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Optimum and late sowing of mustard varieties show similar seed yield

Sushan Chowhan*, Majharul Islam, Md. Shohel Rana, Mst. Rokeya Sultana, Shampa Rani Ghosh, Foysal Ahmmed, Hossain Md. Ferdous, Md. Ibrahim Ali, Nazmul Alam Khan & Md. Moshiur Rahman

Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh

*Email: sushan04@yahoo.com

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Abstract

Appropriate planting time of mustard (*Brassica* sp.) during winter determines the growth yield and quality of a particular cultivar. Since the shift of winter period over the last few years driven by climate change, a transformation in mustard cultivation is also observed. Thus, to study the extent of these variations we studied 6 mustard varieties (V_1- Binasarisha-4, V_2- Binasarisha-9, V_3- Binasarisha-10, V_4- BARI Sarisha-14, V_5- BARI Sarisha-16 and V_6- BARI Sarisha-17) under 3 different planting dates (D_1-31st October, D_2-10th November and D_3-20th November) in the Magura district of Bangladesh to evaluate yield differences over sowing times. Field experimentation was set followed RCB (Randomized complete block) design. Data on growth and yield parameters were collected at various days after sowing. Outcomes noted that, most number of siliqua/plant was obtained with treatment combination $D_3 \times V_5$ (190.33), siliqua length with $D_3 \times V_2$ (7.95 cm), number of seeds per siliqua by $D_3 \times V_6$ (36.30), thousand grain weight by $D_1 \times V_1$ (3.90 g). Hence, correlation study suggested that, seed yield was positively related to number of siliqua/plant, siliqua length and number of seeds/siliqua. Though, BARI Sarisha-16 (V_5) delivered top seed and stover yield in all sowing dates. But interaction effects depicted that planting on 10th (2.00 t/ha) and 20th November (1.99, 1.94 t/ha) gave similar seed yield like 31st October planting (2.31 t/ha); in addition, stover yield (6.70, 6.83 t/ha) also remained at peak with the later plantings (D_2, D_3). An increase in the tendency of life duration was noticed when sown on 20th November for most treatment combination. Overall, delayed sowing of mustard didn't affect the yield and related attributes rather it accelerated to some attributes. Hence, rescheduling of optimum sowing time for mustard is now a time demanding concern with regard to weather change.

Keywords

late sowing, planting time, mustard, Magura, BARI Sarisha, Binasarisha, seed yield.

Introduction

Oil seed crops play a key role in the agricultural production of Bangladesh. Among the major oil crops mustard is the top produced crop over sesame, groundnut, sunflower, soyabean and linseed. Rape seed or mustard commonly known as *sarisha* in Bangladesh which falls under the genera *Brassica* of Brassicaceae family (formally Cruciferae). Among the three species of this genus, *Brassica campestris* and *Brassica napus* are recognized as rape seed and *Brassica juncea* is regarded as mustard. It is the major edible oil in the country after soyabean. Consumption of mustard oil is better than soyabean in terms of body and health as it has no trans-fat, has minimal saturated fats and a high amount of mono and poly-unsaturated fats such as omega-3 (1). Seeds of mustard contain 40-45% oil and 20-25% protein (2). Besides oil usage it is also used in the industrial, agricultural (oil cake manure) and as animal feeds due to high (40%) protein content (3, 4). Mean national seed yield of rape and mustard (HYV and local) during 2020-21 was 1.20 t/ha; Whereas, this was about 1.00 t/ha in Magura district of Bangladesh within this period. Though the total cultivation area of this crop shows a variable trend but it's cultivation has increased over the last 2 years (5, 6). Currently total need of edible oil is about 2.5 million metric tons; where mustard along with locally produced oil crops meet just 0.5 million tons of demand and the rest are filled by soyabean, palm and other oil crops which are mainly import depended. Only 3% of the total cultivable land is utilized for oil seed production in the country where mustard alone holds 60% land area among the oil crops (5); however, there is a potential scope to extend this area to 2.2 million hectares where the land remains fallow between 2 crops (in between aman and boro or other crops) (7, 8). Hence an additional amount of 1 million tons production may be gained which can save 170 billion BDT (9). Due to continuous price hike of available edible oil soyabean; now a days farmers are being motivated and focused to grow mustard due to higher market price and profit. Though achievable seed yield of is mustard is around 2.0 t/ha but this figure is rarely attained.

A number reasons are liable behind low yield of mustard. Firstly, farmers often cannot sow mustard due to *joe* condition (available soil moisture) of the soil; hence timely planting is hindered. Time line for mustard planting in Bangladesh is very short varying from 15 October to 15 November (10). Though earlier results suggested planting in the late October yields higher than late November (11); but due to weather shift; this knowledge seldomly works. However, due to delayed harvesting of T. Aman rice, mustard planting become late in the rice-based cropping system at northern region. 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 resulting considerable yield loss (12). Timely sowing enables the crop plants to complete both vegetative and reproductive growth phases with better yield (13). Secondly, lack of quality seeds of the high yielding varieties (HYV) and improper agronomic practices. Farmers hardly use balanced fertilizer; moreover, they are reluctant to use micro nutrient fertilizer (7). Possibility of increasing yield of mustard still underlies in the selection of HYVs and improved management practices through proper seed rate, plant spacing, fertilization, irrigation, pest control etc. (14). Thirdly, 30 to 50% of mustard flowers fail to develop into mature pods (15). This implies that potential fruit or seed number is usually much more than the number actually produced by the plant community. Fourthly, under late sowing plants get less time for growth and directly moves to the reproductive stage. Furthermore, a rise in temperature also takes place in the end of winter which is favorable for insect infestation (16, 17).

So far BINA (Bangladesh institute of nuclear agriculture) has developed 7 and BARI (Bangladesh agricultural research institute) has developed 20 high yielding varieties (HYV) of mustard. Among them Binasarisha-9, BARI Sarisha -14, BARI Sarisha-16 are admired in the farming community (18, 19). Even if the varieties from research organizations are of best categories but the yield gap that lies within; limits the yielding efficacy. Further due to global climate change and disparities in weather patterns a continuous shifting of winter season is being noticed every year. Being thermo sensitive and photosensitive (12, 20); mustard plants must also adapt to this change. Hence, late planting results in early flowering and may also cause severe insect pest infestation. Whereas, early planting results greater vegetative growth and takes more time for floral initiation consequently affecting seed yield and quality. To resolve these problems, it is now a time and climate change led demand for fixing zone or area specific sowing times depending on the climatic data. With a view to unraveling the aforementioned constraints in mustard cultivation the current research programme was aimed to determine the optimum sowing time and select a suitable variety in terms various morpho-physiological attributes; which can deliver best yield in the context of Magura district.

Materials and Methods

Experiment site

The experimental location was BINA, Sub-station Farm, Magura (Agro Ecological Zone 11). This area was characterized by high Ganges river flood plain and high to medium land type. Soils were calcareous floodplain soils ranging from dark grey to brown. Organic matter content of brown ridge soils is low, whereas dark grey soils have a greater amount. Soils were somewhat alkaline, with a fertility deficiency (21). Fig. 1 depicts the meteorological parameters for the experimental period in detail.

Sowing and field management

Rabi (winter) season (2019) was used to carry out the field experiment and the land was prepared as per (22). Fertilizer amount and application was done accounting less fertility level with yield goal 2.0±0.2 t/ha (23). The entire P, K, S, Zn, B and half of N were administered as a basal dosage, while the leftover 50% of N was top-dressed with light irrigation at 22 days after seedling emergence (DAE). 1.5 m × 2.0 m individual plot size with line to line and plot to plot distance 30 cm used. Seed rate of 7.5 kg/ha i.e. 10,000 m^2 were line broadcasted. 20 days after sowing (DAS) weeding and thinning were done to ensure optimum plant density (24). Mustard seeds were harvested when siliquae reached near 75% maturity with brownish to straw color.

Design

For experimentation, randomized complete block design (RCBD) with 3 replications was used. Gap between

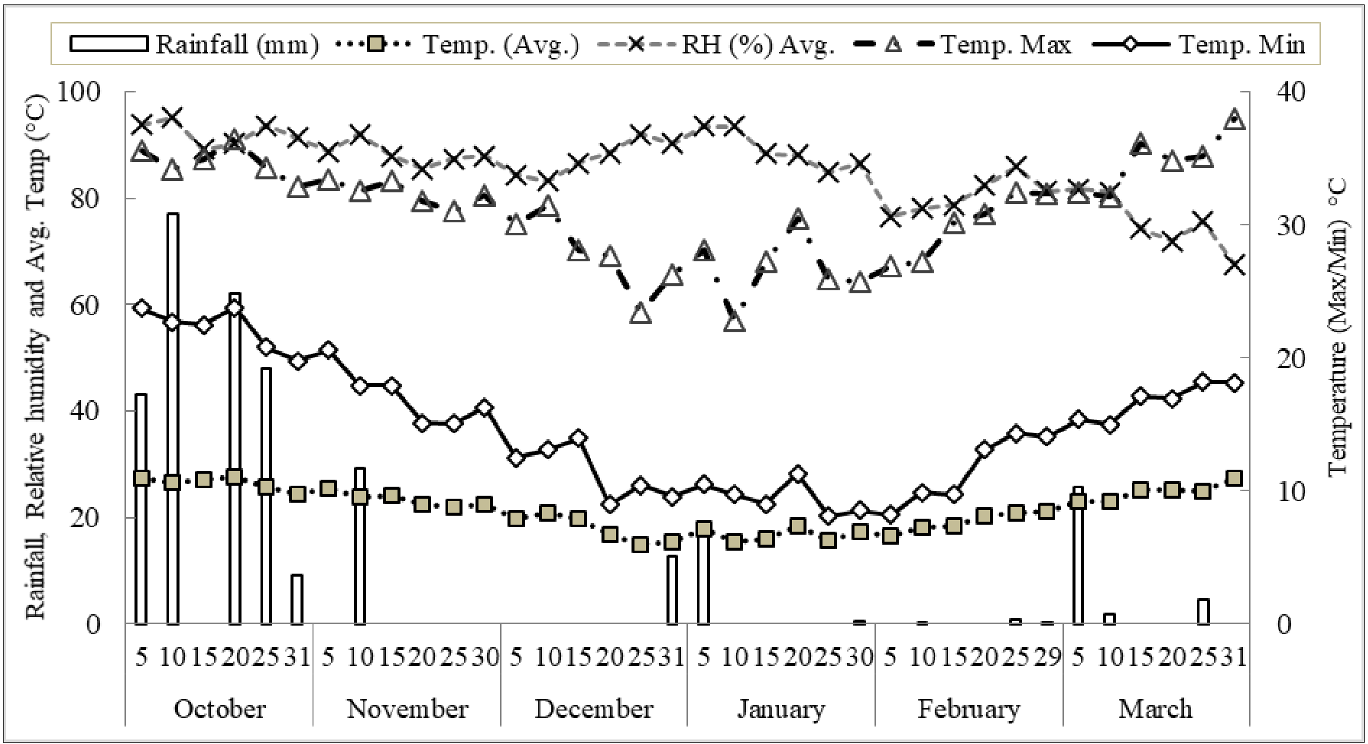


Fig. 1. Mean weather parameters of the experimental site during October 2019 to March 2020 (38).

replications were 1m. Variety and sowing date were two factors in the experiment. Six varieties; *viz*. Binasarisha-4, Binasarisha-9, Binasarisha-10, BARI Sarisha-14, BARI Sarisha-16, BARI Sarisha-17 and 3 sowing dates *viz.* 31st October, 10th November, 20th November were randomly assigned in the unit plots.

Observation and Analysis

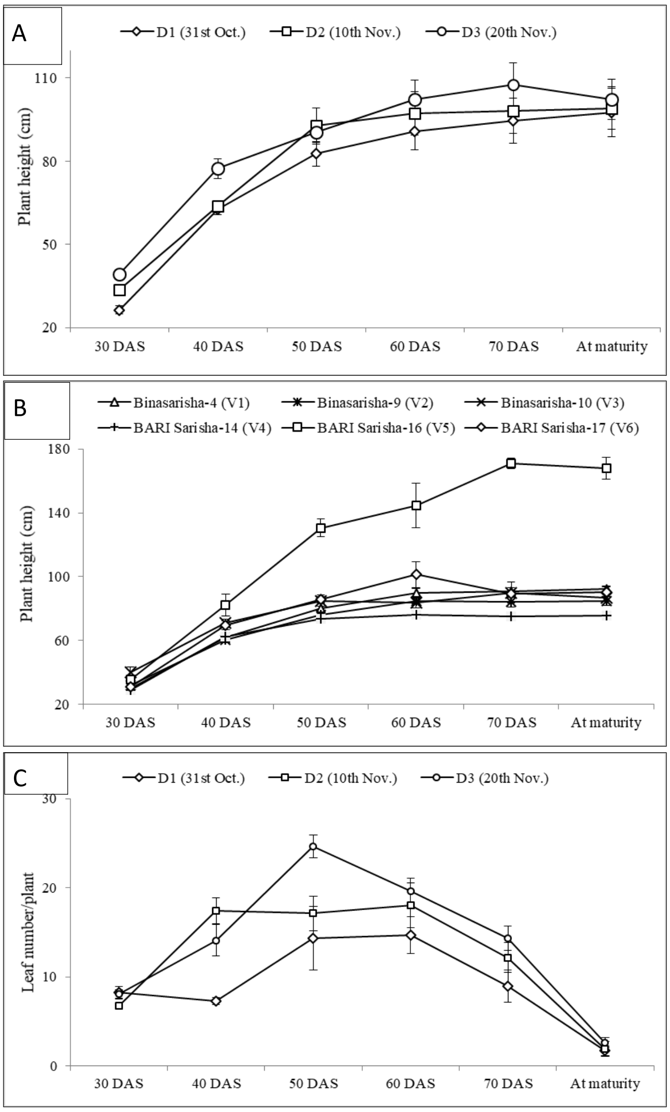
Plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of leaves per plant were recorded 10 days interval starting from 30 DAS and continued up to harvest. Number of siliquae per plant, number of seeds per siliqua, siliqua length (cm), thousand grain weight (TGW) (g), seed yield (t/ha), stover yield (t/ha) and crop duration (days to maturity) was recorded after final crop cutting. Seeds harvested from individual plots were weighed (adjusting 10% moisture content) and the was converted (g/plot and t/ha). Stover yield (t/ha) was calculated through sun drying. For each observation five plants were sampled. Data obtained from the parameters were analyzed statistically with ANOVA (analysis of variance) technique by Statistix 10 (25) and the mean differences were adjudged by LSD (least significant difference) test (26, 27) at 5% level of probability.

Results and Discussion

Morpho-physical features

Plant height

All sowing dates showed significant deviation in plant height from 30 DAS to 50 DAS and 70 DAS; but the height was statistically similar at 60 DAS and during harvesting time. Up to 70 DAS, plant height increased rapidly and had a upline trend (Fig. 2A). After 70 DAS the growth was slowed down and during harvesting stage all planting time followed a steady state. Interestingly sowing time D_3 (20th Nov.) had a downward tendency of the height at final harvest.



All varieties except BARI Sarisha-16 (V_5) had similar trend of plant height increase. However, at maturity stage BARI Sarisha-16 (V_5) had the highest and BARI Sarisha-14 (V_4) demonstrated the lowest height (Fig. 2B).

Combined effect of planting time and variety showed a great variation at different sowing intervals. At maturity, BARI Sarisha-16 (V_5) acquired maximum height in all sowing dates (D_1, D_2, D_3); whereas, the least was seen by BARI Sarisha-14 (V_4) with D_1 and D_2 planting time (Table 1).

Even if the sowing time was different but plant height at final stage was almost similar with planting time effect. But in case of varietal effect the deviations might be due to varietal characters which might be genetic. Thus, interaction effects prove that plant height may not change by shifting the sowing times rather it might be an indication that certain variety will reach to a certain height irrespective of planting time intervals. It was reported variations in plant height under various sowing dates and with different Indian mustard varieties (28).

Leaf number

D_3 planting resulted most number of leaves at 50 DAS but for D_1 and D_2 it was highest at 60 DAS. Up to 70 DAS sowing dates had significant differences in number of leaves per plant but it was non-significant during harvest (Fig. 2C).

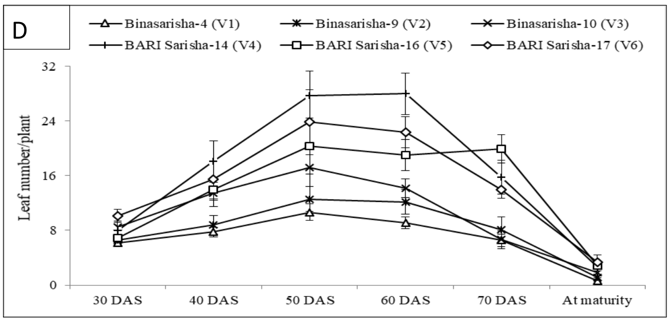


Fig. 2. Effect of sowing dates and varieties on plant height and leaf numbers. (**A**) Each line represents mean plant height at the specified planting date; (**B**) Individual lines present respective variety's average height at different days after sowing (DAS); (**C**) Each line showing mean leaf number per plant of a particular sowing time; (**D**) Individual lines present corresponding variety's average number of leaves at different days after sowing. Each data point presents mean of 5 samples (n=5). Error bars are the standard error values.

Varietal influences on leaf number had an increasing trend; which was almost alike up to 50 DAS. But after 50 DAS the leaf growth declined from 60 DAS except BARI Sarisha-16 (V_5). At the final point of maturity BARI Sarisha-17 (V_6) had statistically highest leaf number and the lowest was observed with Binasarisha-4 (V_1) (Fig. 2D).

Table 1. Interaction effect of sowing time and varieties and on plant height (cm) of mustard.

Treatments	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
$D_1 \times V_1$	21.66 h	54.66 h	70.88 ef	83.44 cd	87.33 c-f	85.99 bcd
$D_1 \times V_2$	28.66 e-h	57.77 gh	73.11 ef	86.11 cd	76.67 ef	80.86 bcd
$D_1 \times V_3$	33.11 c-f	67.22 c-g	77.00 def	74.11 d	78.55 def	85.89 bcd
$D_1 \times V_4$	23.33 gh	60.22 e-h	72.55 ef	76.44 cd	72.44 f	74.00 d
$D_1 \times V_5$	28.11 fgh	71.44 bcd	120.44 b	104.55 bc	167.78 a	175.85 a
$D_1 \times V_6$	23.11 h	65.55 c-h	81.88 cde	120.44 b	84.33 c-f	82.55 bcd
$D_2 \times V_1$	31.44 def	59.44 e-h	86.89 cd	91.55 cd	89.44 b-e	97.34 b
$D_2 \times V_2$	31.22 def	58.33 fgh	76.67 def	79.66 cd	84.44 c-f	81.54 bcd
$D_2 \times V_3$	40.99 ab	69.88 b-e	85.88 cd	86.44 cd	85.66 c-f	85.83 bcd
$D_2 \times V_4$	31.44 def	62.11 d-h	69.11 f	70.77 d	71.44 f	73.24 d
$D_2 \times V_5$	35.99 b-e	69.22 b-f	150.00 a	166.78 a	169.89 a	163.44 a
$D_2 \times V_6$	30.88 d-g	64.00 d-h	87.77 cd	88.11 cd	88.33 c-f	93.36 bc
$D_3 \times V_1$	36.33 bcd	72.00 bcd	83.33 cde	95.00 bcd	95.67 bc	94.00 bc
$D_3 \times V_2$	36.99 bcd	65.44 c-h	78.11 def	89.03 cd	92.44 b-e	91.35 bc
$D_3 \times V_3$	47.22 a	75.78 bc	92.11 c	90.72 cd	105.74 b	88.63 bcd
$D_3 \times V_4$	32.99 c-f	65.44 c-h	79.55 def	81.60 cd	81.20 c-f	79.93 cd
$D_3 \times V_5$	43.44 ab	106.11 a	121.22 b	162.55 a	175.44 a	164.31 a
$D_3 \times V_6$	39.22 bc	79.33 b	88.22 cd	95.72 bcd	95.05 bcd	95.74 bc
$LSD_{0.05}$	7.55	11.00	12.54	28.75	16.96	17.13
Level of significance	*	*	*	*	*	*
SEm	3.72	5.41	6.17	14.15	8.34	8.43
CV	13.75%	9.75%	8.53%	17.89%	10.21%	10.36%

Figures in a column having different letter (s) differ significantly at 5% level of probability according to LSD. , $P < 0.05$; by analysis of variance with randomized complete block design.

Most of the combined effect shows that leaf growth reduced after 60 DAS. However, during harvest; treatment combination $D_3 \times V_5$ retained the maximum leaves and treatments $D_1 \times V_1$ and $D_1 \times V_2$ beard no leaves (Table 2).

It was noted that earlier planting resulted least leaves compared to late planting. The reason may be favorable weather conditions prevailed later than earlier sowing times. Therefore, varietal influence of leaf initiation followed a similar trend. But the leaf growth gradually declined after 50 DAS. Mustard shed leaves when it reached to maturity stage thus the leave number was least at the end of the crop life cycle. In the interaction effect we noticed that almost all treatment combinations had lower leaf number at harvest; but, BARI Sarisha-16 (V_5) planted on 20th Nov. (D_3) attained leaf number identical to 30 DAS. Actually, this variety might still be accumulating photosynthates to the pod and seeds and also due to longer life duration (19) which might be the reason for more leaf numbers. It was reported variation in leaf number under different sowing dates of Tori-7 mustard variety (29).

Table 2. Interaction effect of sowing time and varieties and on number of leaves per plant

Treatments	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
$D_1 \times V_1$	6.22 cd	5.88 fg	9.44 f	7.33 e	3.56 g	0.00 b
$D_1 \times V_2$	6.11 cd	5.33 g	12.55 def	10.99 de	4.77 fg	0.00 b
$D_1 \times V_3$	8.67 bc	7.22 efg	12.55 def	11.66 de	5.55 fg	1.55 ab
$D_1 \times V_4$	8.22 bcd	7.00 fg	17.77 b-f	21.66 bc	11.11 c-g	3.11 ab
$D_1 \times V_5$	7.77 bcd	9.89 d-g	18.39 b-f	18.67 cd	16.78 a-d	2.00 ab
$D_1 \times V_6$	12.44 a	8.22 efg	15.44 c-f	17.89 cd	11.99 b-f	3.55 ab
$D_2 \times V_1$	5.66 d	10.22 d-g	10.67 ef	9.89 de	6.77 efg	1.22 b
$D_2 \times V_2$	6.10 cd	12.55 c-f	12.89 def	12.99 cde	10.89 c-g	0.89 b
$D_2 \times V_3$	6.88 cd	18.66 bc	14.55 c-f	14.11 cde	5.55 fg	2.44 ab
$D_2 \times V_4$	7.77 bcd	26.11 a	27.22 a-d	29.44 ab	13.66 b-e	2.22 ab
$D_2 \times V_5$	6.11 cd	15.88 bcd	14.11 c-f	21.89 bc	23.89 a	0.50 b
$D_2 \times V_6$	8.11 bcd	20.88 ab	23.44 a-f	19.77 bcd	12.11 b-f	4.11 ab
$D_3 \times V_1$	6.66 cd	7.11 fg	11.78 ef	9.99 de	9.33 d-g	0.66 b
$D_3 \times V_2$	7.55 bcd	8.55 efg	12.33 def	12.44 cde	8.55 efg	2.33 ab
$D_3 \times V_3$	9.88 ab	14.33 b-e	24.61 a-e	16.77 cde	8.88 efg	1.55 ab
$D_3 \times V_4$	7.88 bcd	21.11 ab	37.99 a	32.78 a	22.44 a	2.61 ab
$D_3 \times V_5$	6.77 cd	16.11 bcd	28.44 abc	16.44 cde	18.99 ab	6.11 a
$D_3 \times V_6$	9.77 ab	17.42 bc	32.66 ab	29.44 ab	17.78 abc	2.33 ab
$LSD_{0.05}$	2.88	7.12	15.10	9.97	7.64	4.57
Level of significance	*	*	*	*	*	*
SEm	1.41	3.50	7.43	4.91	3.76	2.25
CV	22.55%	33.22%	48.62%	34.43%	38.99%	133.38%

Figures in a column having different letter (s) differ significantly at 5% level of probability according to LSD. , $P < 0.05$; by analysis of variance with randomized complete block design.

Branches per plant

Number of primary branches were unaffected by sowing dates (Fig. 3A); but in case of secondary branches, D_3 planting gave higher and D_1 produced the lowest number secondary branches (Fig. 3C).

Varietal effect showed paired pattern of primary branch development (Fig. 3B); where BARI Sarisha-17 (V_6) along with BARI Sarisha-14 (V_4), BARI Sarisha-16 (V_5) along with Binasarisha-10 (V_3) and Binasarisha-9 (V_2) along with Binasarisha-4 (V_1) had a closed relationship. Yet, at maturity Binasarisha-9 (V_2) and Binasarisha-4 (V_1) had the lowest number of primary branches per plant. Whereas, for secondary branches all the varieties followed a similar fashion of branch rise except for BARI Sarisha-16 (V_5) and Binasarisha-10 (V_3) (Fig. 3D). These two varieties displayed statistically similar number of branches.

Interaction effect of planting time and variety on primary branch number at harvesting stage exposed that, treatment combinations $D_1 \times V_1$, $D_1 \times V_2$ and $D_2 \times V_1$ generated lowest branches (Table 3). On the contrary, variety V_3, V_4 and V_6 with D_1planting seemed to have peak number of branches (Table 3). While, for secondary number of branches most was attained with $D_3 \times V_3$ and least was gotten by $D_1 \times V_1$ and $D_1 \times V_6$ treatment amalgamations (Table 4).

There were no changes at different DAS in case of primary branch number but some varieties followed a combined relation in developing branch numbers. But planting time influenced the secondary branch numbers. As seen from Fig. 3D, 2 top most secondary branch bearing varieties distinctly varied from other four varieties. Early sowing had a temperature advantage on the secondary branch number of the studied varieties compared to late

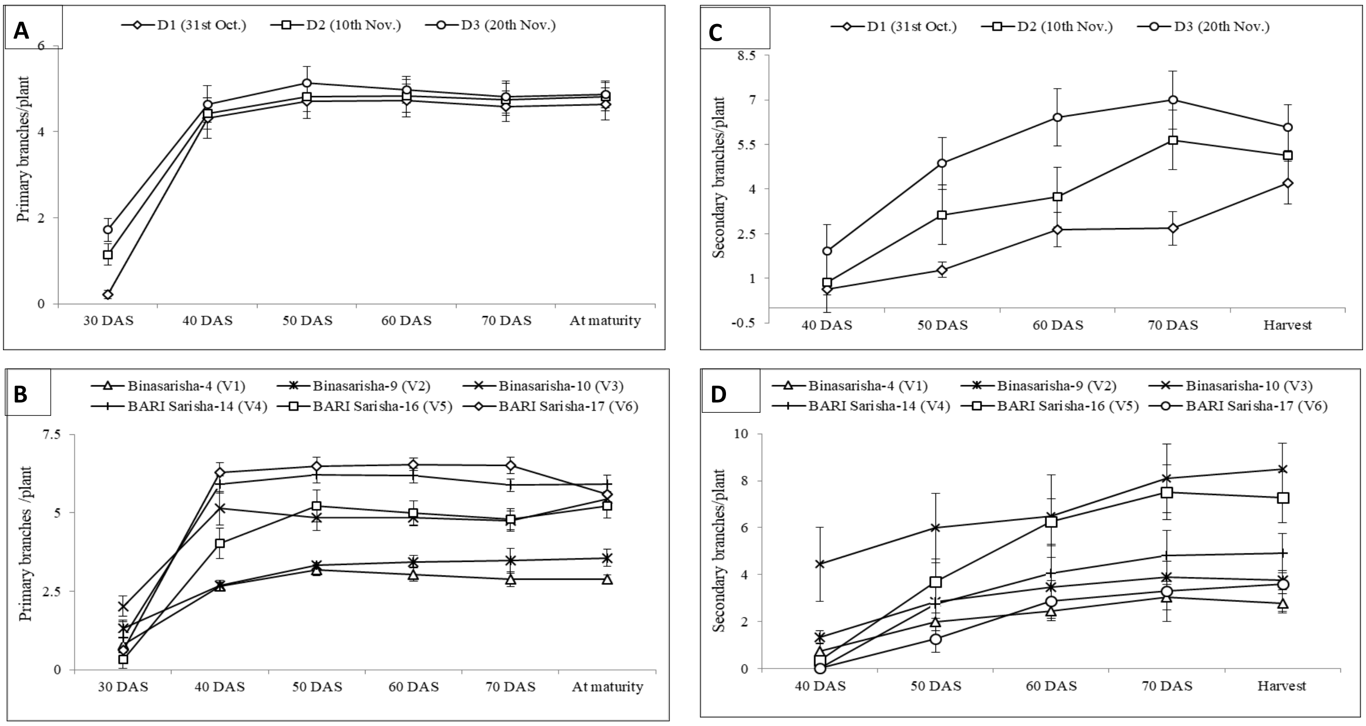


Fig. 3. Influence of planting time and varieties on number of primary and secondary branches. (**A**) Each line represents mean number of primary branches per plant at the specified planting date; (**B**) Individual lines present respective variety's average number of primary branches per plant at different days after sowing (DAS); (**C**) Each line showing mean number of secondary branches per plant of a particular sowing time; (**D**) Individual lines present corresponding variety's average number of secondary branches per plant at different days after sowing. Each data point presents mean of 5 samples (n=5). Error bars are the standard error values.

Table 3. Number of primary branches per plant with combined effect of planting dates and mustard varieties.

Treatments	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
$D_1 \times V_1$	0.00 f	2.33 e	2.66 f	2.67 h	2.55 i	2.44 e
$D_1 \times V_2$	0.44 def	2.44 e	3.22 ef	3.22 gh	3.77 f-i	3.22 e
$D_1 \times V_3$	0.89 c-f	5.89 ab	4.99 bcd	5.33 bcd	4.22 e-h	5.55 a
$D_1 \times V_4$	0.00 f	5.67 ab	6.44 ab	6.22 ab	6.11 abc	5.77 a
$D_1 \times V_5$	0.00 f	3.11 de	4.44 cde	4.44 d-g	4.55 c-g	4.99 abc
$D_1 \times V_6$	0.00 f	6.44 a	6.44 ab	6.44 ab	6.33 ab	5.89 a
$D_2 \times V_1$	1.11 c-f	2.99 de	3.66 def	2.99 h	2.89 hi	2.88 e
$D_2 \times V_2$	1.88 abc	3.11 de	3.44 ef	3.55 e-h	3.33 ghi	3.89 b-e
$D_2 \times V_3$	2.66 a	4.66 bcd	4.22 cde	4.44 d-g	5.22 a-f	5.11 ab
$D_2 \times V_4$	0.66 c-f	6.55 a	6.66 a	6.66 a	6.00 a-d	6.22 a
$D_2 \times V_5$	0.11 ef	3.33 cde	4.44 cde	4.66 c-f	4.44 d-h	4.78 a-d
$D_2 \times V_6$	0.44 def	5.89 ab	6.44 ab	6.66 a	6.66 a	5.99 a
$D_3 \times V_1$	1.33 b-e	2.66 e	3.22 ef	3.44 fgh	3.22 ghi	3.33 de
$D_3 \times V_2$	1.66 a-d	2.55 e	3.33 ef	3.55 e-h	3.33 ghi	3.61 cde
$D_3 \times V_3$	2.55 ab	4.89 abc	5.33 abc	4.78 cde	4.77 b-g	5.66 a
$D_3 \times V_4$	2.44 ab	5.52 ab	5.55 abc	5.67 a-d	5.55 a-e	5.77 a
$D_3 \times V_5$	0.89 c-f	5.66 ab	6.77 a	5.88 abc	5.44 a-e	5.89 a
$D_3 \times V_6$	1.44 a-d	6.55 a	6.55 a	6.55 ab	6.55 a	4.89 abc
$LSD_{0.05}$	1.26	1.68	1.48	1.31	1.60	1.46
Level of significance	*	*	*	*	*	*
SEm	0.62	0.83	0.73	0.64	0.79	0.71
CV	74.21%	22.69%	18.34%	16.34%	20.55%	18.46%

Figures in a column having different letter (s) differ significantly at 5% level of probability according to LSD. , $P < 0.05$; by analysis of variance with randomized complete block design.

Table 4. Secondary branches per plant with relation to sowing time and mustard varieties.

Treatments	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
$D_1 \times V_1$	0.55 bc	1.22 cd	2.11 cde	1.66 ef	2.22 f
$D_1 \times V_2$	1.22 bc	2.22 cd	3.33 cde	3.44 def	4.22 b-f
$D_1 \times V_3$	1.89 bc	1.99 cd	3.11 cde	3.44 def	5.99 b-f
$D_1 \times V_4$	0.00 c	0.67 cd	1.00 de	1.44 f	2.99 def
$D_1 \times V_5$	0.22 c	1.55 cd	5.99 bc	5.55 b-e	7.66 abc
$D_1 \times V_6$	0.00 c	0.00 d	0.33 e	0.55 f	2.22 f
$D_2 \times V_1$	0.00 c	1.77 cd	1.88 cde	3.78 c-f	2.55 ef
$D_2 \times V_2$	1.33 bc	2.33 cd	2.99 cde	4.22 c-f	3.44 c-f
$D_2 \times V_3$	3.89 b	6.33 ab	4.99 bcd	8.44 ab	8.66 ab
$D_2 \times V_4$	0.00 c	3.66 bcd	5.44 bc	6.66 bcd	6.27 b-f
$D_2 \times V_5$	0.00 c	3.33 bcd	4.66 b-e	7.67 bc	6.99 a-e
$D_2 \times V_6$	0.00 c	1.33 cd	2.44 cde	3.11 def	2.89 def
$D_3 \times V_1$	1.66 bc	2.99 bcd	3.29 cde	3.67 c-f	3.55 c-f
$D_3 \times V_2$	1.44 bc	3.99 bc	4.11 b-e	3.99 c-f	3.66 c-f
$D_3 \times V_3$	7.55 a	9.66 a	11.33 a	12.42 a	10.85 a
$D_3 \times V_4$	0.00 c	3.88 bc	5.78 bc	6.33 bcd	5.50 b-f
$D_3 \times V_5$	0.77 bc	6.22 ab	8.11 ab	9.33 ab	7.22 a-d
$D_3 \times V_6$	0.00 c	2.44 cd	5.89 bc	6.22 bcd	5.66 b-f
$LSD_{0.05}$	3.39	3.73	4.37	4.00	4.45
Level of significance	*	*	*	*	*
SEm	1.67	1.83	2.15	1.96	2.19
CV	179.40%	72.83%	61.74%	47.22%	52.25%

Figures in a column having different letter (s) differ significantly at 5% level of probability according to LSD. , $P < 0.05$; by analysis of variance with randomized complete block design.

sowing. Therefore, genetic backup of the varieties acting with environment and weather was another factor for variation in the branch numbers. Similar findings were also reported earlier (30).

Yield attributes

Siliqua per plant

Number of siliqua remained neutral with different planting time. But among the varieties, BARI Sarisha-16 (V_5) produced utmost and BARI Sarisha-14 (V_4) generated slightest number of siliqua/plant. When BARI Sarisha-16 (V_5) sown late (D_3); it seemed to have maximum number of siliqua; contrary the minimum was gained by BARI Sarisha-17 (V_6) with medium planting time (D_2) (Table 5).

The reason for more number of siliqua production by BARI Sarisha-16 (V_5) in late sowing might be due to the varietal character and it may have a late sowing potentiality to show better performance. However, previous studies indicate later sowing reduces number of siliqua in mustard (30).

Siliqua length

Mysteriously D_3 planting time had more siliqua length than D_1 and D_2. While, Binasarisha-9 (V_2) appeared to have longest siliqua followed by Binasarisha-4 (V_1). Varieties V_4, V_5 and V_6 had statistically identical shortest siliqua length. Binasarisha-9 (V_2) planted at D_3 exhibited lengthiest siliqua over other treatment amalgamations and the shortest was gotten with the D_1 sowing with BARI Sarisha-14 (V_4) (Table 5).

Length of siliqua is mainly genetic attribute but it

Table 5. Yield attributes of mustard under various treatments and their amalgamation.

Treatments	No. of siliqua/ plant	Siliqua length (cm)	No. of seeds/ siliqua	Thousand grain weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Days to maturity
Sowing Time							
D_1 (31st Oct.)	88.45	5.20 c	21.39 b	3.07 a	1.29 b	2.97 b	87.5 b
D_2 (10th Nov.)	95.62	5.51 b	22.83 ab	3.21 a	1.48 ab	3.41 a	88.33 b
D_3 (20th Nov.)	102.29	5.86 a	24.32 a	2.87 b	1.69 a	3.52 a	90.67 a
$LSD_{0.05}$	24.24	0.25	2.23	0.20	0.21	0.19	1.44
Level of significance	NS	*	*	*	*	*	*
SEm	11.93	0.12	1.09	0.10	0.11	0.09	0.71

Treatments / *Sowing Time*	No. of siliqua/ plant No. of siliqua/plant	Siliqua length (cm) Siliqua length (cm)	No. of seeds/ siliqua No. of seeds/ siliqua	Thousand grain weight (g) Thousand grain weight (g)	Seed yield (t/ha) Seed yield (t/ha)	Stover yield (t/ha) Stover yield (t/ha)	Days to maturity Days to maturity
Variety							
Binasarisha-4 (V_1)	76.52 bc	6.95 b	26.70 ab	3.38 a	1.63 b	3.85 b	98.11 a
Binasarisha-9 (V_2)	86.50 bc	7.43 a	25.21 b	3.47 a	1.46 bc	3.27 c	92.78 b
Binasarisha-10 (V_3)	108.37 b	5.12 c	17.07 c	2.49 c	0.92 d	2.32 d	76.78 e
BARI Sarisha-14 (V_4)	66.83 c	4.43 d	23.59 b	2.71 c	1.20 cd	1.65 e	81.22 d
BARI Sarisha-16 (V_5)	158.96 a	4.62 d	15.37 c	3.24 ab	2.08 a	6.45 a	98.78 a
BARI Sarisha-17 (V_6)	75.55 bc	4.58 d	29.27 a	3.08 b	1.64 b	2.26 d	85.33 c
$LSD_{0.05}$	34.28	0.36	3.16	0.28	0.30	0.28	2.04
Level of significance	*	*	*	*	*	*	*
SEm	16.87	0.17	1.55	0.13	0.15	0.13	1.00
Sowing Time × Variety							
$D_1 \times V_1$	73.33 cde	6.23 c	22.76 d-g	3.90 a	1.55 b-e	3.59 d	100.67 a
$D_1 \times V_2$	71.05 cde	6.93 b	23.96 b-f	3.43 abc	0.85 fg	2.90 ef	92.33 de
$D_1 \times V_3$	98.68 cde	4.55 fgh	14.06 ij	2.17 h	0.65 g	1.89 hij	72.67 i
$D_1 \times V_4$	62.44 de	4.10 h	21.50 e-h	2.43 fgh	1.05 efg	1.75 ij	77.00 h
$D_1 \times V_5$	128.00 bc	4.54 fgh	17.25 hij	3.67 ab	2.31 a	5.82 b	98.00 abc
$D_1 \times V_6$	97.22 cde	4.85 efg	28.83 ab	2.80 efg	1.36 c-f	1.86 hij	84.33 fg
$D_2 \times V_1$	83.11 cde	7.31 b	29.04 ab	3.50 abc	1.51 b-e	4.34 c	95.67 bcd
$D_2 \times V_2$	95.22 cde	7.41 ab	23.11 c-g	3.70 ab	1.62 bcd	3.62 d	91.00 e
$D_2 \times V_3$	114.55 bcd	5.20 de	17.80 g-j	2.30 gh	0.98 fg	2.00 hi	75.67 hi
$D_2 \times V_4$	68.83 cde	4.29 fgh	26.65 a-e	3.07 cde	1.20 def	1.48 j	84.33 fg
$D_2 \times V_5$	158.55 ab	4.58 fgh	13.07 j	3.33 bcd	2.00 ab	6.70 a	99.00 ab
$D_2 \times V_6$	53.44 e	4.24 gh	27.33 a-d	3.33 bcd	1.57 b-e	2.30 gh	84.33 fg
$D_3 \times V_1$	73.11 cde	7.33 b	28.30 abc	2.74 efg	1.84 abc	3.63 d	98.00 abc
$D_3 \times V_2$	93.22 cde	7.95 a	28.55 abc	3.02 cde	1.91 ab	3.27 de	95.00 cd
$D_3 \times V_3$	111.89 b-e	5.59 d	19.33 f-i	3.00 de	1.14 d-g	3.08 ef	82.00 g
$D_3 \times V_4$	69.22 cde	4.90 ef	22.63 d-h	2.63 e-h	1.35 c-f	1.70 ij	82.33 g
$D_3 \times V_5$	190.33 a	4.76 efg	15.48 ij	2.71 efg	1.94 ab	6.83 a	99.33 a
$D_3 \times V_6$	76.00 cde	4.64 e-h	36.30 a	3.09 cde	1.99 ab	2.62 fg	87.33 f
$LSD_{0.05}$	59.37	0.62	5.47	0.49	0.53	0.47	3.54
Level of significance	*	*	*	*	*	*	*
SEm	29.22	0.31	2.69	0.24	0.25	0.24	1.74
CV	37.48%	6.80%	14.43%	9.63%	21.29%	8.75%	2.40%

Figures in a column having different letter (s) differ significantly at 5% level of probability according to LSD. NS, not significant; *, $P < 0.05$; by analysis of variance with randomized complete block design.

may also depend on soil nutrition and fertility status. Our findings show BARI Sarisha-14 when planted earlier produce short siliqua. This means D_2 is not the optimum sowing time for this variety. Similar results are with 3 planting time intervals with Tori-7 (29).

Seeds per silique

Late sowing (D_3) contained higher number of seeds among the mustard varieties but BARI Sarisha-17 (V_6) generated utmost amount of seeds and the lowest was noted with BARI Sarisha-16 (V_5). Interestingly, BARI Sarisha-17 (V_6) produced top amount of seed number at late planting (D_3). The fewest number of seeds were obtained by BARI Sarisha-16 (V_5) with mid planting time (D_2) (Table 5).

Later sowing showed more seed number in 2 varieties. This is the indication that, optimum sowing time might be changed over weather conditions. It was revealed that, late sowing decreases seed number of Indian mustard variety. Our findings may have differed due to the shifting in weather parameters (31).

Thousand grain weight

Heaviest and bold grain was gained sowing on 31st October (D_1) and 10th November (D_1); but the late sowing of 20th November (D_3) produced the lightest seed weight. Binasarisha-9 (V_2) and Binasarisha-4 (V_1) produced statistically most grain weight over the other varieties and the least thousand grain was seen by Binasarisha-10 (V_3) and BARI Sarisha-14 (V_4) which seemed to have statistically identical seed weight. Treatment interactions showed that, maximum thousand grain weight was seen with $D_1 \times V_1$ and the minimum was marked with $D_1 \times V_3$ (Table 5).

Grain weight was not so much deviated with the first 2 sowing times; but the late sowing (D_3) significantly reduced grain weight which was also clear from the interaction effect. This may be because of changes in day length and temperature which effected crop maturity; this ultimately led to poor seed filling in siliqua and a decrease in total seed weight (32). Therefore, it was the varietal trait that Binasarisha-4 has the bolder and heavier seed weight and Binasarisha-10 has smaller and lighter seed size and weight (18).

Yield and duration

Seed yield

Notably the seed yield was highest with D_3 and D_2 planting. Whereas, BARI Sarisha-16 (V_5) showed the maximum seed yield and the minimum was recorded in Binasarisha-10 (V_3). Combined effects exhibited the better yield of BARI Sarisha-16 (V_5) over D_1, D_2 and D_3 planting time; which was more or less 2.0 t/ha. BARI Sarisha-14 (V_4) gave moderate yield (1.05 t/ha to 1.35 t/ha) over various sowing times (Table 5).

Reports are there focusing on the seed yield reduction of mustard in late sowing; but the present study shows higher seed yield in D_3 planting; which indicates better seed yield is possible in later sowing (2, 33). Therefore BARI Sarisha-16 (V_5), Binasarisha-4 (V_1) and Binasarisha-10 (V_3) were the top three seed yield producing variety. This yield potential was genotypic. In the combined effects it was evident that, BARI Sarisha-16 (V_5) tried to give the peak yield on irrespective of sowing times. Consequently, seed yield of Bina varieties was increasing in the later sowing time (D_3). These implies that winter may have shifted to some later time thus some mustard varieties gained better seed yield.

Stover yield

Alike and highest amount of stover yield was gained by D_2 and D_3 sowing times. Relatively extreme stover yield was obtained by BARI Sarisha-16 (V_5) followed by Binasarisha-4 (V_1) and Binasarisha-9 (V_2). In case of interaction effect also BARI Sarisha-16 (V_5) produced the most stover yield in the later sowing times. The Bina varieties gave the second most stover yield with D_2 planting (Table 5).

Stover yield was depended on the plant's capability to accumulate dry matter within a specific period of time. As BARI Sarisha-16 (V_5) followed by Binasarisha-4 (V_1) and Binasarisha-9 (V_2) had the most stover yield their maturity duration (over 90 days) was also higher than other varieties. So, this was depended on varietal trait and plant inherent capacity. It was reported a variable trend of straw yield production among 5 Indian mustard varieties with 3 different sowing dates during winter season (34).

Crop duration

Harvesting maturity was late in case of delayed planting (D_3). While D_1 and D_2 planting had identical maturity period. BARI Sarisha-16 (V_5) and Binasarisha-4 (V_1) had statistically identical and longest maturity period while shortest duration was seen with Binasarisha-10 (V_3). Binasarisha-10 (V_3) with D_1 and D_2 planting matured earliest compared to other treatment interactions. Combined effect of $D_1 \times V_1$ and $D_3 \times V_5$ showed the latest maturity among the treatments (Table 5).

In our findings, delayed sowing enhanced crop duration. Generally, for mustard if seeds are sown very late; it flowers in short time; actually it depends on the weather factors particularly temperature (vernalization) and day length. But interaction effects show that sowing times had little influence on life duration of the mustard varieties; rather it may be the varietal traits where some are suitable for late planting and some for earlier.

previously different durations of six Bangladeshi mustard varieties under saline prone areas were reported (35). Delay in sowing shortened time (days) to flowering and maturity, regardless of mustard varieties was also reported earlier (36). The current outcomes are more or less in line with the above findings.

Correlation among different yield features

Seed yield tends to be strongly and positively associated with the number of siliqua/plant, siliqua length, number of seeds/siliqua and harvest index (HI); this suggests that seed yield would increase with the increase of these yield attributes. But it had a positive non-significant correlation with stover yield, biological yield and crop duration along with negative non-significant relation with 1000 seed weight (Table 6). These outcomes are in line with (37).

Table 6. Link between yield and yield contributing characters.

Parameter	No. of siliqua/ plant	Siliqua length (cm)	No. of seeds/ siliqua	TGW (g)	Seed yield (t/ ha)	Stover yield (t/ ha)	Biological yield (t/ha)	HI (%)	Days to maturity
No. of siliqua/ plant	1	0.99*	0.99*	-0.57NS	0.99*	0.95NS	0.99NS	0.99*	0.96NS
Siliqua length (cm)		1	0.99**	-0.61NS	0.99**	0.94NS	0.98NS	0.99*	0.97NS
No. of seeds/ siliqua			1	-0.59NS	0.99**	0.94NS	0.98NS	0.99*	0.97NS
TGW (g)				1	-0.62NS	-0.30NS	-0.43NS	-0.51NS	-0.78NS

Parameter	No. of siliqua/ plant	Siliqua length (cm)	No. of seeds/ siliqua	TGW (g)	Seed yield (t/ ha)	Stover yield (t/ ha)	Biological yield (t/ha)	HI (%)	Days to maturity
Seed yield (t/ha)					1	0.94NS	0.98NS	0.99*	0.97NS
Stover yield (t/ha)						1	0.99*	0.97NS	0.83NS
Biological yield (t/ha)							1	0.99*	0.90NS
HI (%)								1	0.94NS
Days to maturity									1

NS, not significant; *, P < 0.05 and **, P < 0.01

Conclusion

Current results reveal that optimum planting time of mustard has been shifted from October to November; as yield showed a up lining trend in the late sowing. Therefore, BARI Sarisha-16, BARI Sarisha-17 and Binasarisha-4 gave better yield among the varieties. However, correlation of seed yield to number of siliqua/plant, siliqua length, number of seeds/siliqua and harvest index was highly positive. Notably late planting on 20th November increased seed yield in most varieties. Depending on the current shift of weather, even if farmers plant mustard seeds within the third week of November they don't have to compromise yield rather it may escalate.

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Authors contributions

Author SC planned, designed, executed, did statistical analysis and wrote the initial draft of the manuscript. MI finalized draft portion of the whole manuscript prepared the figures. MSR gathered relevant review of literature and incorporated in the article. MRS, SRG, FA, HMF aided in field data collection and recording. MIA, NAK, MMR wrote the conclusion, furnished the figures, tables and references.

Compliance with ethical standards

Conflict of interest: **:** Authors do not have any conflict of interests to declare.

Ethical issues: None

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