 20th November (D_3) and six varieties *viz*. Binasarisha-4 (V_1), Binasarisha-9 (V_2), Binasarisha-10 (V_3), BARI Sarisha-14 (V_4), BARI Sarisha-16 (V_5), BARI Sarisha-17 (V_6) were put on a replicated factorial randomized complete block design (RCBD) during *rabi* 2019 at BINA Sub-station farm, Magura. At the final harvest stage, outcomes depicted that highest and lowest total dry mass (g/plant) was produced by treatment $D_3\times V_5$ (64.03) and $D_1\times V_1$ (15.34), maximum and minimum absolute growth rate (mg/plant/day) by $D_1\times V_5$ (2389.10) and $D_2\times V_1$ (184.50), most and least relative growth rate (mg/g/day) in $D_1\times V_4$ (53.34) and $D_2\times V_1$ (3.55), maximum and least crop growth rate (g/m^2/day) with $D_1\times V_3$ (55.60) and $D_3\times V_4$ (20.04). BY was the peak (8.13, 8.71, 8.77 t/ha) under all plantings (D_1, D_2, D_3) with V_5

* Corresponding author

E-mail: sushan04@yahoo.com (Sushan Chowhan)

Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI] (http://www.horizonpublisherindia.in/).

variety, but HI (44.96%) was most in variety V_4 with D_2 sowing. Therefore, correlation studies showed a significant positive relationship between biological yield and harvest index. Overall, BARI Sarisha-16 performed well in all three sowing times, and remarkably, BY was rising with delayed planting in the case of Binasarisha-9, Binasarisha-10, and BARI Sarisha-14. This implies that delayed planting might not hamper yield but boost yield to some extent.

1 Introduction

Mustard (*Brassica spp*.) is a major edible oilseed crop grown worldwide, including Bangladesh. It is produced in cool temperatures during winter with or without irrigation (Chowhan and Islam 2022a). It is a photo and thermosensitive crop (Ghosh and Chatterjee 1988), and a temperature between 12°C to 25°C is an ideal growth temperature, but low temperatures may hamper the growth of this plant (Wahhab et al. 2002). Hence this crop needs to be sowed within a specific time. In Bangladesh, Mustard is the time window for planting in mid-October to mid-November (Alam et al. 2014). Due to seasonal inundation driven by climate change, the mustard sowing date does not remain constant. Rather it depends on the location and weather of a particular region. However, the planting date has been delayed for the past few years due to sudden rainfall in mid-October. So, farmers are facing a big challenge to cope with this situation. Though productivity drops owing to the shortening of the vegetative and reproductive phases under late-seeded conditions. During the reproductive period, late-sown Mustard is subjected to high temperatures combined with high evaporative demand of the atmosphere, resulting in forced maturity, increased senescence, and reduced yield (Porter 2005). Therefore, crop plants consider a single-degree temperature rise over the threshold level as heat stress (Hasanuzzaman et al. 2013). Mustard prefers cool weather throughout the vegetative growth and slightly warm (>25°C) during the reproductive period. So, planting time is a vital factor in determining a cultivar's growth development, yield and quality.

Accumulation of total dry mass is an essential criterion for gaining improved morpho-physical and yield quality properties which are also influenced by sowing dates (Singh and Yeshpal 2011). It is notable in Mustard that, during the reproductive stage, the flowering, fruiting and vegetative growth coincide until physiological maturity (Mondal et al. 2013). Thus, developing reproductive sinks are competing for assimilates with vegetative sinks. It was evident that seeds per unit area are related to canopy photosynthesis during flowering and pod set. Furthermore, the canopy photosynthesis rate determines through the leaf area index (LAI) and crop growth rate (CGR). Main physiological properties, for example, absolute growth rate (AGR), CGR, relative growth rate (RGR), net assimilation rate (NAR) and total dry mass (TDM), vary, and these depend on crop variety and environmental factors. Thus, these parameters can address various constraints for increasing productivity (Tandale and Ubale 2007).

Up to date, BARI (Bangladesh agricultural research institute) and BINA (Bangladesh Institute of nuclear agriculture) have developed more than 25 rapeseed mustard varieties (BINA 2022; Azad et al. 2020); most of them have satisfactory levels of growth and better yield capacity. Considering the above factors, we tested some popular BINA and BARI mustard varieties concerning various planting dates to disclose the optimum sowing date and varieties with better growth, development, biological yield and harvest index.

2 Materials and methods

2.1 Experimental site

BINA, Sub-station farm, Magura was the experimental site under the Agro-Ecological Zone 11 (AEZ); this area was characterized by a high Ganges river flood plain with high to medium land type. Soils were calcareous dark grey to brown floodplain soils. Organic matter content in brown ridge soils is low but higher in dark grey soils. Soils were slightly alkaline with a deficit in fertility (FRG 2012). Details of the weather parameters during the experimental period are expressed in Figure 1.

2.2 Crop Establishment and Cultural Practices

The experiment was established on the farm during *rabi* (winter) 2019. Tillage was followed as per methods stated by Chowhan and Nahar (2022); Chowhan and Islam (2022b). Considering the low soil fertility level, yield goal (2±0.2 t/ha) fertilizers were applicated following the procedures described by Chowhan et al. (2023) and Ahmmed et al. (2018). A full dose of P, K, S, Zn, B and half N was given on soil as the basal. The rest of the N was top-dressed at 22 days of seedling age, comprising light irrigation. Line-to-line and plot-to-plot distances were each 30 cm, and the unit plot measured 1.5 m by 2.0 m. In the three planting dates (31 October, 10 November and 20 November), seeds were line sown (broadcast method) at a 7.5 kg/ha rate. To maintain the target plant population, surplus plants were thinned and mulched 20 days after sowing (DAS) (BINA 2014). Seeds were harvested when the siliquae gained 75% maturity and appeared brownish to straw colour

(A)

(B)

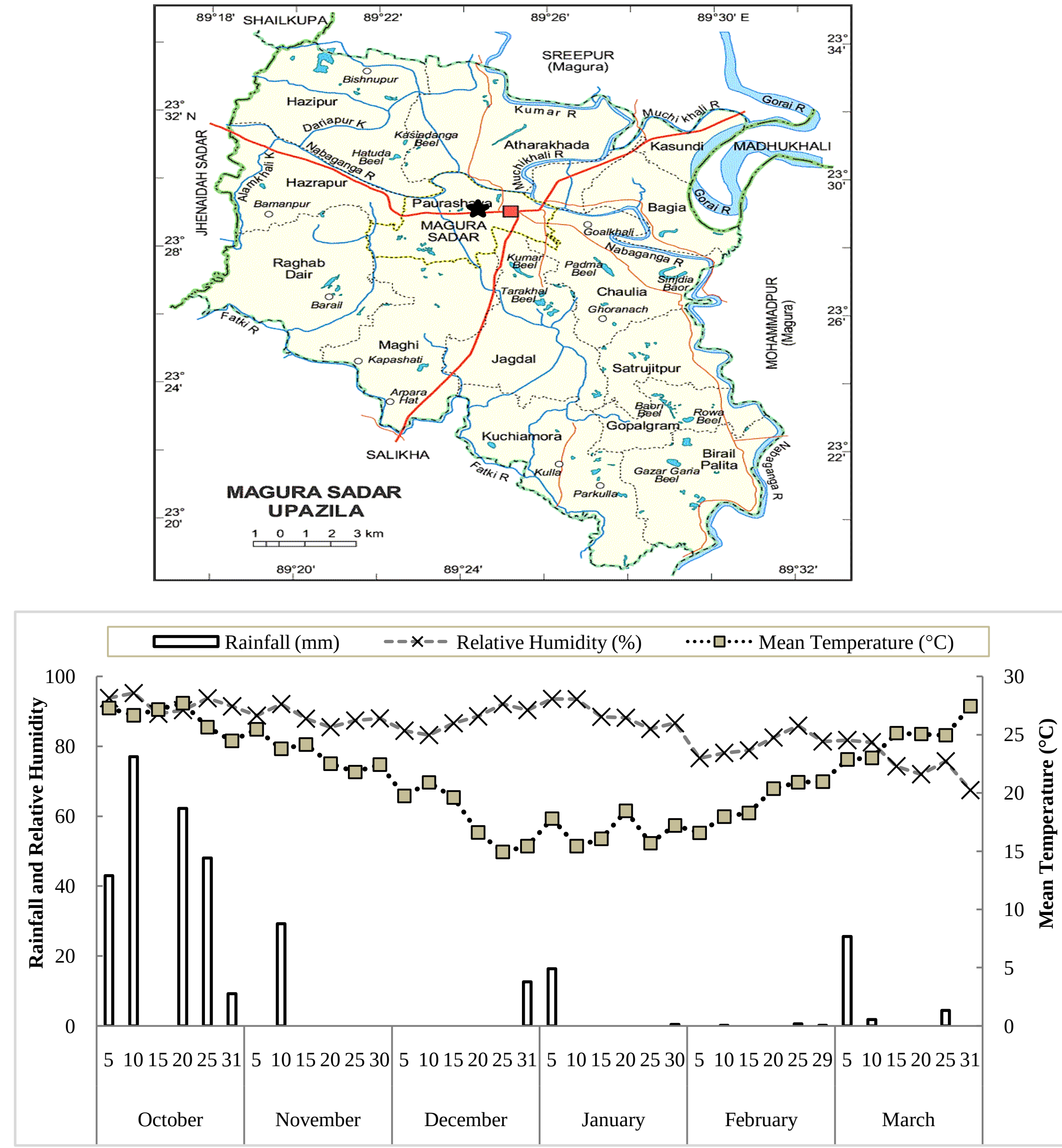


Figure 1 Experimental location and weather status of Magura sadar upazila (A) Black star indicates the experimental site; (B) Mean weather parameters of the experimental area from October 2019 to March 2020 (BINA 2020)

2.3 Experimental design

The experiment followed a factorial Randomized complete block design (RCBD) with three replications. Replication to replication gap was 1m. There were two factors (variety and sowing date) in the experiment. Three sowing dates were assigned as factor A, and six varieties were considered factor B. Details of the factors and treatment are pointed below

Factor A: Sowing dates (3)

D_1 = 31-10-2019, D_2 = 10-11-2019, D_3 = 20-11-2019.

Factor B: Variety (6)

V_1 = Binasarisha-4, V_2 = Binasarisha-9, V_3 = Binasarisha-10, V_4 = BARI Sarisha-14, V_5 = BARI Sarisha-16, V_6 = BARI Sarisha-17

2.4 Data Collection and Analysis

Five plants were randomly sampled for growth parameters from 30 DAS and continued at an interval of 10 days up to harvest. Plants were separated into roots, stems, leaves and siliquae and the corresponding dry weights were recorded after oven drying at 80 ± 2°C for 72 hours. The following physiological parameters were noted according to Hunt et al. (2002) and Sarkar et al. (2016)

Total dry mass (TDM) = $W_1 - W_2$ (g/plant)

Absolute growth rate (AGR) = $\frac{W_f - W_i}{t_2 - t_1}$ (mg/plant/day)

Relative growth rate (RGR) = $\frac{\ln W_f - \ln W_i}{t_2 - t_1}$ (mg/g/day)

Crop growth rate (CGR) = $\frac{1}{A} \times \frac{W_f - W_i}{t_2 - t_1}$ (g/m^2/day)

Where,

W_1= Fresh weight of the plant (g)

W_2= Oven dry weight of the plant (g)

W_i= Total plant dry matter at initial time t_1 (g)

W_f= Total plant dry matter at final time t_2 (g)

t_2= final time (day)

t_1= initial time (day)

$t_2 > t_1$

A = Ground area (m^2)

ln= Natural logarithm

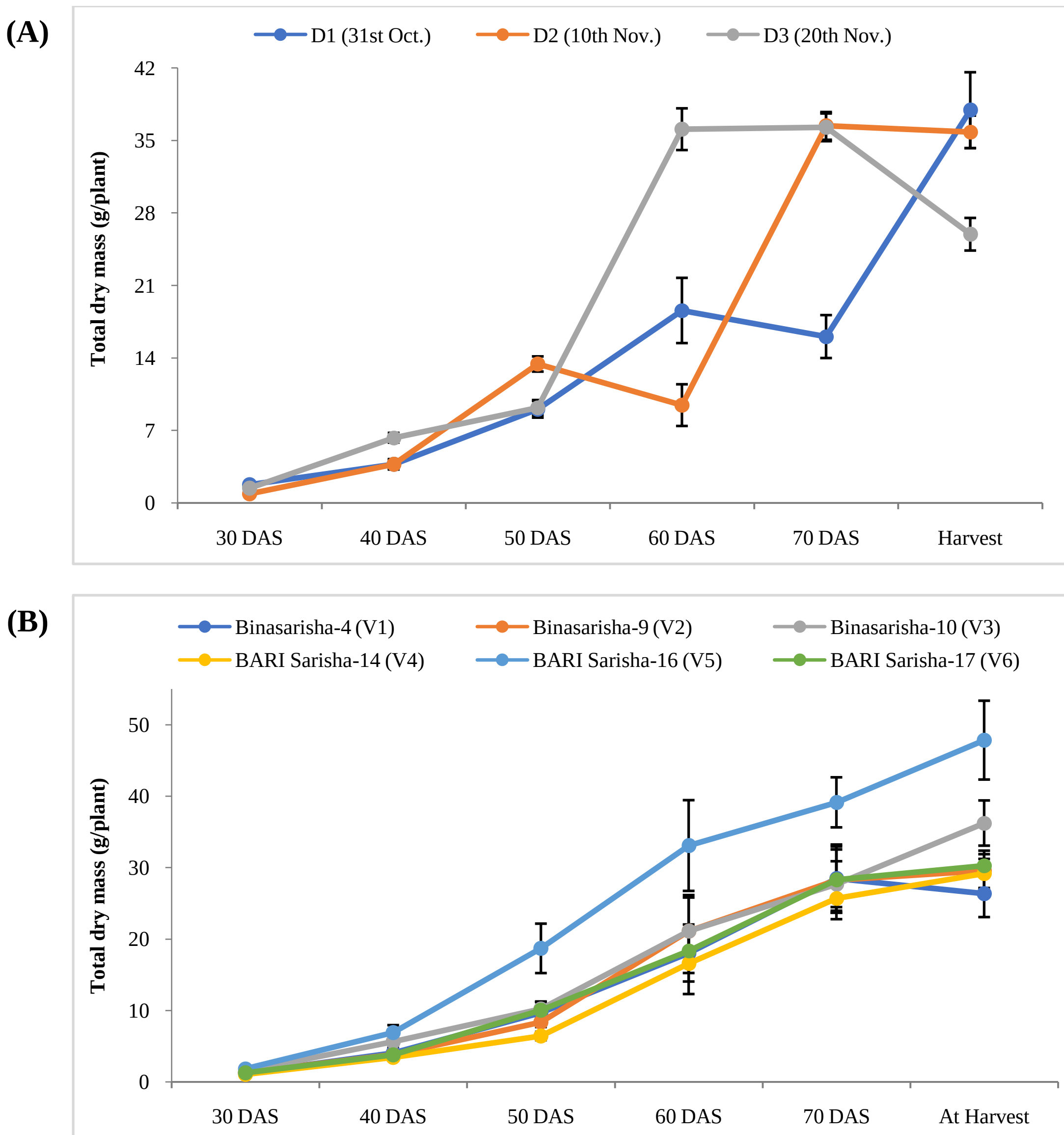


Figure 2 Total dry mass (TDM) under three planting times of six mustard varieties (A) Individual lines show the mean TDM of the defined planting time on different days after sowing (DAS) up to harvest (B) Indicates the average TDM of the cultivars at various intervals (DAS) until harvest (Each data point represents the mean of 5 plant samples; Error bars are the standard error values)

Harvest index (HI) (%) (Chowhan et al. 2018) and biological yield (Chowhan et al. 2017) was recorded using the following formulae

- HI (%) = {Economic (grain) yield ÷ biological yield} × 100
- Biological yield (t/ha) = seed yield + straw yield

Data taken on the parameters were analyzed statistically by Statistix 10 (Statistix 2022) subject to LSD (least significant difference) test at a 5% level of probability was used for average distinctions (Russel 1986) among the treatments.

3 Results and discussion

3.1 Total dry mass

Dry matter accumulation was more or less alike up to 50 DAS (Figure 2A). Later from 60 DAS, dry mass deposition followed a zigzag pattern for all the sowing dates. However, at the harvest time, D1 and D2 treatments produced statistically identical dry mass; the lowest was found with the D_3 treatment. All the varieties followed a similar lift of dry mass increase except BARI Sarisha-16 (V_5); the total dry mass of this variety was significantly higher than others (Figure 2B).

The interaction effect of the treatments implied that $D_3 \times V_5$ had the maximum and $D_1 \times V_1$ had the minimum amount of total dry mass at the maturity stage of the crop (Table 1). The sowing date may have played a significant role in dry matter production; thus, late sowing showed a lesser dry mass. A contrary varietal trait is another important criterion that is also responsible for the dry matter content. So, BARI Sarisha-16 (V_5) gained abundant dry mass. The combined effect indicated that early sowing always favours more dry mass than late sowing, as plants get enough time for adequate growth. However, dry matter content may also depend on variety as some may be suitable for early sowing and others not. These findings are consistent with those of Sharif et al. (2017).

Table 1 Collective effect of sowing time, varieties on total dry mass (g/plant)

Treatments	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
$D_1 \times V_1$	0.71^{f}	3.18^{c-f}	6.55^{de}	7.37^{e}	10.43^{d}	15.34^{f}
$D_1 \times V_2$	0.97^{def}	1.85^{f}	9.21^{b-e}	8.99^{e}	12.76^{d}	21.98^{ef}
$D_1 \times V_3$	1.10^{c-f}	5.70^{bcd}	7.39^{b-e}	6.95^{e}	16.46^{d}	29.94^{de}
$D_1 \times V_4$	0.71^{f}	2.95^{def}	6.11^{e}	7.78^{e}	16.67^{d}	27.46^{de}
$D_1 \times V_5$	1.10^{c-f}	5.77^{bcd}	13.99^{b}	14.83^{e}	29.23^{c}	30.02^{de}
$D_1 \times V_6$	0.78^{ef}	3.02^{def}	11.03^{b-e}	10.82^{e}	10.88^{d}	30.98^{de}
$D_2 \times V_1$	1.26^{b-f}	4.00^{c-f}	8.68^{b-e}	14.08^{e}	37.44^{abc}	36.39^{cd}
$D_2 \times V_2$	1.44^{b-e}	3.54^{c-f}	8.74^{b-e}	19.49^{cde}	33.73^{bc}	37.25^{cd}
$D_2 \times V_3$	1.49^{b-e}	3.97^{c-f}	10.66^{b-e}	16.38^{de}	32.56^{bc}	35.48^{cd}
$D_2 \times V_4$	1.23^{b-f}	2.26^{ef}	6.699^{cde}	8.83^{e}	30.07^{c}	27.51^{de}
$D_2 \times V_5$	1.92^{ab}	5.28^{bcd}	13.72^{bcd}	37.42^{ab}	47.63^{a}	49.48^{b}
$D_2 \times V_6$	1.19^{b-f}	3.35^{c-f}	6.76^{cde}	15.34^{e}	37.05^{bc}	28.86^{de}
$D_3 \times V_1$	1.73^{bc}	4.91^{b-e}	13.81^{bc}	32.67^{bc}	37.49^{abc}	27.30^{de}
$D_3 \times V_2$	1.54^{bcd}	6.08^{bc}	7.09^{b-e}	34.86^{ab}	38.23^{abc}	29.45^{de}
$D_3 \times V_3$	1.90^{ab}	7.16^{ab}	12.59^{b-e}	39.96^{ab}	33.99^{bc}	43.26^{bc}
$D_3 \times V_4$	1.14^{c-f}	5.05^{b-e}	6.43^{e}	33.16^{b}	30.40^{bc}	32.53^{cde}
$D_3 \times V_5$	2.52^{a}	9.66^{a}	28.32^{a}	46.98^{a}	40.51^{ab}	64.03^{a}
$D_3 \times V_6$	1.77^{bc}	4.92^{b-e}	12.26^{b-e}	28.93^{bcd}	36.97^{bc}	31.03^{de}
$LSD_{0.05}$	0.72	2.96	7.19	13.35	10.28	11.16
SEm	0.35	1.45	3.53	6.56	5.05	5.49
CV	32.02%	38.84%	41.05%	37.62%	20.95%	20.23%

Figures in a column with a different letter (s) differ significantly at a 5% probability level, according to LSD; n=5, $P < 0.05$; by analysis of variance with factorial randomized complete block design; SEm - Standard error mean; CV - Coefficient of variation

3.2 Absolute growth rate (AGR)

Sowing dates caused differential AGR. At 70-80 DAS highest AGR was obtained from D_1, and the lowest was observed in the D_2 treatment (Figure 3A). Only BARI Sarisha-16 (V5) among the tested varieties reached the ultimate AGR. Rest five varieties showed similar AGR at 70-80 DAS (Figure 3B). The combined effect demonstrated that treatment D1 × V5 had the highest AGR; contrary, the lowest was noted with $D_2 \times V_1$ at 70-80 DAS (Table 2). Interestingly combined effect illustrates that varietal interaction with D_2 sowing lessens the AGR, but when combined with D_3 sowing, again, the AGR rises; the same phenomenon is also spotted with the sole effect of planting time. This may be due to the variable weather parameters during the experimental period. BARI Sarisha-16 (V_5) followed a different pattern of AGR, which might be of its inherent attributes. Mondal et al. (2018) ascertained variable AGR of mutants/variety at different growth stages of *Brassica juncea*.

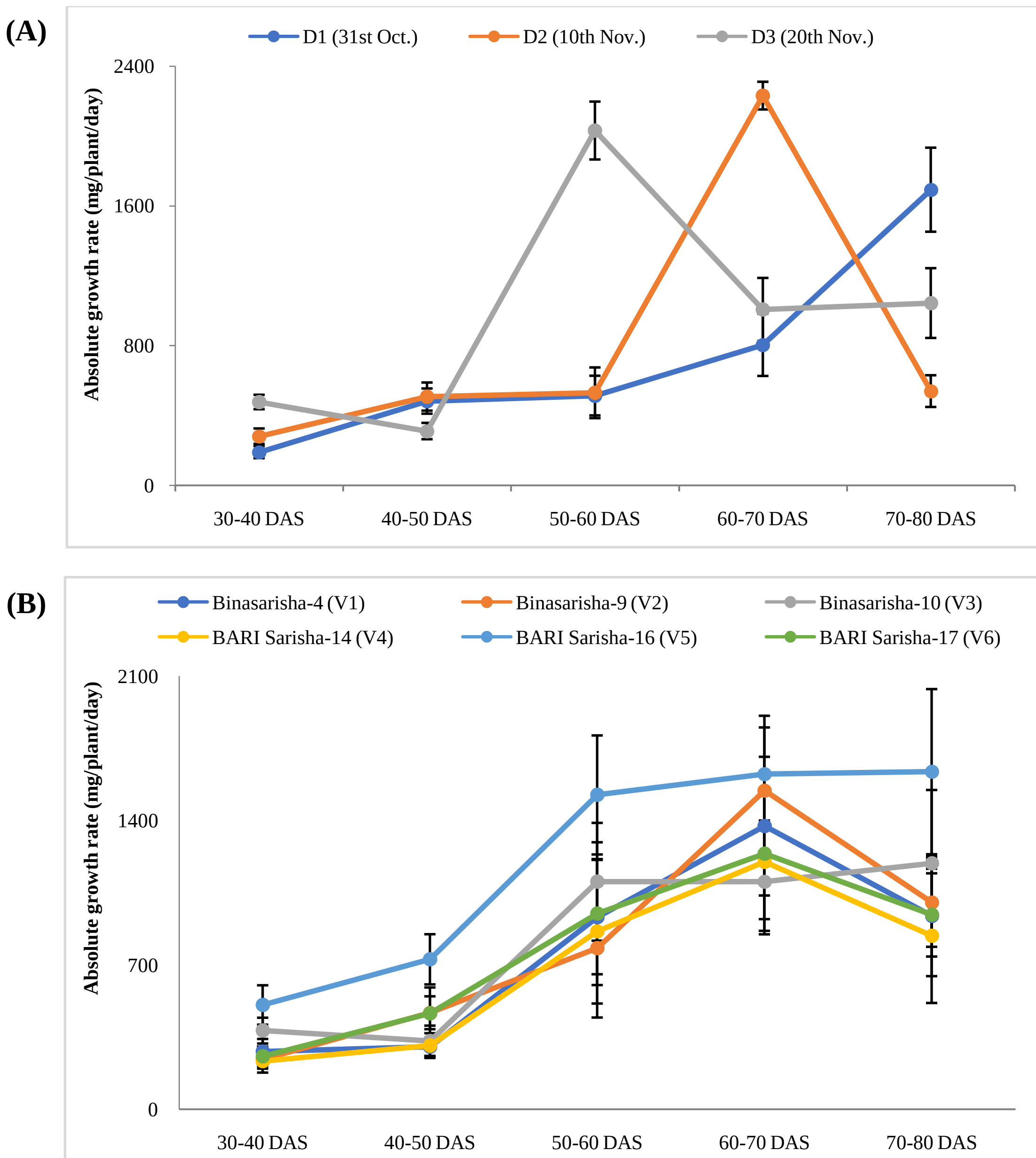


Figure 3 Absolute growth rate (AGR) under three sowing dates of six mustard varieties (A) Individual lines show the mean AGR of the three planting time at different sowing intervals (DAS) up to harvest (B) Indicates the average AGR of six mustard cultivars at different durations (DAS) until harvest (Each data point represents the mean of 5 plant samples; Error bars are the standard error values)

Table 2 Absolute growth rate (mg/plant/day) of mustard affected by sowing time and varieties

Treatment combinations	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
$D_1 \times V_1$	145.10^{ef}	198.75^{e}	527.50 ^{cde}	499.20 ^{f}	1186.30 $^{b-e}$
$D_1 \times V_2$	33.07^{f}	732.88^{abc}	219.80 ^{e}	948.90 ^{def}	1070.40 ^{cde}
$D_1 \times V_3$	322.17^{b-e}	284.67^{de}	528.80 ^{cde}	632.30 ^{f}	2368.10 ^{ab}
$D_1 \times V_4$	180.53^{def}	316.30^{de}	226.00 ^{e}	875.90 ^{def}	1733.10 ^{abc}
$D_1 \times V_5$	325.70^{b-e}	822.12^{ab}	1252.00 $^{a-d}$	1362.60 $^{a-f}$	2389.10 ^{a}
$D_1 \times V_6$	137.90^{ef}	541.40^{b-e}	331.50 ^{de}	510.50 ^{f}	1410.30 $^{a-d}$
$D_2 \times V_1$	329.53^{b-e}	336.42^{cde}	643.90 $^{b-e}$	2363.60 ^{abc}	184.50 ^{e}
$D_2 \times V_2$	257.12^{c-f}	346.77^{cde}	206.70 ^{e}	2465.70 ^{a}	543.20 ^{cde}
$D_2 \times V_3$	272.40^{c-f}	327.50^{cde}	549.30 ^{cde}	1997.10 $^{a-d}$	291.80 ^{de}
$D_2 \times V_4$	154.78^{ef}	416.82^{b-e}	134.90 ^{e}	2228.90 ^{abc}	324.00 ^{de}
$D_2 \times V_5$	417.95^{bcd}	955.18^{a}	1348.10 ^{abc}	1931.60 $^{a-e}$	1076.20 ^{cde}
$D_2 \times V_6$	257.62^{c-f}	668.68^{a-d}	298.50 ^{de}	2402.20 ^{ab}	819.20 ^{cde}
$D_3 \times V_1$	365.43^{b-e}	376.33^{cde}	1624.90 ^{ab}	1256.10 $^{b-f}$	1440.60 $^{a-d}$
$D_3 \times V_2$	434.30^{bc}	325.83^{cde}	1916.00 ^{a}	1221.80 $^{c-f}$	1395.90 $^{a-d}$
$D_3 \times V_3$	551.27^{ab}	380.97^{cde}	2231.70 ^{a}	682.90 ^{f}	916.30 ^{cde}
$D_3 \times V_4$	366.60^{b-e}	194.80^{e}	2228.90 ^{a}	494.20 ^{f}	466.40 ^{de}
$D_3 \times V_5$	774.75^{a}	405.12^{cde}	1972.00 ^{a}	1582.90 $^{a-f}$	1445.80 $^{a-d}$
$D_3 \times V_6$	372.68^{b-e}	183.78^{e}	2216.30 ^{a}	804.10 ^{ef}	598.30 ^{cde}
$LSD_{0.05}$	252.60	409.14	1002.50	1148.80	1197.80
SEm	124.30	201.22	493.32	565.29	589.42
CV	48.08%	56.80%	58.92%	51.37%	66.10%

Figures in a column having a different letter (s) differ significantly at a 5% level of probability according to LSD; n=5, $P < 0.05$; by analysis of variance with factorial randomized complete block design; SEm, Standard error mean; CV - Coefficient of variation

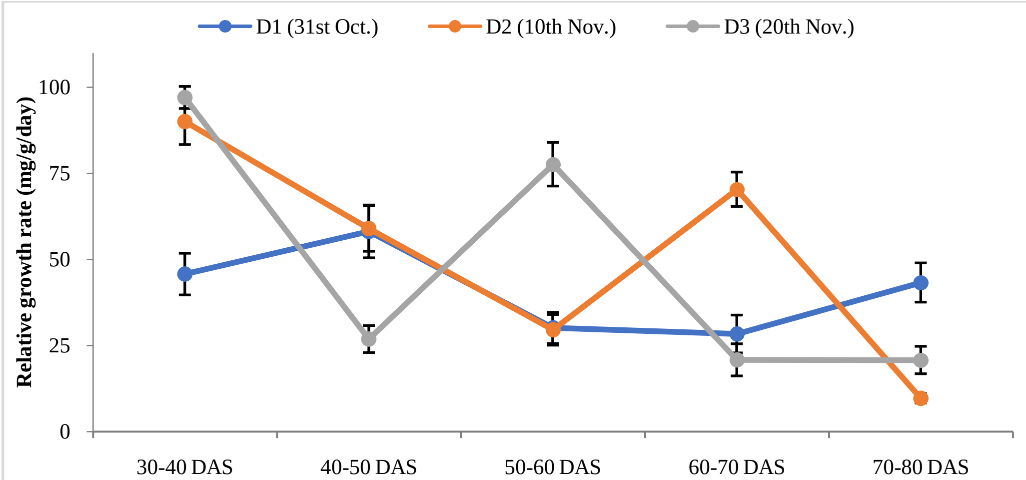
3.3 Relative growth rate (RGR)

An up-down trend of RGR was seen during the planting times. But, early sowing, i.e. D_1 had the greatest RGR over the other planting times at 70-80 DAS (Figure 4A). A varietal consequence of RGR was nonsignificant for all sowing intervals except 40-50 DAS, where Binasarisha-9 (V_2) had the utmost RGR. But at the final time (70-80 DAS) all the varieties had a centered RGR level (Figure 4B). The combined effect exhibited a zigzag pattern of RGR at different DAS. However, at 70-80 DAS, extreme RGR was marked with treatment $D_1 \times V_4$ and the minimum was recorded with $D_2 \times V_1$ (Table 3). Sowing dates had a significant influence on the RGR. But the varietal effect was not prominent on RGR. With the advancement of time, RGR declined for all varieties, as per the findings of Uddin et al. (2012). Interaction of the two factors perceived that advance planting (D_1) with Binasarisha-10 (V_3) and BARI Sarisha-14 (V_4) might be better for obtaining the best RGR. Maurya et al. (2022) noted RGR of two Indian mustard varieties declined upon the progress of crop duration. But our results show different findings, possibly due to varietal and weather factors.

3.4 Crop growth rate (CGR)

Initially, the CGR was slow up to 50-60 DAS for all sowing dates and varieties; but after that, it had a sharp increase from 60-70 DAS; Thus, at 70-80 DAS, the CGR value drastically rose about two to five times than 60-70 DAS (Figure 5A, 5B). At the final stage (70-80 DAS), CGR was unaffected by planting times. Interaction effects depicted that, at 70-80 DAS, significantly higher CGR was obtained from $D_1 \times V_3$ and the lowest was identified with $D_3 \times V_4$ treatment combination, which differed from the other treatments (Table 4). Though there was variation in CGR from 30-40 DAS to 60-70 DAS, but at 70-80 DAS, both sowing dates and varieties didn't significantly affect CGR value. Initial variation might be due to cultural practice. But after the flowering stage, no major

(A)



(B)

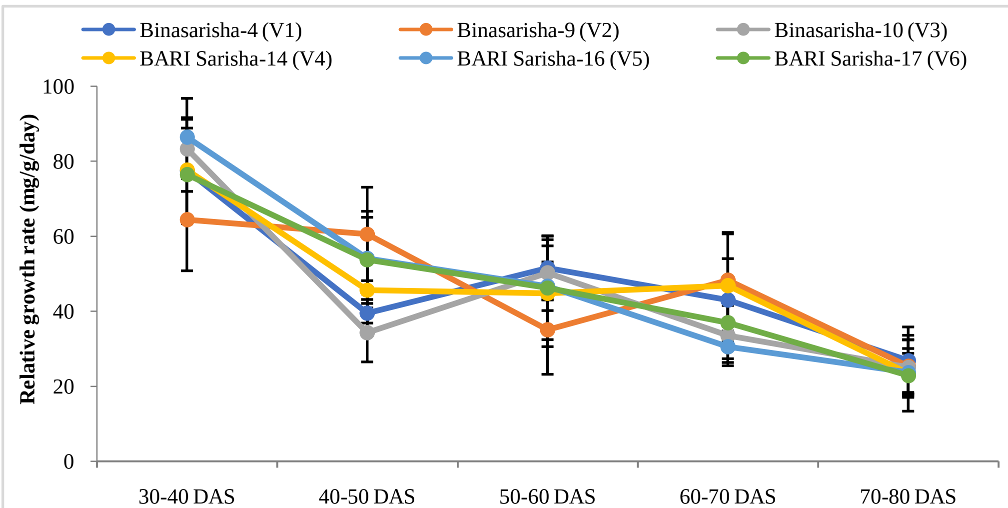


Figure 4 Relative growth rate (RGR) under three sowing dates of six mustard varieties (A) Individual lines show the mean RGR of the three planting time at different sowing intervals (DAS) up to harvest (B) Indicates the average RGR of six mustard cultivars at different durations (DAS) until harvest (Each data point represents the mean of 5 plant samples; Error bars are the standard error values)

Table 3 Effect of sowing time, varieties and their interaction on RGR (mg/g/day)

Treatment combinations	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
$D_1 \times V_1$	39.58 de	33.69 c-f	45.99 c-f	24.05 d	41.42 abc
$D_1 \times V_2$	14.22 e	88.49 a	13.27 f	29.77 cd	37.77 a-e
$D_1 \times V_3$	62.57 bcd	31.80 c-f	36.01 ef	24.94 d	52.47 ab
$D_1 \times V_4$	63.06 bcd	47.32 b-f	22.04 f	41.19 bcd	53.34 a
$D_1 \times V_5$	56.52 cd	60.86 b-e	40.12 def	26.88 d	34.15 a-f
$D_1 \times V_6$	38.42 de	68.58 a-d	23.18 f	23.18 d	40.52 a-d
$D_2 \times V_1$	102.43 ab	46.05 b-f	45.82 c-f	70.38 ab	3.55 g
$D_2 \times V_2$	86.09 abc	47.47 b-f	17.38 f	88.27 a	9.99 d-g
$D_2 \times V_3$	84.47 abc	41.61 b-f	39.10 ef	63.34 abc	5.86 fg
$D_2 \times V_4$	76.91 a-d	68.89 a-d	14.44 f	90.92 a	7.54 efg
$D_2 \times V_5$	94.01 abc	78.32 ab	40.95 c-f	38.80 bcd	14.72 c-g

Treatment combinations	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
$D_2 \times V_6$	96.32 [abc]	71.42 [abc]	19.56 [f]	70.41 [ab]	16.41 [c-g]
$D_3 \times V_1$	90.39 [abc]	38.71 [b-f]	62.75 [b-e]	34.51 [cd]	35.70 [a-f]
$D_3 \times V_2$	92.92 [abc]	27.83 [ef]	74.49 [a-d]	26.82 [d]	28.26 [a-g]
$D_3 \times V_3$	102.75 [ab]	29.44 [def]	75.57 [abc]	12.23 [d]	17.04 [c-g]
$D_3 \times V_4$	92.82 [abc]	20.83 [f]	97.94 [a]	8.28 [d]	9.54 [efg]
$D_3 \times V_5$	108.77 [a]	23.07 [ef]	58.92 [cde]	25.90 [d]	22.32 [b-g]
$D_3 \times V_6$	94.46 [abc]	21.30 [ef]	96.10 [ab]	17.20 [d]	11.76 [c-g]
$LSD_{0.05}$	40.82	39.65	34.83	35.67	30.56
SEm	20.09	19.51	17.14	17.55	15.04
CV	31.70%	49.80%	45.87%	53.97%	74.95%

Figures in a column with a different letter (s) differ significantly at a 5% probability level according to LSD; n=5, $P < 0.05$; by analysis of variance with factorial randomized complete block design; SEm - Standard error mean; CV - Coefficient of variation

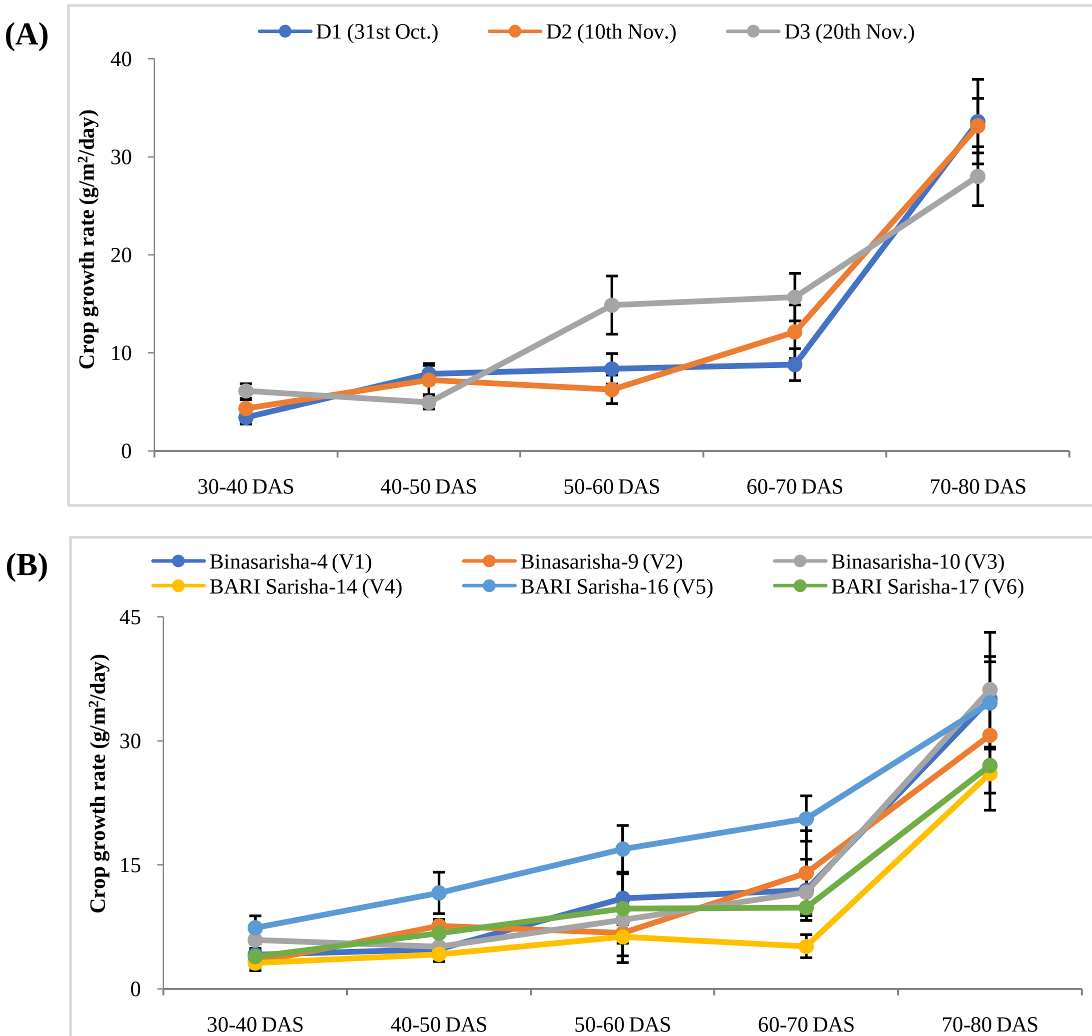


Figure 5 Crop growth rate under three sowing dates of six mustard varieties (A) Individual lines show the mean CGR of the three planting time at different sowing intervals (DAS) up to harvest (B) Indicates the average CGR of six mustard cultivars at different durations (DAS) until harvest (Each data point represents the mean of 5 plant samples; Error bars are the standard error values)

Table 4 Crop growth rate (g/m^2/day) with the interaction effect of sowing time and varieties

Treatment combinations	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
$D_1 \times V_1$	2.54 ^{bcd}	3.20^{d}	7.43 ^{ab}	6.31^{bcd}	21.04 ^{d}
$D_1 \times V_2$	0.48^{d}	10.34 ^{b}	3.16^{ab}	3.63 ^{d}	24.81 ^{cd}
$D_1 \times V_3$	7.23 ^{ab}	6.82 ^{bcd}	12.31 ^{ab}	14.91 $^{a-d}$	55.60^{a}
$D_1 \times V_4$	3.09 ^{bcd}	5.60 ^{bcd}	3.69^{ab}	5.42 ^{cd}	36.35 $^{a-d}$
$D_1 \times V_5$	4.26^{bcd}	11.18 ^{b}	16.56^{ab}	16.16 $^{a-d}$	33.59^{bcd}
$D_1 \times V_6$	2.94 ^{bcd}	10.04^{bc}	7.09^{ab}	6.39^{bcd}	30.11^{bcd}
$D_2 \times V_1$	5.76 ^{abc}	4.08^{cd}	8.62 ^{ab}	11.76^{a-d}	46.87^{ab}
$D_2 \times V_2$	5.02 ^{bcd}	6.65^{bcd}	3.86^{ab}	21.85^{ab}	35.72^{a-d}
$D_2 \times V_3$	3.29^{bcd}	3.24^{d}	4.63 ^{ab}	6.36^{b-d}	23.43^{cd}
$D_2 \times V_4$	1.53^{cd}	4.04 ^{cd}	1.31 ^{b}	3.05 ^{d}	21.77^{cd}
$D_2 \times V_5$	7.32^{ab}	18.03^{a}	15.68^{ab}	20.64^{abc}	42.98^{abc}
$D_2 \times V_6$	3.10^{bcd}	7.36^{bcd}	3.59^{ab}	9.22^{bcd}	28.25 ^{bcd}
$D_3 \times V_1$	4.13^{bcd}	7.08 ^{bcd}	16.80^{ab}	17.86^{a-d}	37.22^{a-d}
$D_3 \times V_2$	4.16^{bcd}	5.91^{bcd}	13.27^{ab}	16.52^{a-d}	31.57 ^{bcd}
$D_3 \times V_3$	7.24 ^{ab}	5.32^{bcd}	8.20^{ab}	13.76 $^{a-d}$	29.47 ^{bcd}
$D_3 \times V_4$	4.84^{bcd}	2.94 ^{d}	14.00 ^{ab}	7.06 ^{bcd}	20.04^{d}
$D_3 \times V_5$	10.61 ^{a}	5.61 ^{bcd}	18.46 ^{a}	24.98^{a}	27.18^{bcd}
$D_3 \times V_6$	5.66^{bc}	2.82^{d}	18.06 ^{a}	13.87^{a-d}	22.65 ^{cd}
$LSD_{0.05}$	4.94	6.14	15.66	15.60	21.84
SEm	2.43	3.02	7.70	7.67	10.74
CV	64.43%	55.46%	95.88%	77.01%	41.65%

Figures in a column with a different letter (s) differ significantly at a 5% probability level according to LSD; n=5, $P < 0.05$; by analysis of variance with factorial randomized complete block design; SEm - Standard error mean; CV - Coefficient of variation

cultural operations were done, so all the varieties attained closer CGR values. The combined effect implies that certain varieties acquire better CGR when planted earlier than late sowing. Thus Binasarisha-10 (V_3), when plated early, may give better CGR, but BARI Sarisha-14 (V_4), if late planted, may give inferior CGR. CGR was; therefore, variety and time sowing depended. Chowhan and Islam (2022c) reported a similar trend of CGR progress in seven Bangladeshi lentil cultivars.

3.5 Biological yield

Peak and significantly higher biological yield were seen with D_2 and D_3 planting, but D_1 showed significantly least yield; contrary, BARI Sarisha-16 (V_5) showed a significantly top biological yield accompanied by Binasarisha-4 (V_1) and Binasarisha-9 (V_2). The statistically lowest yield was observed in BARI Sarisha-14 (V_4) (Figure 6A). Treatment amalgamations noted that Binasarisha-10 (V_3) and BARI Sarisha-14 (V_4) produced significantly least biological yield in D_1 planting, while BARI Sarisha-16 (V_5) showed the best yield in all plantings (D_1, D_2 and D_3). Additionally, Binasarisha-4 (V_1) and Binasarisha-9 (V_2) delivered better yields in D_2 planting over the treatment combinations (Figure 6B). Current results do not align with the findings of Bala et al. (2011), who investigated the biological yield of Mustard under seven planting times and reported a decline of yield over time (late sowing). This may be due to the shift of weather over time and some areas' late start of winter.

3.6 Harvest index

Late planting (D_3) induced a significantly maximum harvest index (HI) over D_1 and D_2 planting. Whereas, BARI Sarisha-17 (V_6) together with BARI Sarisha-14 (V_4) rendered statistically peak HI; conversely, the lowest was produced by BARI Sarisha-16 (V_5) accompanied by Binasarisha-10 (V_3) (Figure 6A). Interaction effects denoted the highest HI of treatment combination was in $D_2 \times V_4$ followed by $D_2 \times V_4$, and the least was acquired by $D_3 \times V_5$ (Figure 6B).

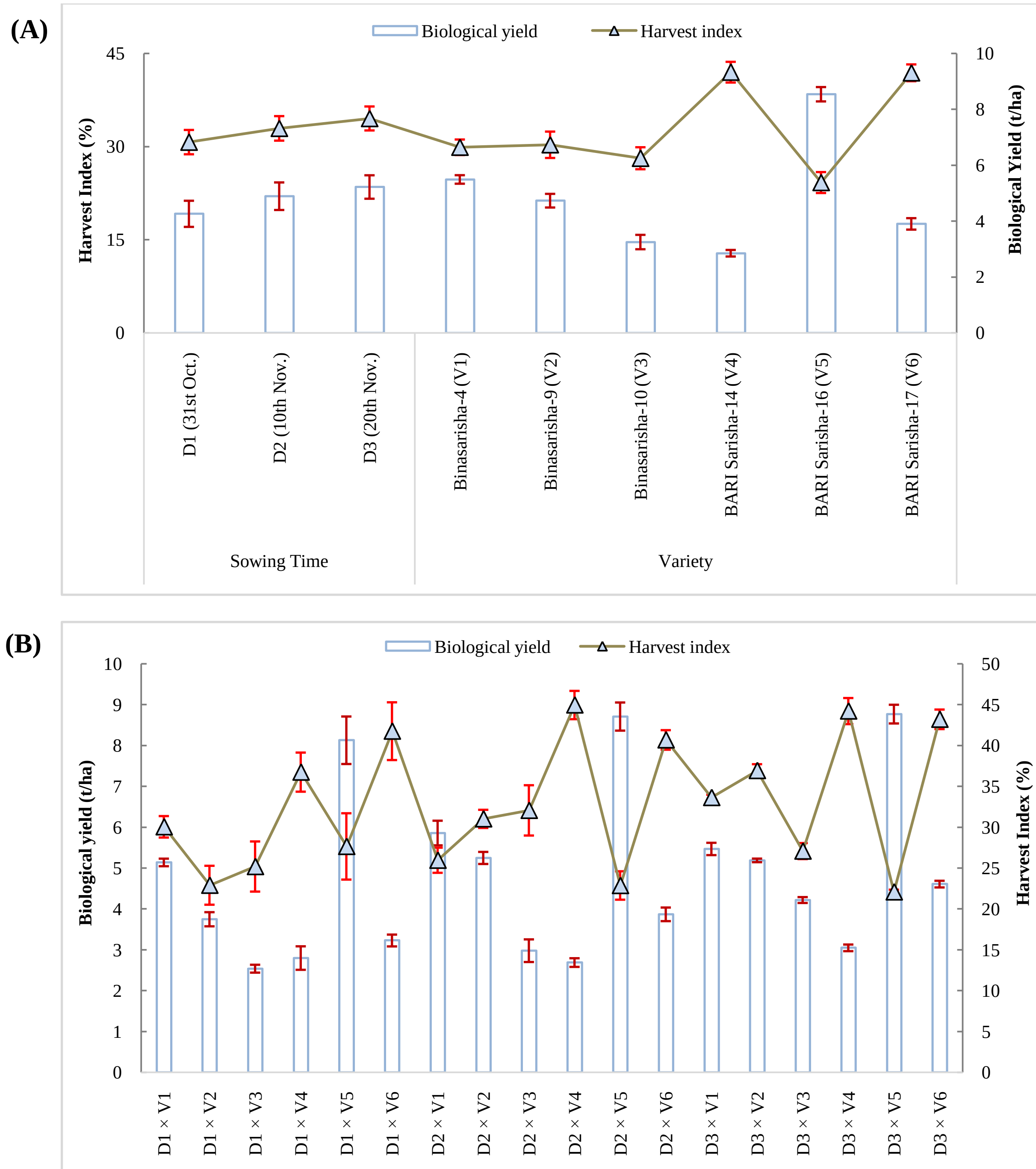


Figure 6 Biological yield (BY) and harvest index (HI) of six mustard varieties at three planting dates after harvest (A) Exhibits the individual influence of sowing times and varieties on HI and BY, (B) Presents the combined effect of sowing times and varieties on HI and BY (Here BY and HI were calculated using whole plot, i.e., 3m^2 harvesting; Error bars are the standard error values)

Kumar et al. (2018) studied the yield attributes of six Indian mustard genotypes (*Brassica juncea* L.) at three sowing times on 23 September, 16 October, 21 November and concluded that later planting (21 November) gives the least harvest index (%). These results are in agreement with the findings of the present.

3.7 Relationship between growth and yield at different sowing times

Results figured that plant height was significantly and positively correlated with days to maturity, which means plant height would

Table 5 Relationship between growth and yield parameters of mustard varieties

Attribute(s)	Plant height	Primary branch	Secondary branch	Total dry matter	Biological yield (t/ha)	HI (%)	Days to maturity
Plant height	1	0.87^{NS}	0.98^{NS}	0.85^{NS}	0.93^{NS}	0.96^{NS}	0.99*
Primary Branch		1	0.95^{NS}	0.99*	0.99*	0.97^{NS}	0.83^{NS}
Secondary Branch			1	0.93^{NS}	0.98^{NS}	0.99*	0.97^{NS}
Total dry matter				1	0.98^{NS}	0.96^{NS}	0.81^{NS}
Biological yield (t/ha)					1	0.99*	0.90^{NS}
HI (%)						1	0.94^{NS}
Days to maturity							1

* indicates 5% level of significance; NS - not significant.

increase with the increase in days to maturity of mustard varieties. Mostofa et al. (2016) established similar results. It was also reported by Aytaç and Kınacı (2009). But it had a positive, nonsignificant correlation with primary branches, secondary branches, biological yield, total dry matter, and harvest index. Primary branches showed a significant and positive relationship with total dry matter and biological yield but a nonsignificant and positive relationship with secondary branches, harvest index and days to maturity. Secondary branches had a significant and positive relationship with harvest index but a nonsignificant and positive relationship with total dry matter, biological yield and days to maturity. Total dry matter showed a nonsignificant and positive relationship with biological yield, harvest index and days to maturity. Similar outcomes were also observed by Sharif et al. (2017). The biological yield had a significant and positive relationship with the harvest index but a nonsignificant and positive relationship with days to maturity. Alikefindings were also obtained by Mostofa et al. (2016). The harvest index showed a nonsignificant but positive relationship with days to maturity (Table 5).

Conclusion

Mid of October is considered the best sowing time for Mustard, but this timing is shifting behind due to seasonal and weather changes. Our results show that most growth parameters were peak under 31st October planting, but varieties showed a different trend. BARI Sarisha-16 seemed to have a wide range of adaptation over the planting times, thus attaining top biological yield with all sowing times and retaining maximum TDM and AGR at harvest. However, the yield of popular cultivars like Binasarisha-9, Binasarisha-10 and BARI Sarisha-14 increased in the late sowing condition. Findings revealed that even if sowing is delayed about three weeks from the optimum time, the yield might not reduce, and it was positively significantly correlated to the harvest index. So, farmers can sow mustard seeds up to 20 November without sacrificing any significant biological yield from Magura's perspective.

Acknowledgements

We would like to express our heartfelt gratitude to Md. Abu Sayed, Farm Manager, Mrinal Kumar Shil, Junior Experimental Officer, ASM Mushfiqur Rahman, SA-1, Outsourcing staffs- Akash, Shohan, Jahangir, Shahin, and labours of BINA sub-station, Magura for their solid cooperation during the research period. We also want to thank the same station's Scientific Officers, Mst. Rokeya Sultana, Md. FoysalAhmmed, Shampa Rani Ghosh, and Fam Superintendent Hossain Md. Ferdous, for their assistance in collecting field data. Finally, we would like to sincerely thank the Bangladesh Institute of Nuclear Agriculture for its logistical support in executing this time-driven research study.

References

Ahmmed, S., Jahiruddin, M., Razia, S., Begum, R.A., et al. (2018). *Fertilizer recommendation guide-2018*. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215, pp. 1-223. ISBN: 984-500-029-1.

Alam, M.M., Begum, F., & Roy, P. (2014). Yield and yield attributes of rapeseed mustard (*Brassica*) genotypes grown under late sown condition. *Bangladesh Journal of Agricultural Research*, *39* (2), 311-336. doi.org/10.3329/bjar.v39i2.20434

Aytaç, Z., & Kınacı, G. (2009). Genetic variability and association studies of some quantitative characters in winter rapeseed (*Brassica napus* L.). *African Journal of Biotechnology*, *8*(15), 3547-3554.

Azad, A.K., Miaruddin, M., Ohab, M.A., Sheikh, H.R., Nag, B.L., & Rahman, H.H. (2020). Krishi projuktihatboi (Handbook on Agro-Technology), 9th edition Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh, pp.93-102. Retrieved from https://drive.google.com/file/d/1h81CIRy3vHF_iuAwY3kyPcl6T2x-tlvY/view?usp=sharing

Bala, P., Azad, A.K., & Hossain, M.F. (2011). Yield response of Mustard to sowing date. *Libyan Agriculture Research Center Journal International, 2* (3), 112-117.

BINA (2014). *Leaflet of Binasarisha-9 and Binasarisha-10* (In *Bengali*). Retrieved from http://bina.portal.gov.bd/sites/default/files/files/bina.portal.gov.bd/page/e598357f_0ebb_46a4_ad26_3b0bbfc4f815/Binasarisha-9%20%26%2010.pdf

BINA (2022). Bangladesh institute of nuclear agriculture. Released varieties (Mustard).Retrieved from http://www.bina.gov.bd/site/page/92a41b28-908c-43a9-8fdc-8950d686806a/[front]

Chowhan, S., & Islam, M. (2022a). Boron regulates growth and morpho physical properties ofmustard in no-till farming. *International Journal of Agricultural and Applied Sciences, 3*(1), 47-53.doi.org/10.52804/ijaas2022.318

Chowhan, S., & Islam, M. (2022b). Alterations in the yield features of mustard varieties under various planting dates. *International Conference on System of Crop Intensification (ICSCI 2022) for Climate Smart Livelihood and Nutritional Security*. 12-14 December 2022, Society for the Advancement of Rice Research, ICAR-Indian Institute of Rice Research, Hyderabad,Telangana, India. pp. 442-444.

Chowhan, S., & Islam, M. (2022c). Varietal roles on morpho-physiological and yield attributes of lentil (*Lens culinaris* Medik). *Legume Research [Online first]*, doi.org/10.18805/LR-4913.

Chowhan, S., & Nahar, K. (2022). Evaluating the role of fertilizer and seed soaking on direct seeded aus rice varieties. *Acta Scientific Agriculture, 6*(2), 02-17. doi.org/10.31080/ASAG.2022.06.1093

Chowhan, S., Gupta, R., Islam, M.M., & Begum, S.N. (2018). Evaluation of NERICA rice mutant in Jhum cultivation. *International Journal of Agronomy and Agricultural Research, 12*(2), 24-31.

Chowhan, S., Haider, M. R., Hasan, A. F. M. F., Hoque, M. I., Kamruzzaman, M., & Gupta, R. (2017). Comparative on farm performance of five modern rice varieties with two local cultivars. *Journal of Bioscience and Agriculture Research, 13*(1), 1074-1086. doi.org/10.18801/jbar.130117.131

Chowhan, S., Islam, M., Rana, M. S., Sultana, M. R., et al. (2023). Optimum and late sowing of mustard varieties show similar seed yield. *Plant Science Today*, *10*(2), 382–392. doi.org/10.14719/pst.2246

FRG (2012). *Fertilization Recommendation Guide*. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215, pp. 01-258. ISBN: 978-984-500-000-0.

Ghosh, R.K., & Chatterjee, B.N. (1988). Effect of dates of sowing on oil content and fatty acid profiles of Indian Mustard. *Indian Journal of Oil Seed Research, 5,* 144-149.

Hasanuzzaman, M., Nahar, K., Alam, M. M., Roychowdhury, R., & Fujita, M. (2013). Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences, 14*, 9643-9684.doi.org/10.3390/ijms14059643

Hunt, R., Causton, D.R., Shipley, B., & Askew, A. (2002). A modern tool for classical plant growth analysis. *Annals of Botany, 90*(4),485–488. doi.org/10.1093/aob/mcf214.

Kumar, A., Lal, M., Mohan, N., Kumar, M., & Kumar, N. (2018). Effect of different sowing dates on yield and yield attributes of Indian mustard (*Brassica juncea* L.) genotypes, *International Journal of Pure and Applied Bioscience, 6*(2), 848-853. doi.org/10.18782/2320-7051.6264

Maurya, S. K., Kalhapure, A., Singh, N., Kumar, A., Yadav, P., Kumar, M., et al. (2022). Growth and yield response of different Indian Mustard [*Brassica juncea* (L.)] varieties to irrigation scheduling. *Biological Forum.– An International Journal,14*(3), 434-439.

Mondal, M. M. A., Malek, M. A., & Bhuiyan, M. S. H. (2018). The role of morpho-physiological attributes on the seed yield of *Brassica juncea*. *Acta Scientific Agriculture, 2*(5),22-26.

Mondal, M.M.A., Puteh, A.B., Malek, M.A., Roy, S., & Yusop, M.R. (2013). Contribution of morpho-physiological traits on yield of lentil (*Lens culinaris*Medik). *Australian Journal of. Crop Science, 7*(8), 1167-1172.

Mostofa, U. H. M., Nazrul, I. M., Kadir, M., & Miah, N. H. (2016). Performance of rapeseed and Mustard (*Brassica* sp.) varieties/lines in north-east region (sylhet) of Bangladesh. *Advances in Plants and Agriculture Research*, *5*(1),457-462. doi.org/10.15406/apar.2016.05.00168

Porter, J. R. (2005). Rising temperatures are likely to reduce crop yields. *Nature*, *436, 174.* doi.org/10.1038/436174b

Russell, D.F. (1986). MSTAT-C computer package programme. Crop and Soil Science Department, Michigan State University, US.

Sarkar, S.C., Akter, M., Islam, M. R., & Haque, M.M. (2016). Performance of five selected hybrid rice varieties in aman season. *Journal of Plant Sciences, 4(2)*, 72-79. doi.org/10.11648/j.jps.20160404.13.

Sharif, M., Haque, M., Howlader, M., & Hossain, M. (2017). Effect of sowing time on growth and yield attributes of three mustard cultivars grown in Tidal Floodplain of Bangladesh. *Journal of the Bangladesh Agricultural University,14(2),* 155–160.

Singh, A.K., & Yeshpal, R.P. (2011). Performance of mustard hybrids under different sowing dates and spacings. *Pantnagar Journal of Research*, *9*(1), 16-19.

Statistix (2022). Data analysis software for researchers (Version 10.0). Analytical Software, 2105 Miller Landing Rd, Tallahassee Florida 32312, USA.

Tandale, M. D., & Ubale, S. S. (2007). Evaluation of effect of growth parameters, leaf area index, leaf area duration, crop growth rate on seed yield of soybean during Kharif season. *International Journal of Agricultural Sciences, 3*(1), 119-123.

Uddin, M.A., Sultana, F., Ullah, M.A., Rahman, K.M., & Mashra, M.M. (2012).Evaluation of some rapeseed mutants based on growth attributes. *Journal of Agroforestry and Environment, 6*(1), 117-120.

Wahhab, M. A., Mondal, M. R. I, Akbar, M. A., Alam, M. S., Ahmed, M. U., & Begum, F. (2002). Status of oil crop production in Bangladesh. Oil seed Research Centre Bangladesh Agricultural Research Institute, Joydebpur, Gazipur pp. 4-62.