



RESEARCH ARTICLE

# Optimizing sowing dates and varietal adaptation for enhanced yield and sustainable production of Mustard (*Brassica juncea*) in the trans-gangetic region of Punjab

Insha Muzaffar<sup>1</sup>, Shimpy Sarkar<sup>2\*</sup> & Arshdeep Singh<sup>3</sup>

<sup>1</sup>Department of Zoology, School of Bio Engineering and Biosciences, Lovely Professional University, Phagwara 144 411, Punjab, India

<sup>2</sup>Department of Entomology, School of Agriculture, Lovely Professional University, Phagwara 144 411, Punjab, India

<sup>3</sup>Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara 144 411, Punjab, India

\*Correspondence email - [shimpy.23645@lpu.co.in](mailto:shimpy.23645@lpu.co.in)

Received: 01 February 2025; Accepted: 28 March 2025; Available online: Version 1.0: 10 May 2025

**Cite this article:** Insha M, Shimpy S, Arshdeep S. Optimizing sowing dates and varietal adaptation for enhanced yield and sustainable production of Mustard (*Brassica juncea*) in the trans-gangetic region of Punjab. Plant Science Today (Early Access). <https://doi.org/10.14719/pst.7560>

## Abstract

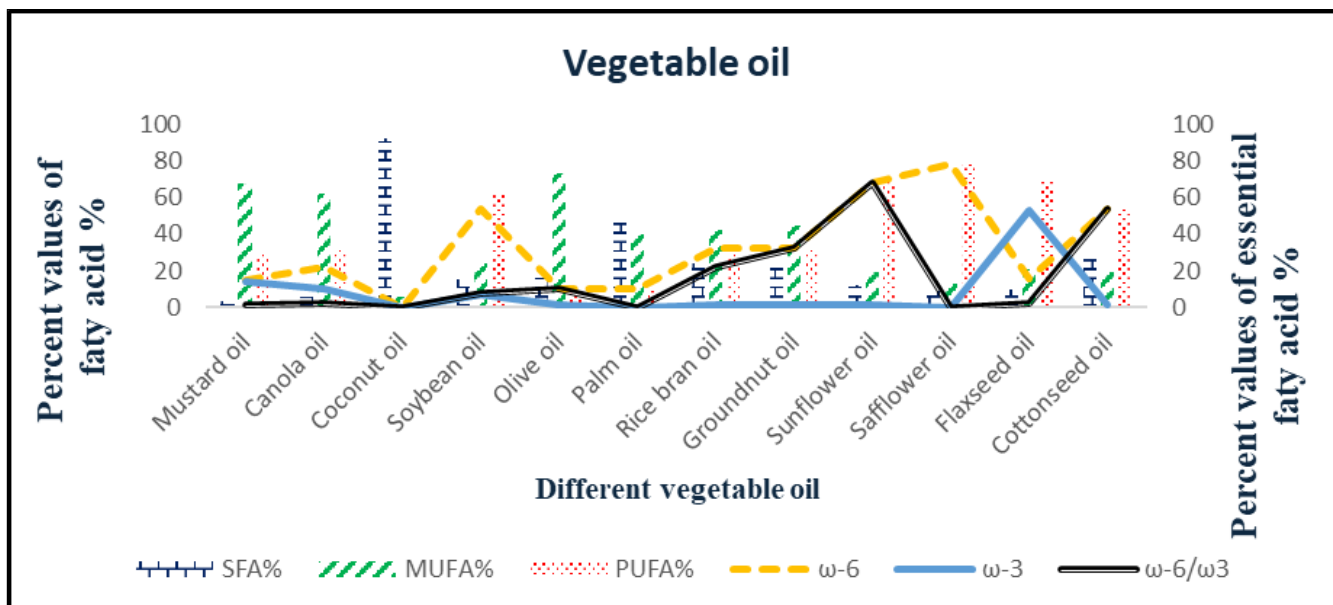
The optimal timing for seeding a crop is essential for maximizing its genetic potential, as it provides the most favorable growing conditions in terms of meteorological parameters. Delay in planting, adverse weather conditions during the flowering period, fertilization and pod formation can result in a reduction in grain production, as well as a decrease in the duration of the maturity phase, the number of siliquae plant<sup>-1</sup> and the number and weight of grains. It is evident from these facts that the timing of mustard sowing has a substantial effect on its production. A field experiment was conducted at the research farm of Lovely Professional University, Jalandhar, Punjab, during the *Rabi* season of 2023-2024, in consideration of these facts. The treatments were comprised of five varieties {V<sub>1</sub> (GSC-07), V<sub>2</sub> (Laxmi-846), V<sub>3</sub> (Durgamani), V<sub>4</sub> (Gujarat Mustard-2) and V<sub>5</sub> (RH-119)} that were replicated thrice under FRBD (Factorial randomized block design). The dates of sowing were as follows: D<sub>1</sub> (15<sup>th</sup> October) for early sown, D<sub>2</sub> (30<sup>th</sup> October) for mid sown and D<sub>3</sub> (15<sup>th</sup> November) for late sown. Data regarding yield attributing parameters and yield were obtained after the harvest. Results revealed that mostly no. of siliqua/plant was obtained with treatment combination D<sub>1</sub>×V<sub>2</sub> (188.820) followed by D<sub>1</sub>×V<sub>3</sub> (186.823), siliqua length (7.467cm) with D<sub>1</sub>×V<sub>2</sub> followed by D<sub>2</sub>×V<sub>2</sub> (7.340 cm), weight of one siliqua/plant (0.150g) by D<sub>1</sub>×V<sub>3</sub> which was at par with D<sub>1</sub>×V<sub>5</sub> and D<sub>2</sub>×V<sub>1</sub>, no. of seeds/siliqua (21.233) by D<sub>1</sub>×V<sub>2</sub> followed by D<sub>2</sub>×V<sub>2</sub> (20.177), weight of seeds/siliqua (0.090g) by D<sub>1</sub>×V<sub>2</sub> which was at par with D<sub>2</sub>×V<sub>1</sub>, test weight (6.967g) by D<sub>1</sub>×V<sub>2</sub> followed by D<sub>2</sub>×V<sub>2</sub> (6.767). Under the agroclimatic conditions of the experimental area, the most effective method of cultivation was the early seeding (15<sup>th</sup> October) and the mid sowing (30<sup>th</sup> October) of the Laxmi-846 (V<sub>2</sub>) variety.

**Keywords :** agronomic practices; mustard; responsible consumption and production; sowing date optimization; varietal adaptation; yield performance

## Introduction

The potential of mustard crops is significant, as they are the third-largest source of edible oil in the world, following palm (*Elaeis guineensis* Jacq.) and soybean (*Glycine max* (L.) Merr.) (Fig. 1). Mustard is a critical component of the nation's oil seed economy. Mustard seeds are composed of 20-25 % protein and 40-45 % oil (1). India is responsible for 20 % of global production and 28 % of global rapeseed-mustard acreage (2). The rapeseed-mustard sector is significantly influenced by India, the world's third-largest producer, following China and Canada (Fig. 2). The area, yield and productivity of this crop in India are 6.9 million hectares, 8.78 million metric tons and 1281 kilograms ha<sup>-1</sup>, respectively (3). Although India occupies an important position on the global oilseed production and acreage map, there is a significant gap between its actual production and its potential (4). Mustard is most frequently cultivated in temperate climates. It is also grown as a cold-

weather crop in certain tropical and subtropical regions. According to reports, Indian mustard can endure soil pH levels between 4.3 and 8.3, temperatures varying from 6 to 27 °C and 500 to 1200 mm of precipitation annually (5). The time of sowing is one of the most significant non-monetary variables that substantially impact the productivity of seeds and oils. Rapeseed and mustard are typically sown in north India between the first week of October and the middle of November (2). Therefore, the timing of mustard cultivation is of the utmost importance. The yield of mustard is reduced when sowing is delayed due to its chilling effects on plant development, flowering duration, seed formation and seed size. Timely fertilization enables the crop plant to complete both the vegetative and reproductive growth periods with a higher yield. In contrast, crops that are planted later are at risk of aphid damage during the flowering and pod development phases, as well as low temperatures during germination and the early



**Fig. 1.** Representing the different vegetable oils' percent value of essential fatty acids.

stages of growth. Consequently, the crop is susceptible to aphid attacks if the sowing process is delayed. The optimal sowing period is essential for the complete utilization of a variety's genetic potential, as it provides the optimal growing conditions, which include temperature, light, humidity and rainfall. The crop's growth period should be aligned with optimal environmental conditions to optimize growth and yield (6). To overcome the aforementioned constraints in mustard production, the present research program aimed to determine the optimal planting time and select a variety that would generate the highest yield in the Jalandhar district of Punjab, taking into account a variety of yield-attributing characteristics.

**Materials and Methods**

**Experimental site**

The research experiment was performed during the cropping season, 2023-2024 at the research farms of Lovely Professional University, Jalandhar, Punjab, India. Geographically, the farm is located at latitude 31.2554°N, longitude 75.7058°E, with an elevation of 235 m above the mean sea level.

**Sowing and agronomic practices**

The land was prepared by tilling once by tractor driven cultivar, one harrowing was done by Disc harrow to obtain the desirable fine seed bed. A uniform dose of RDF (100:60:40 kg NPK ha<sup>-1</sup>) was applied. After a month of emergence of crop for all the three dates of sowing, thinning was carried out, weed control was done manually and no chemicals were used. The experimental farm was irrigated during the growing seasons and harvesting was done at crop maturity. Five varieties/strains namely GSC-07(V<sub>1</sub>), Laxmi-846 (V<sub>2</sub>), Durgamani (V<sub>3</sub>), Gujarat Mustard-2 (V<sub>4</sub>) and RH-119 (V<sub>5</sub>) were sown at three planting dates, early (15<sup>th</sup> October), mid (30<sup>th</sup> October) and late (15<sup>th</sup> November). This was done to find out the maximum yield and yield attributes with respect to the three dates of sowing. Prior to sowing, a laboratory germination test was conducted for each mustard variety in the Agronomy Laboratory of Lovely Professional University to

determine seed viability and establish the appropriate seeding rate. For each variety, a sample of ten seeds was selected and placed on moist filter paper in petri dishes under controlled temperature and light conditions. The seeds were monitored over a period of 7-10 days and the number of seeds that successfully germinated was recorded. Germination was defined as the emergence of a radicle (Fig. 3). The germination percentage was calculated using the following formula

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds tested}} \times 100$$

**Design**

The experiment was laid out in Factorial Randomized Block Design (FRBD) with two factors and three replications. The treatments comprised of three dates of sowing treated as a main factor and five different varieties treated as sub-factor. A total of 45 plots were laid out with the net plot size of 5×4 m for each entry. The row to row spacing was kept as 30 cm while 10 cm was plant to plant spacing. The crop was sown with the seed rate of 4-6 kg ha<sup>-1</sup> at depth of 3-4 cm.

**Observation and analysis**

Observations such as number of siliquae plant<sup>-1</sup>, length of siliqua plant<sup>-1</sup> (cm), weight of one siliqua plant<sup>-1</sup> (g), number of seeds siliqua<sup>-1</sup>, weight of the seeds siliqua<sup>-1</sup> (g), test weight (g), seed yield (q ha<sup>-1</sup>), stover yield (q ha<sup>-1</sup>), biological yield (q ha<sup>-1</sup>) and Harvest Index (HI %) were recorded after the harvest. The seed yield was calculated by weighing the seeds harvested from each plot and converted to q ha<sup>-1</sup>. Using sun drying, the stover yield (q ha<sup>-1</sup>) was determined. Biological yield and HI (%) was recorded using the following formulae.

$$\text{Biological yield (q ha}^{-1}\text{)} = \text{seed yield} + \text{stover yield}$$

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The biological yield from each plot was computed

by adding seed yield to stover yield of the individual plot and expressed in  $q\ ha^{-1}$ . The HI for each plot was calculated from the ratio of seed yield to biological yield and expressed in terms of percentage (7). Five plants were sampled for every observation. Analysis of Variance (ANOVA) from the data was employed to compute variable effects in both the factors and their interaction. Significant differences between means of sowing dates, varieties and interactions were determined by CD. Treatment means were compared at the 5 %, 1 %, 0.1 % level of significance ( $P=0.05$ ,  $P=0.01$ ,  $P=0.001$ ) using CD and hence results based on pooled analysis are presented here to draw logical inferences. Pearson correlation was employed to ascertain the link between the yield and yield parameters at 5 % significance level, evaluating both significant and non-significant parameters. Principal Component Analysis (PCA) was done using GRAPES software.

## Results and Discussion

### Pre-sowing germination test

The results of germination indicated that variety Laxmi-846 ( $V_2$ ) exhibited the highest germination rate (100 %), varieties Durgamani ( $V_3$ ) and RH-119 ( $V_5$ ) recorded identical germination percentages, with 90 % of the seeds successfully germinating followed by GSC-07 ( $V_1$ ) which displayed a germination percentage of 80 % while variety Gujarat Mustard-6 ( $V_4$ ) exhibited the lowest germination rate (70 %). The differences in germination percentages observed among the mustard varieties suggest variability in seed viability which could significantly influence early stand establishment and subsequent yield.

### Yield attributes of mustard

**Number of siliquae plant<sup>-1</sup>:** Under early sowing ( $D_1$ ), the highest number of siliquae per plant (184.002) was observed, followed by the right time sowing ( $D_2$ ) and late sowing ( $D_3$ ). Laxmi-846 ( $V_2$ ) exhibited the maximum siliqua count (168.144) among the varieties, while Gujarat Mustard-6 ( $V_4$ ) recorded the lowest (155.064). The highest siliquae number (188.820) was achieved by the combination of early sowing ( $D_1$ ) with Laxmi-846 ( $V_2$ ), while the lowest siliquae count (135.447) was achieved by the combination of late sowing ( $D_3$ ) with Gujarat Mustard-6 ( $V_4$ ) (Table 1). The varietal characteristics of Laxmi-846 ( $V_2$ ) may be responsible for its consistently high siliqua count across all sowing dates, which indicates its adaptability to early, timely and late planting. Consequently, the fertilization date had a negligible effect on the production of siliqua for this variety. These results are consistent with those reported by (8).

**Length of siliqua per plant (cm) :** The maximum length of siliqua (6.462 cm) was recorded with  $D_1$  planting time, which was more than  $D_2$  and  $D_3$ . Laxmi-846 ( $V_2$ ) exhibited the longest siliqua (6.918 cm), followed by Durgamani ( $V_3$ ) and RH - 119 ( $V_5$ ), which appeared to have statistically identical siliqua lengths. Treatment interactions indicated that the longest siliqua (7.467 cm) was observed with  $D_1 \times V_2$ , while the shortest (3.557 cm) was identified with  $D_3 \times V_4$  (Table 1). Genetics, environmental conditions, agronomic practices and stress factors all contribute to the multifactorial trait of siliqua

length. It was discovered that the siliqua length in Gujarat Mustard-2 ( $V_4$ ) is reduced because of late sowing. This implies that the optimal sowing time for this variety is not  $D_3$ . BARI Sarisha-14 has yielded comparable results (9).

**Weight of one siliqua per plant (g):** The highest (0.141 g) weight of siliqua was recorded with early sowing ( $D_1$ ) while sowing of 30<sup>th</sup> October produced the lowest (0.123 g) siliqua weight. GSC-07( $V_1$ ) produced the highest (0.139 g) siliqua and the lowest (0.123 g) siliqua was recorded by RH-119 ( $V_5$ ). In terms of treatment interactions,  $D_1 \times V_3$ ,  $D_1 \times V_5$  and  $D_2 \times V_1$  had statistically identical maximum (0.150 g) siliqua weight and minimum (0.103 g) was recorded in  $D_2 \times V_5$  (Table 1). Siliqua weight was significantly lowest with the mid sowing ( $D_2$ ) which was also revealed from the interaction effect. Since different mustard varieties have different genetic compositions, their siliqua characteristics differ (10). This may be attributed to the varietal trait that GSC-07 has longer and heavier siliqua and RH-119 has shorter and lighter siliqua. The current findings are in line with previous results (11).

**No. of seeds per siliqua:**  $D_1$  recorded the maximum (18.869) number of seeds per siliqua followed by  $D_2$ . Among the mustard varieties, Laxmi-846 ( $V_2$ ) generated the maximum (19.404) number of seeds and the minimum (14.078) was marked with Gujarat Mustard-2 ( $V_4$ ). Interestingly, Laxmi-846 ( $V_2$ ) recorded the highest (21.233) seed number at both early ( $D_1$ ) as well as mid planting ( $D_2$ ). The lowest (11.583) seed number was noted with Gujarat Mustard-2 ( $V_4$ ) at late planting ( $D_3$ ) (Table 1). Late sowing resulted in the decrease in seed number for all the mustard varieties. High temperatures and long days hastened the pod development phase, resulting in faster pod maturity and reduced seed number (12).

**Weight of seeds per siliqua (g):** Early planting of 15<sup>th</sup> October ( $D_1$ ) produced the highest (0.072g) seed weight per siliqua followed by  $D_2$  and  $D_3$ . Laxmi-846 ( $V_2$ ) produced the maximum (0.069 g) seed weight per siliqua followed by Durgamani ( $V_3$ ) and RH-119 ( $V_5$ ) which seemed to have statistically identical seed weight per siliqua. In case of interaction effect maximum (0.090g) seed weight per siliqua was noted with  $D_1 \times V_2$  and the minimum (0.023g) was obtained by Gujarat Mustard-2 ( $V_4$ ) with  $D_3$  planting time (Table 1).

Seed weight per siliqua was obtained lowest for the late sowing ( $D_3$ ). The reason for the lower seed weight may be attributed to the changes in weather parameters, temperature and day length variations that affected crop development, which in turn caused poor seed filling in siliqua and a drop in seed weight siliqua<sup>-1</sup> (13).

**Test weight (g):** Planting on October 15<sup>th</sup> ( $D_1$ ) yielded the heaviest (4.540) and boldest grain, whereas the late planting on November 15<sup>th</sup> ( $D_3$ ) yielded the lightest (3.944) seed weight. Among the varieties, Laxmi-846 ( $V_2$ ) produced the highest (4.568) test weight and the lowest (3.572) thousand grain weight was recorded by Gujarat Mustard-2 ( $V_4$ ). Laxmi-846 ( $V_2$ ) planted at  $D_1$  and Durgamani ( $V_3$ ) planted at  $D_1$  both exhibited statistically identical maximum (4.923), (4.893) test weight over all other treatment amalgamations. Combined effect of  $D_2 \times V_4$  and  $D_3 \times V_4$  produced minimum (3.417) test weight which seemed to be statistically identical. Test weight

**Table 1.** Yield attributes of mustard under various treatments and their amalgamation

Treatments	No. of siliqua/plant	Siliqua length (cm)	Weight of one siliqua/plant (g)	No. of seeds/siliqua	Weight of seeds / siliqua(g)	Test weight (g)
<i>Sowing Dates</i>						
D <sub>1</sub> (15 <sup>th</sup> Oct.)	184.002 <sup>a</sup>	6.462 <sup>a</sup>	0.141 <sup>a</sup>	18.869 <sup>a</sup>	0.072 <sup>a</sup>	4.540 <sup>a</sup>
D <sub>2</sub> (30 <sup>th</sup> Oct.)	158.701 <sup>b</sup>	5.896 <sup>b</sup>	0.123 <sup>c</sup>	17.700 <sup>b</sup>	0.053 <sup>b</sup>	4.085 <sup>b</sup>
D <sub>3</sub> (15 <sup>th</sup> Nov.)	142.946 <sup>c</sup>	4.725 <sup>c</sup>	0.133 <sup>b</sup>	14.308 <sup>c</sup>	0.037 <sup>c</sup>	3.944 <sup>c</sup>
CD (P = 0.05)	0.82	0.38	0.01	0.55	0.00	0.05
SEm±	0.28	0.13	0.00	0.19	0.00	0.02
Treatments	No. of siliqua/plant	Siliqua length (cm)	Weight of one siliqua/plant (g)	No. of seeds/siliqua	Weight of seeds / siliqua(g)	Test weight (g)
<i>Variety</i>						
GSC-07 (V <sub>1</sub> )	159.158 <sup>d</sup>	5.166 <sup>c</sup>	0.139	15.924 <sup>d</sup>	0.044 <sup>c</sup>	4.058 <sup>d</sup>
Laxmi-846 (V <sub>2</sub> )	168.144 <sup>a</sup>	6.918 <sup>a</sup>	0.132	19.404 <sup>a</sup>	0.069 <sup>a</sup>	4.568 <sup>a</sup>
Durgamani (V <sub>3</sub> )	164.929 <sup>b</sup>	6.204 <sup>b</sup>	0.133	18.174 <sup>b</sup>	0.060 <sup>b</sup>	4.459 <sup>b</sup>
Gujarat Mustard-2 (V <sub>4</sub> )	155.064 <sup>e</sup>	4.218 <sup>d</sup>	0.134	14.078 <sup>e</sup>	0.040 <sup>c</sup>	3.572 <sup>e</sup>
RH-119 (V <sub>5</sub> )	162.120 <sup>c</sup>	5.967 <sup>b</sup>	0.123	17.213 <sup>c</sup>	0.056 <sup>b</sup>	4.291 <sup>c</sup>
CD (P = 0.05)	1.06	0.50	-	0.70	0.00	0.07
SEm±	0.37	0.17	0.00	0.24	0.00	0.02
Sowing Time × Variety	No. of siliqua/plant	Siliqua length (cm)	Weight of one siliqua/plant (g)	No. of seeds/siliqua	Weight of seeds siliqua(g)	Test weight (g)
D <sub>1</sub> ×V <sub>1</sub>	181.740 <sup>d</sup>	5.833	0.130 <sup>bcd</sup>	17.997	0.063	4.327 <sup>d</sup>
D <sub>1</sub> ×V <sub>2</sub>	188.820 <sup>a</sup>	7.467	0.147 <sup>ab</sup>	21.233	0.090	4.923 <sup>a</sup>
D <sub>1</sub> ×V <sub>3</sub>	186.823 <sup>b</sup>	7.167	0.150 <sup>a</sup>	19.623	0.083	4.893 <sup>a</sup>
D <sub>1</sub> ×V <sub>4</sub>	178.750 <sup>e</sup>	4.933	0.130 <sup>bcd</sup>	16.793	0.053	3.883 <sup>h</sup>
D <sub>1</sub> ×V <sub>5</sub>	183.877 <sup>c</sup>	6.910	0.150 <sup>a</sup>	18.697	0.070	4.673 <sup>b</sup>
D <sub>2</sub> ×V <sub>1</sub>	155.850 <sup>f</sup>	5.597	0.150 <sup>a</sup>	16.763	0.043	4.033 <sup>g</sup>
D <sub>2</sub> ×V <sub>2</sub>	166.320 <sup>f</sup>	7.340	0.127 <sup>cde</sup>	20.177	0.067	4.457 <sup>c</sup>
D <sub>2</sub> ×V <sub>3</sub>	161.907 <sup>g</sup>	6.190	0.110 <sup>ef</sup>	19.200	0.057	4.337 <sup>d</sup>
D <sub>2</sub> ×V <sub>4</sub>	150.997 <sup>i</sup>	4.163	0.127 <sup>cde</sup>	13.857	0.043	3.417 <sup>i</sup>
D <sub>2</sub> ×V <sub>5</sub>	158.433 <sup>h</sup>	6.190	0.103 <sup>f</sup>	18.503	0.053	4.180 <sup>e</sup>
D <sub>3</sub> ×V <sub>1</sub>	139.883 <sup>m</sup>	4.067	0.137 <sup>abc</sup>	13.013	0.027	3.813 <sup>h</sup>
D <sub>3</sub> ×V <sub>2</sub>	149.293 <sup>j</sup>	5.947	0.123 <sup>cde</sup>	16.803	0.050	4.323 <sup>d</sup>
D <sub>3</sub> ×V <sub>3</sub>	146.057 <sup>k</sup>	5.257	0.140 <sup>abc</sup>	15.700	0.040	4.147 <sup>ef</sup>
D <sub>3</sub> ×V <sub>4</sub>	135.447 <sup>n</sup>	3.557	0.147 <sup>ab</sup>	11.583	0.023	3.417 <sup>i</sup>
D <sub>3</sub> ×V <sub>5</sub>	144.050 <sup>l</sup>	4.800	0.117 <sup>def</sup>	14.440	0.043	4.020 <sup>g</sup>
CD (P = 0.05)	1.83	-	0.02	-	-	0.12
SEm±	0.63	0.30	0.01	0.42	0.00	0.04
CV	0.68	9.02	8.62	4.30	15.96	1.69

seemed to be influenced by both the factors, sowing date and variety. Both sowing dates and mustard variety selection play critical roles in determining the test weight of mustard. Sowing at an optimal time with a variety that aligns well with the local climate and growing conditions generally leads to higher test weights, while delayed sowing or the choice of unsuitable varieties can result in lower seed weights (14).

### Yield and yield characters

**Seed yield (q/ha):** The highest (21.181 q/ha) seed yield was obtained by D<sub>1</sub> planting followed by D<sub>2</sub> and lowest (16.285) by D<sub>3</sub>. Relatively maximum (22.139 q/ha) seed yield was recorded in Laxmi-846 (V<sub>2</sub>) followed by Durgamani (V<sub>3</sub>) and RH-119 (V<sub>5</sub>). Interaction effects exhibited the maximum (24.713q/ha) (22.403q/ha) yield of Laxmi-846 over D<sub>1</sub> and D<sub>2</sub> and Durgamani (V<sub>3</sub>) over D<sub>1</sub> (22.677q/ha) planting time. Gujarat Mustard-2 (V<sub>4</sub>) produced minimum (12.590q/ha) yield in the later sowing time (D<sub>3</sub>) (Table 2). Our findings are like those reported previously which indicate that late planting leads to possible decrease in the seed yield as late-sown mustard crops have a shorter growing period, meaning less time for vegetative growth before the flowering and seed-setting stages, which limits biomass and yield potential. Also, late sowing exposes the crop to higher temperatures during critical growth stages which can lead to premature flowering and quicker seed maturation, reducing seed size and quality. Late sowing can increase susceptibility to pests (like aphids) and diseases due to higher population levels in warmer, late-season conditions.

These stresses can significantly affect seed yield (14).

**Stover yield (q/ha):** Early planting (D<sub>1</sub>) noted the highest (27.527) amount of stover yield followed by mid planting (D<sub>2</sub>). Among the varieties, the maximum (27.683) stover yield was produced by Laxmi-846 (V<sub>2</sub>) followed by Durgamani (V<sub>3</sub>) and RH-119 (V<sub>5</sub>). Combined effects revealed that most (30.953) stover yield was gained with D<sub>1</sub>×V<sub>2</sub> and least (17.477) with D<sub>3</sub>×V<sub>4</sub> (Table 2).

Different mustard varieties have distinct genetic potential for growth, biomass accumulation and stover yield. As Laxmi-846 (V<sub>2</sub>) generated the highest stover yield for the early planting D<sub>1</sub> compared to the mid and late sowing dates (D<sub>2</sub> and D<sub>3</sub>). So, this can be attributed to the planting schedule and varietal adaptation. Early sowing allows mustard plants to grow during periods with better light conditions, leading to enhanced photosynthesis and more biomass accumulation whereas late sowing can shorten the time available for the crop to capture light, reducing growth and stover yield. Moreover, late-sown crops often experience higher temperatures, which accelerate the transition from vegetative growth to reproductive phases, shortening the period available for stover accumulation (15, 16).

### Biological yield (q/ha)

The highest (48.708 q/ha) biological yield was gained by early planting date (D<sub>1</sub>) and D<sub>3</sub> generated the lowest (35.519 q/ha) biological yield. The maximum (49.822 q/ha) biological yield was produced by Laxmi-846 (V<sub>2</sub>) followed by Durgamani (V<sub>3</sub>) while minimum (35.903 q/ha) biological yield was seen with

**Table 2.** Yield and yield characters under different treatments and their amalgamation

Treatments Sowing Dates	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	HI (%)
D <sub>1</sub> (15 <sup>th</sup> Oct.)	21.181 <sup>a</sup>	27.527 <sup>a</sup>	48.708 <sup>a</sup>	43.437
D <sub>2</sub> (30 <sup>th</sup> Oct.)	18.849 <sup>b</sup>	23.547 <sup>b</sup>	42.397 <sup>b</sup>	44.434
D <sub>3</sub> (15 <sup>th</sup> Nov.)	16.285 <sup>c</sup>	21.235 <sup>c</sup>	37.519 <sup>c</sup>	43.263
CD (P = 0.05)	0.71	0.72	1.18	-
SEm±	0.25	0.25	0.41	0.35
Treatments Variety	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	HI (%)
GSC-07 (V <sub>1</sub> )	16.860 <sup>d</sup>	22.369 <sup>d</sup>	39.229 <sup>d</sup>	42.931
Laxmi-846 (V <sub>2</sub> )	22.139 <sup>a</sup>	27.683 <sup>a</sup>	49.822 <sup>a</sup>	44.406
Durgamani (V <sub>3</sub> )	20.584 <sup>b</sup>	25.988 <sup>b</sup>	46.572 <sup>b</sup>	44.244
Gujarat Mustard-2 (V <sub>4</sub> )	15.504 <sup>e</sup>	20.399 <sup>e</sup>	35.903 <sup>e</sup>	43.140
RH-119 (V <sub>5</sub> )	18.771 <sup>c</sup>	24.076 <sup>c</sup>	42.847 <sup>c</sup>	43.836
CD (P = 0.05)	0.92	0.93	1.52	-
SEm±	0.32	0.32	0.53	0.46
Treatments Sowing Dates × Variety	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	HI (%)
D <sub>1</sub> ×V <sub>1</sub>	19.383	25.593	44.977	43.087
D <sub>1</sub> ×V <sub>2</sub>	24.713	30.953	55.667	44.380
D <sub>1</sub> ×V <sub>3</sub>	22.677	29.373	52.050	43.560
D <sub>1</sub> ×V <sub>4</sub>	18.330	24.270	42.600	43.033
D <sub>1</sub> ×V <sub>5</sub>	20.803	27.443	48.247	43.123
D <sub>2</sub> ×V <sub>1</sub>	16.827	21.573	38.400	43.827
D <sub>2</sub> ×V <sub>2</sub>	22.403	27.503	49.907	44.880
D <sub>2</sub> ×V <sub>3</sub>	20.520	25.803	46.323	44.300
D <sub>2</sub> ×V <sub>4</sub>	15.593	19.450	35.043	44.490
D <sub>2</sub> ×V <sub>5</sub>	18.903	23.407	42.310	44.673
D <sub>3</sub> ×V <sub>1</sub>	14.370	19.940	34.310	41.880
D <sub>3</sub> ×V <sub>2</sub>	19.300	24.593	43.893	43.957
D <sub>3</sub> ×V <sub>3</sub>	18.557	22.787	41.343	44.873
D <sub>3</sub> ×V <sub>4</sub>	12.590	17.477	30.067	41.897
D <sub>3</sub> ×V <sub>5</sub>	16.607	21.377	37.983	43.710
CD (P = 0.05)	-	-	-	-
SEm±	0.55	0.55	0.91	0.79
CV	5.08	3.98	3.68	3.13

Values in a column having different letter (s) differ significantly at 5 %, 1 % and 0.1 % level of probability according to CD, Minimum value between the interaction, NS, not significant, \*, P < 0.05, \*\*, P < 0.01 and \*\*\*, P < 0.001 by analysis of variance with randomized complete block design

Gujarat Mustard-2 (V<sub>4</sub>). Treatment combinations showed that highest (55.667 q/ha) biological yield was seen with D<sub>1</sub>×V<sub>2</sub>, followed by D<sub>1</sub>×V<sub>3</sub> and the least (17.477 q/ha) was marked with D<sub>3</sub>×V<sub>4</sub> (Table 2).

Since Laxmi-846 (V<sub>2</sub>) exhibited the highest biological yield under early planting (D<sub>1</sub>). This may be because of the varietal adaptability to different environmental conditions and their genetic potential which allows them to exhibit varying capacities for biomass production (17). In addition, early sowing extends the growing period, allowing mustard plants to fully utilize available sunlight, moisture and nutrients. This longer vegetative and reproductive phase contributes to higher biomass accumulation and consequently, higher biological yield. In contrast, late sowing can expose mustard to warmer temperatures during the reproductive phase, shortening the growth period and reducing biomass production (18). The biological yield of mustard under different planting dates and reported a decline in the biological yield under late planting (16).

### Harvest Index (HI)

Mid planting (D<sub>2</sub>) induced a significantly maximum (44.434 %) HI over D<sub>1</sub> and D<sub>3</sub> planting. Contrary, Laxmi-846 (V<sub>2</sub>) exhibited highest (44.406 %) HI while the lowest (42.931 %) was generated by GSC-07 (V<sub>1</sub>). In terms of combination effects, the highest (44.38 %) HI was acquired by D<sub>2</sub>×V<sub>2</sub> and D<sub>3</sub>×V<sub>1</sub> marked

the lowest (41.88 %) HI. As GSC-07 (V<sub>1</sub>) noted the least HI for the late planting date (D<sub>3</sub>). Late sowing tends to reduce the harvest index in mustard by diminishing both the biomass and the economic yield. The extent of the reduction depends on the specific variety and its adaptability to heat stress or shorter growing periods (16, 19).

### Correlation among different yield attributes

Table 3 represents a correlation matrix that displays the correlation coefficients between multiple variables, which shows the strength and direction of the relationship between each pair of variables. This table provides insight into how strongly yield attributes are related to each other and to the yield. Each cell in the table represents the correlation coefficient (rr) between two traits. The values range from -1 to +1. Positive values indicate a direct relationship (as one trait increases, the other tends to increase). Negative values indicate an inverse relationship. Values closer to ±1 indicate strong correlations, while values close to 0 suggest weak or no correlation. (Fig. 4) figured that number of siliquae per plant had a highly significant and positive correlation with siliqua length per plant (0.716), number of seeds per siliqua (0.789), weight of seeds per siliqua (0.852), test weight (0.746), seed yield (0.779), stover yield (0.845) and biological yield (0.825). But it had a positive nonsignificant correlation with weight of one siliqua per plant and harvest index. Siliqua length per plant

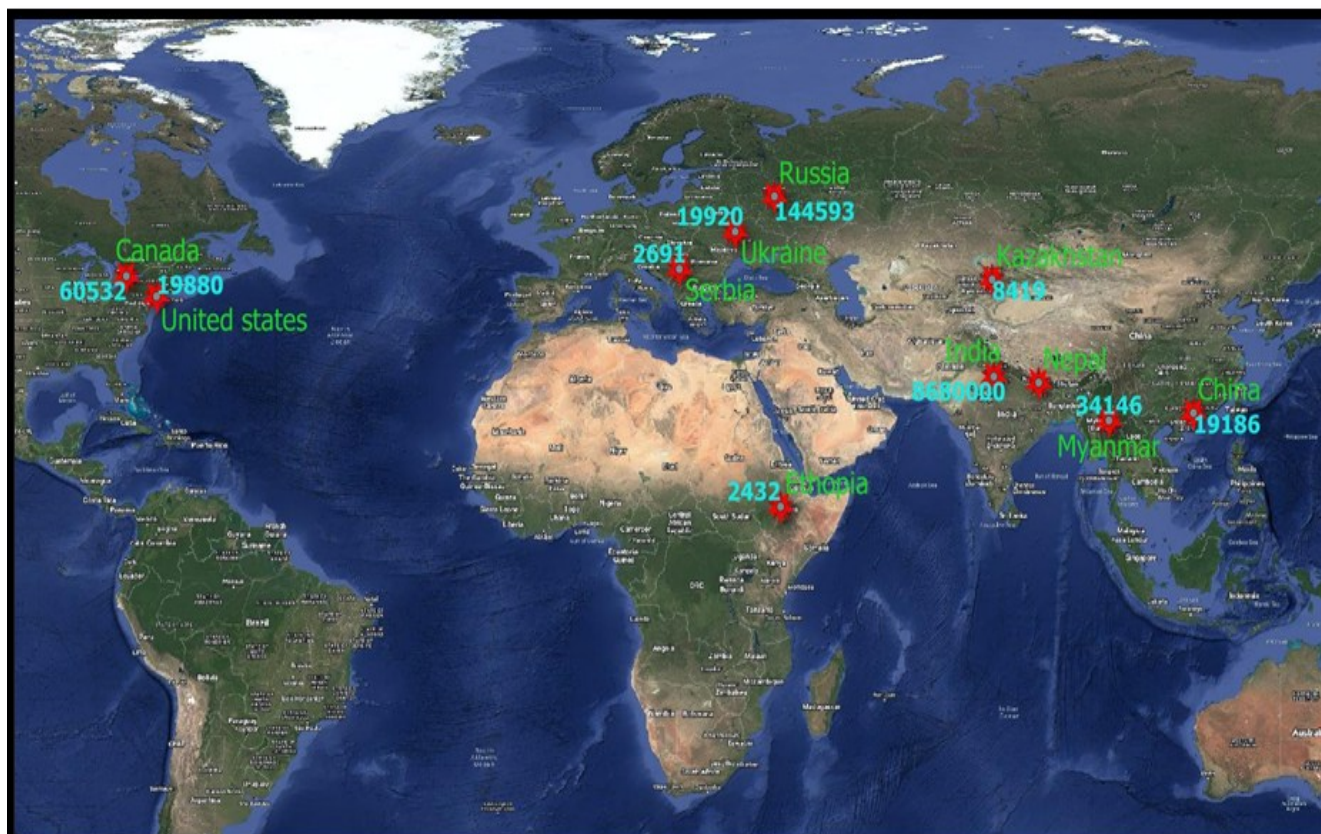
**Table 3.** Pearson correlation between yield and yield contributing characters

Parameters	No. of siliqua/plant	Siliqua length/plant (cm)	Weight of one siliqua/plant (g)	No. of seeds/siliqua	Weight of seeds/Siliqua (g)	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	HI (%)
No. of siliqua/plant	1	0.716***	0.212NS	0.789***	0.852***	0.746***	0.779***	0.845***	0.825***	0.089NS
Siliqua length/plant (cm)		1	0.052NS	0.864***	0.792***	0.891***	0.881***	0.889***	0.896***	0.267NS
Weight of one siliqua/plant (g)			1	-0.016NS	0.166NS	0.153NS	0.056NS	0.086NS	0.073NS	-0.082NS
No. of seeds siliqua				1	0.83***	0.86***	0.913***	0.906***	0.921***	0.316*
Weight of seeds/siliqua (g)					1	0.814***	0.863***	0.871***	0.878***	0.268NS
Test weight (g)						1	0.896***	0.936***	0.929***	0.174NS
Seed yield (q/ha)							1	0.951***	0.986***	0.416**
Stover yield (q/ha)								1	0.989***	0.168NS
Biological yield (q/ha)									1	0.308*
HI (%)										1

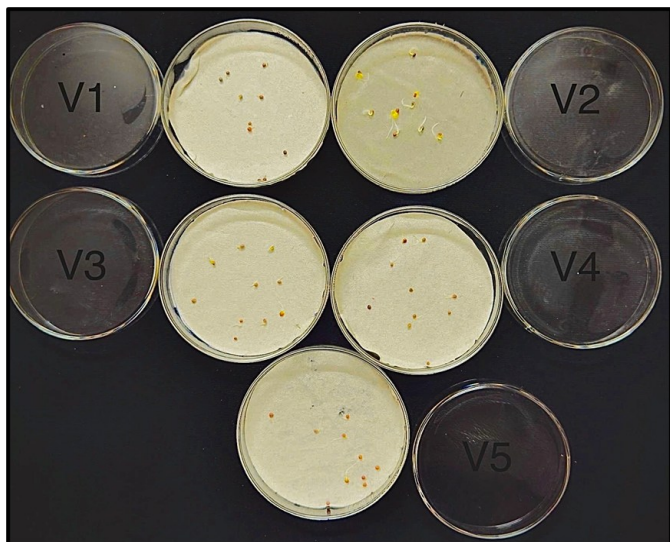
NS, not significant; \*, P < 0.05, \*\*, P < 0.01 and \*\*\*, P < 0.001

implied highly significant and positive correlation with number of seeds per siliqua (0.864), weight of seeds per siliqua (0.792), test weight (0.891), seed yield (0.881), stover yield (0.889) and biological yield (0.896) but a non-significant and positive correlation with weight of one siliqua per plant and HI. Weight of one siliqua per plant had a non-significant positive correlation with weight of seeds per siliqua, test weight, seed yield, stover yield and biological yield. However, a non-significant negative correlation was established with number of seeds per siliqua (-0.016) and HI (-0.082). Number of seeds per siliqua showed a highly significant and positive correlation with weight of seeds per siliqua (0.83), test weight (0.86), seed yield (0.913), stover yield (0.906) and biological yield (0.921) and a significant, positive correlation with HI (0.316). Weight of seeds per siliqua had a highly significant and positive correlation with

test weight (0.814 g), seed yield (0.863 q/ha), stover yield (0.871 q/ha) and biological yield (0.878 q/ha) but a nonsignificant and positive correlation with HI. Test weight established a highly significant and positive correlation with seed yield (0.896 q/ha), stover yield (0.936 q/ha) and biological yield (0.929 q/ha) but a nonsignificant positive correlation with HI (0.174 %). Seed yield implied a highly significant and positive correlation with stover yield (0.951 q/ha) and biological yield (0.986 q/ha) and a significant positive correlation with HI (0.416 q/ha). Stover yield had a highly significant and positive correlation with biological yield (0.989 q/ha) and a nonsignificant positive correlation with harvest index. Biological yield implied a significant positive correlation with HI (0.308) (20).



**Fig. 2.** Representing the world mustard producing countries with their production in Tonnes.

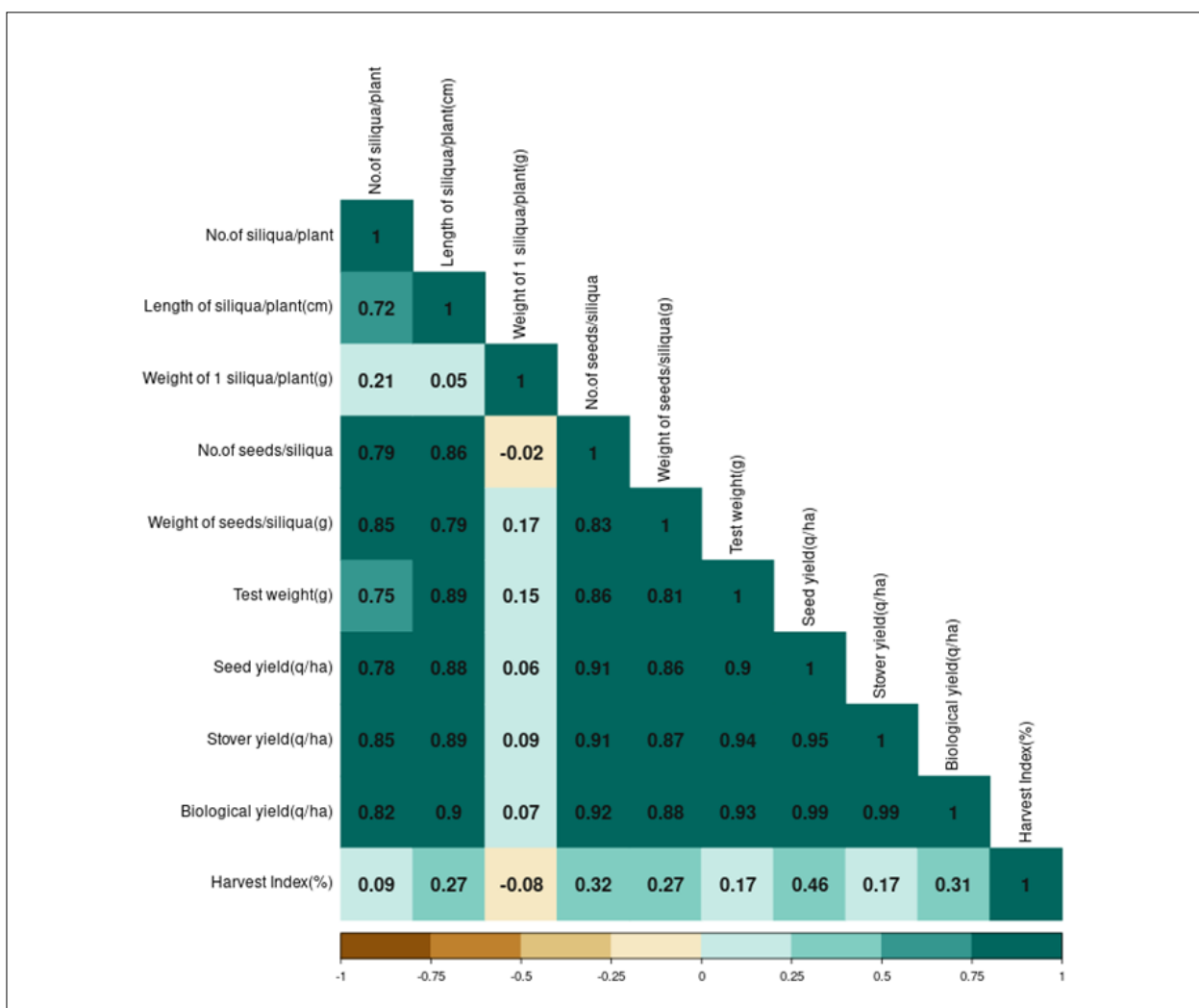


**Fig. 3.** Representing the emergence of radicle in Mustard varieties during germination test.

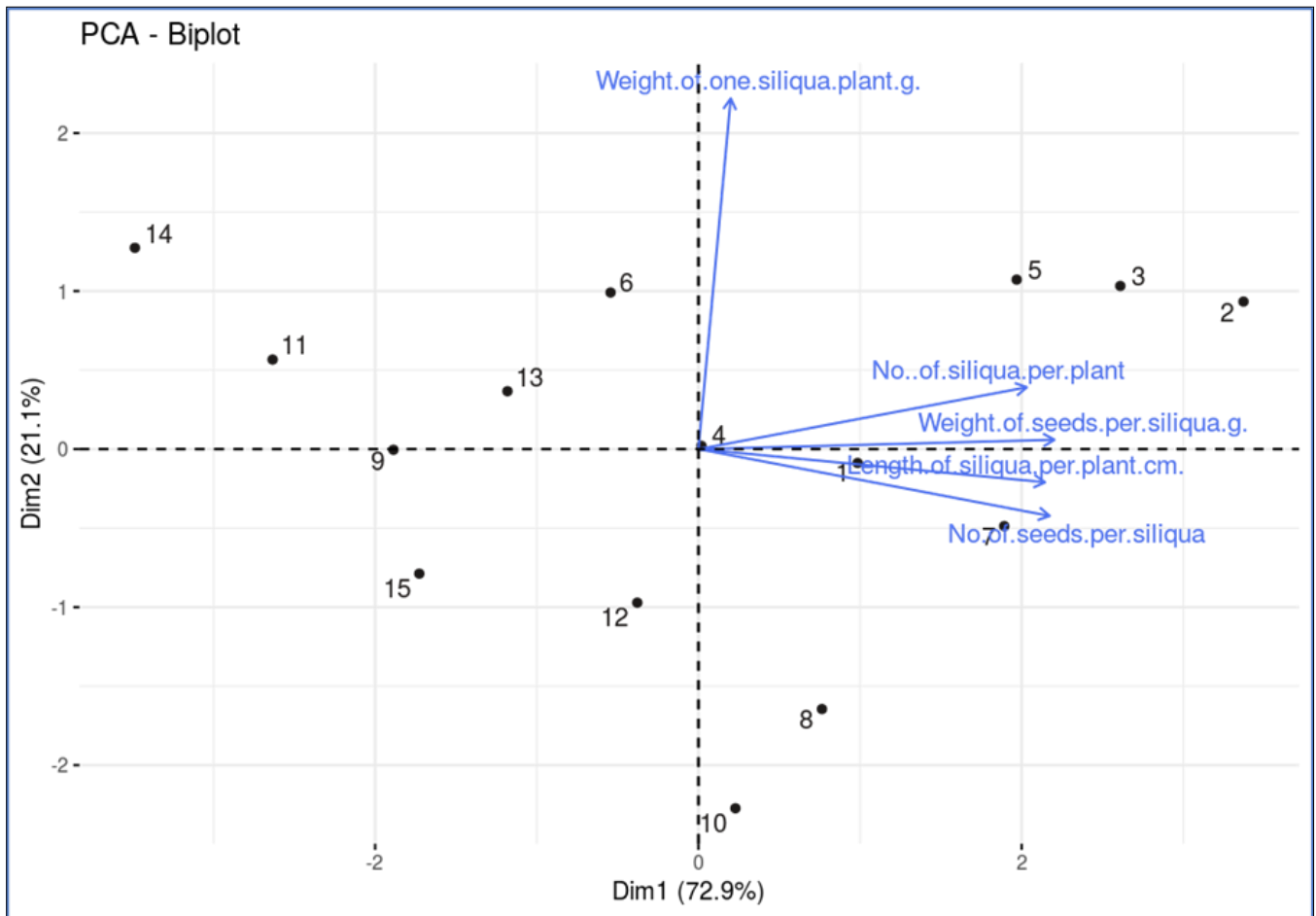
### Principal Component Analysis (PCA)

Fig. 5 image represents a PCA biplot, commonly used to diminish data dimensionality and illustrate the variation explained by various factors in a two-dimensional framework. The centre signifies a connection space. Points nearer to the circumference of the circle have a stronger correlation with the

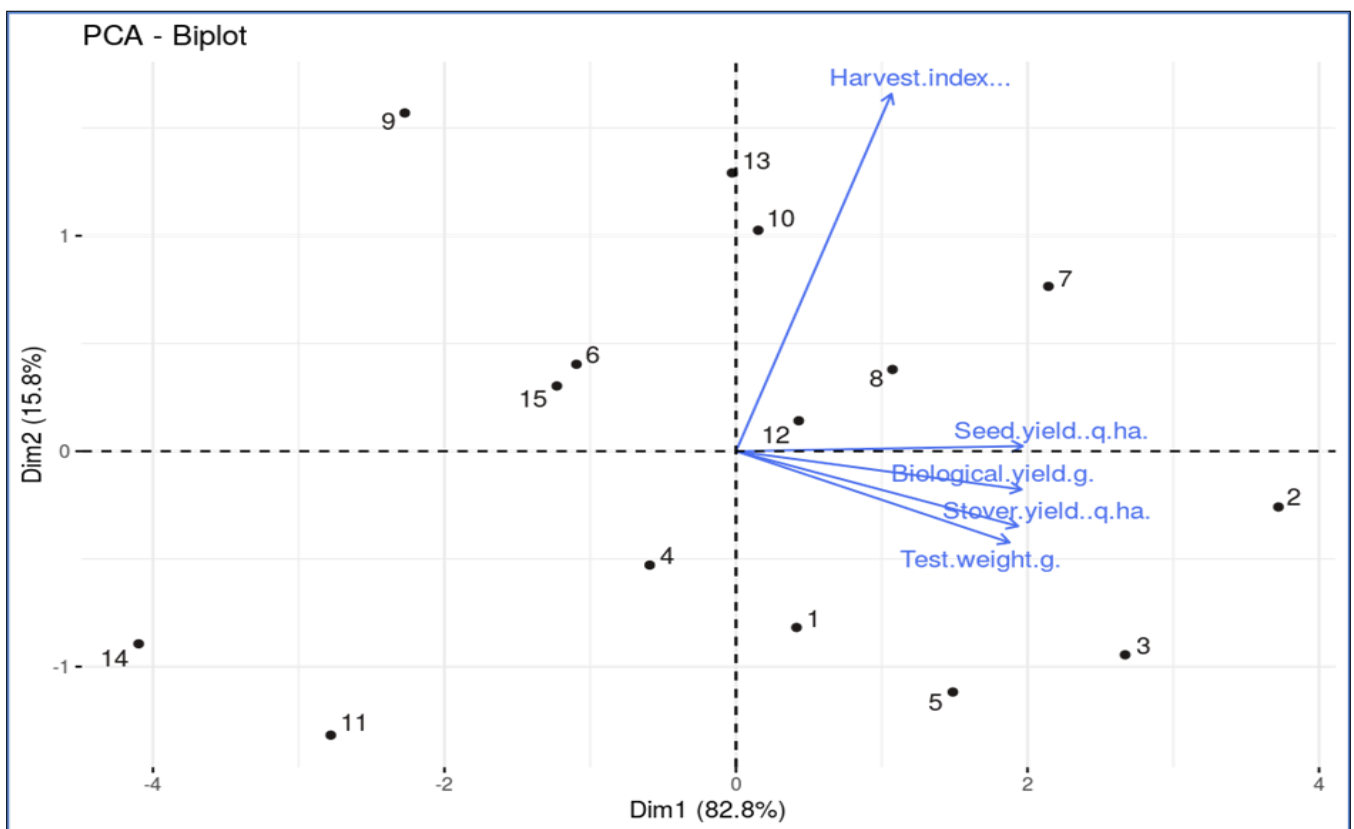
principal components (PC1 and PC2, generally the axes). Points proximate to the origin have a modest correlation. The variables, including  $D_1 \times V_2$  (number of siliqua plant<sup>-1</sup>),  $D_1 \times V_3$  (weight of seeds siliqua<sup>-1</sup>),  $D_1 \times V_2$  (length of siliqua plant<sup>-1</sup>) and  $D_1 \times V_2$  (number of seeds siliqua<sup>-1</sup>), positively influence the first principal component (horizontal axis), indicating that these qualities likely exhibit concurrent variation in the same direction. However, the variable (weight of one siliqua plant<sup>-1</sup>) with longer arrow exerts a more significant impact on the data structure. These characteristics are crucial for elucidating the variance along PC1. Variables that align in the same direction exhibit positive correlations, whereas those that diverge exhibit negative correlations. Path coefficient analysis allows for the comparison of the component elements based on their relative contributors and is more helpful in distinguishing between the direct and indirect impacts of correlation (21). Fig. 6 biplot illustrates the correlations among various yield-related variables (e.g., test weight, seed yield, stover yield, biological yield and harvest index) and their contributions to the fundamental framework of the data (principal components). The variable (HI) with longer arrow exerts a more significant impact on the data structure. The proximity and orientation of arrows provide insight into the interrelationship of the variables (22).



**Fig. 4.** Correlation heat map between yield and yield attributes of Mustard illustrating the pairwise correlations among several yield characteristics. Every column in the matrix denotes the correlation coefficient, which ranges from -1 to 1, between two parameters. Dark green signifies a strong positive correlation (+1 indicates a perfect positive correlation). Brown signifies a strong negative correlation (-1 denotes a perfect negative correlation). Slight lighter shades in the center indicate lower interactions, approaching 0 (no correlation).



**Fig. 5.** Principal Component Analysis (PCA) biplot showing the relationship between yield attributes and the two principal components. The arrows represent the following traits: No. of siliqua/plant, length of siliqua/plant, weight of 1 siliqua/plant, no. of seeds/siliqua, weight of seeds/siliqua and test weight. The direction and length of the arrows indicate the contribution of each attribute to the principal components.



**Fig. 6.** PCA biplot, showing the relationship between various yield and yield-related characters and their contributions to the principal components. The arrows represent the following characters: Test weight, seed yield, stover yield, biological yield and harvest index. The direction and length of the arrows indicate the contribution of each character to the principal components.



## Conclusion

Most yield attributes recorded highest under planting on October 15<sup>th</sup>, according to our results. Additionally, varietal adaptability was also seen. Laxmi-846 achieved the highest biological yield at every sowing time, indicating a broad range of adaptation during the planting periods. This research has shown that both sowing date and mustard variety has significant impact on yield parameters and yield. These findings provide actionable recommendations for improving mustard crop productivity through informed decision-making. Although our study is limited, future research that includes a wider range of environmental factors and agronomic practices will further enhance the applicability of these recommendations across different mustard-growing regions.

## Acknowledgements

Authors are highly thankful for the Lovely Professional University for funding to conduct the research and all the authors are showing no conflict interest.

## Authors' contributions

IM performed the fieldwork, collected data and wrote the paper, AS analysed the data and prepared figures and SS reviewed and approved the final manuscript.

## Compliance with ethical standards

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

**Ethical issues:** None

## References

- Alam MJ, Ahmed KS, Mollah MR, Tareq MZ, Alam J. Effect of planting dates on the yield of mustard seed. *International Journal of Applied Sciences and Biotechnology*. 2015;3(4):651-54. <https://doi.org/10.3126/ijasbt.v3i4.13974>
- dates and varieties on mustard growth and yield in Prayagraj conditions. *International Journal of Environment and Climate Change*. 2022;12(11):231. <https://doi.org/10.9734/ijec/2022/v12i11131226>
- Agricultural Statistics at a Glance 2019. Government of India. <https://tinyurl.com/6kf4ewp4>
- Jat AL, Desai AG, Rathore BS. Effect of different sowing schedule and crop geometry on productivity and profitability of Indian mustard (*Brassica juncea* L.). *J Oilseed Res*. 2019;36:17-9. <https://doi.org/10.56739/faa94v80>
- Singh AK, Singh H, Rai OP, Singh G, Singh VP, Singh NP, et al. Effect of sowing dates and varieties for higher productivity of Indian mustard (*Brassica juncea* L.). *Journal of Applied and Natural Science*. 2017;9(2):883-87. <https://doi.org/10.31018/jans.v9i2.1292>
- Tripathi KB, Gaur T, Pandey L, Singh A, Tiwari A, Prakash V, et al. Effect of sowing dates on growth and yield of Indian mustard (*Brassica juncea* L.). *International Journal of Current Microbiology and Applied Science*. 2021;10(01):3046-57. <https://doi.org/10.20546/ijemas.2021.1001.355>
- Chowhan S, Islam M, Rana MS, Sultana MR, Ghosh SR, Ahmmed F, et al. Optimum and late sowing of mustard varieties show similar seed yield. *Plant Science Today*. 2023;10(2):382-92. <https://doi.org/10.14719/pst.2246>
- Azam MG, Akter R, Rahman MS, Mahmud S, Alam MR, Faruq MO, et al. Optimization of sowing time of BARI Sarisha 14 & BARI Sarisha 15 in Chittagong region. *Journal of Bioscience and Agriculture Research*. 2018;17(2):1431-35. <https://doi.org/10.18801/jbar.170218.177>
- Kamaliya YH, Patel HF, Makawana AI, Attar SK, Kumar N. Response of date of sowing and varieties on growth and yield of mustard (*Brassica juncea* L.) under humid climatic conditions. *International Journal of Plant & Soil Science*. 2024;36(8):999-1003. <https://doi.org/10.9734/ijpss/2024/v36i84932>
- Islam MA, Nupur JA, Robin AH. Trait association, genetic analyses and fatty acid profiles in oilseed producing rapeseed-mustard (*Brassica* spp.) genotypes. *Plant Breeding and Biotechnology*. 2020;8(4):316-26. <https://doi.org/10.9787/PBB.2020.8.4.316>
- Guarise M, Borgonovo G, Bassoli A, Ferrante A. Evaluation of two wild populations of hedge mustard (*Sisymbrium officinale* (L.) Scop.) as a potential leafy vegetable. *Horticulturae*. 2019;5(1):13. <https://doi.org/10.3390/horticulturae5010013>
- Alam MM, Begum F, Roy P. Yield and yield attributes of rapeseed mustard (*Brassica*) genotypes grown under late sown condition. *Bangladesh Journal of Agricultural Research*. 2014;39(2):311-36. <https://doi.org/10.3329/bjar.v39i2.20434>
- Reddy PS, Reddy GS, Devi KB, Chaitanya AK. Effect of sowing dates, tillage and establishment methods on growth and yield of mustard. *International Journal of Environment and Climate Change*. 2021;11(11):179-86. <https://doi.org/10.9734/ijec/2021/v11i1130531>
- Prasad S, Mishra AN, Singh AK, Kumar M. Effect of sowing temperature on growth & yield of Indian Mustard (*Brassica juncea* L.). *Journal of Pharmacognosy and Phytochemistry*. 2020;9(2):446-49.
- Bazzaz MM, Hossain A, Farooq M, Alharby H, Bamagoos A, Nuruzzaman M, et al. Phenology, growth and yield are strongly influenced by heat stress in late sown mustard (*Brassica* spp.) varieties. *Pak J Bot*. 2020;52(4):1189-95. [https://doi.org/10.30848/PJB2020-4\(44\)](https://doi.org/10.30848/PJB2020-4(44))
- Kumar P, Singh RV, Kaushik S, Kumar P, Kumar A, Yadav V, et al. Effect of sowing dates on performance of different mustard varieties (*Brassica juncea* L.) in western Uttar Pradesh, India. *International Journal of Plant & Soil Science*. 2024;36(6):91-8. <https://doi.org/10.9734/ijpss/2024/v36i64609>
- Mamun F, Ali MH, Chowdhury IF, Hasanuzzaman M, Matin MA. Performance of rapeseed and mustard varieties grown under different plant density. *Scientia Agriculturae*. 2014;8(2):70-5. <https://doi.org/10.15192/pscp.sa.2014.4.2.7075>
- Raghuvansi G, Tyagi PK, Dubey K, Sahu MP. Effect of sowing dates and crop geometry on total plant dry matter, oil content and yield of Indian mustard. *Intl J Pure App Biosci*. 2019;7(2):440-45. <http://doi.org/10.18782/2320-7051.7342>
- Agrahari RK, Mishra SR, Singh AK, Mishra AN, Pandey A, Gupta S. Effect of varying thermal regimes on yield and yield attributes of mustard varieties (*Brassica juncea* L.). *Environment and Ecology*. 2023;41(4D):3120-25. <https://doi.org/10.60151/envec/MMAC7114>
- Singh VV, Prashad L, Sharma HK, Meena ML, Rai PK. Character association and path coefficient analysis in Indian mustard (*Brassica juncea* L.). *Indian Journal of Agricultural Research*. 2024;58(6). <https://doi.org/10.18805/IJARE.A-5875>
- Adhikari A, Punetha H, Pant U. Genetic diversity analysis using agro-morphological traits of *Brassica juncea* subspecies *rugosa* (Pahari rai) from North-Eastern Himalayan region. *Electronic Journal of Plant Breeding*. 2022;13(3):790-99. <https://doi.org/10.37992/2022.1303.106>

22. Nelson MN, Nesi N, Barrero JM, Fletcher AL, Greaves IK, Hughes T, et al. Strategies to improve field establishment of canola: A review. *Advances in Agronomy*. 2022;175:133-77. <https://doi.org/10.1016/bs.agron.2022.05.001>

#### Additional information

**Peer review:** Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

**Reprints & permissions information** is available at [https://horizonpublishing.com/journals/index.php/PST/open\\_access\\_policy](https://horizonpublishing.com/journals/index.php/PST/open_access_policy)

**Publisher's Note:** Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Indexing:** Plant Science Today, published by Horizon e-Publishing Group, is

covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc  
See [https://horizonpublishing.com/journals/index.php/PST/indexing\\_abstracting](https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting)

**Copyright:** © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

**Publisher information:** Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.